RS1 Launch Vehicle

Payload User's Guide

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Change Log

Version	Release Date	Notes
1	21 January 2018	Initial release
2	3 August 2020	Updated architecture and performance

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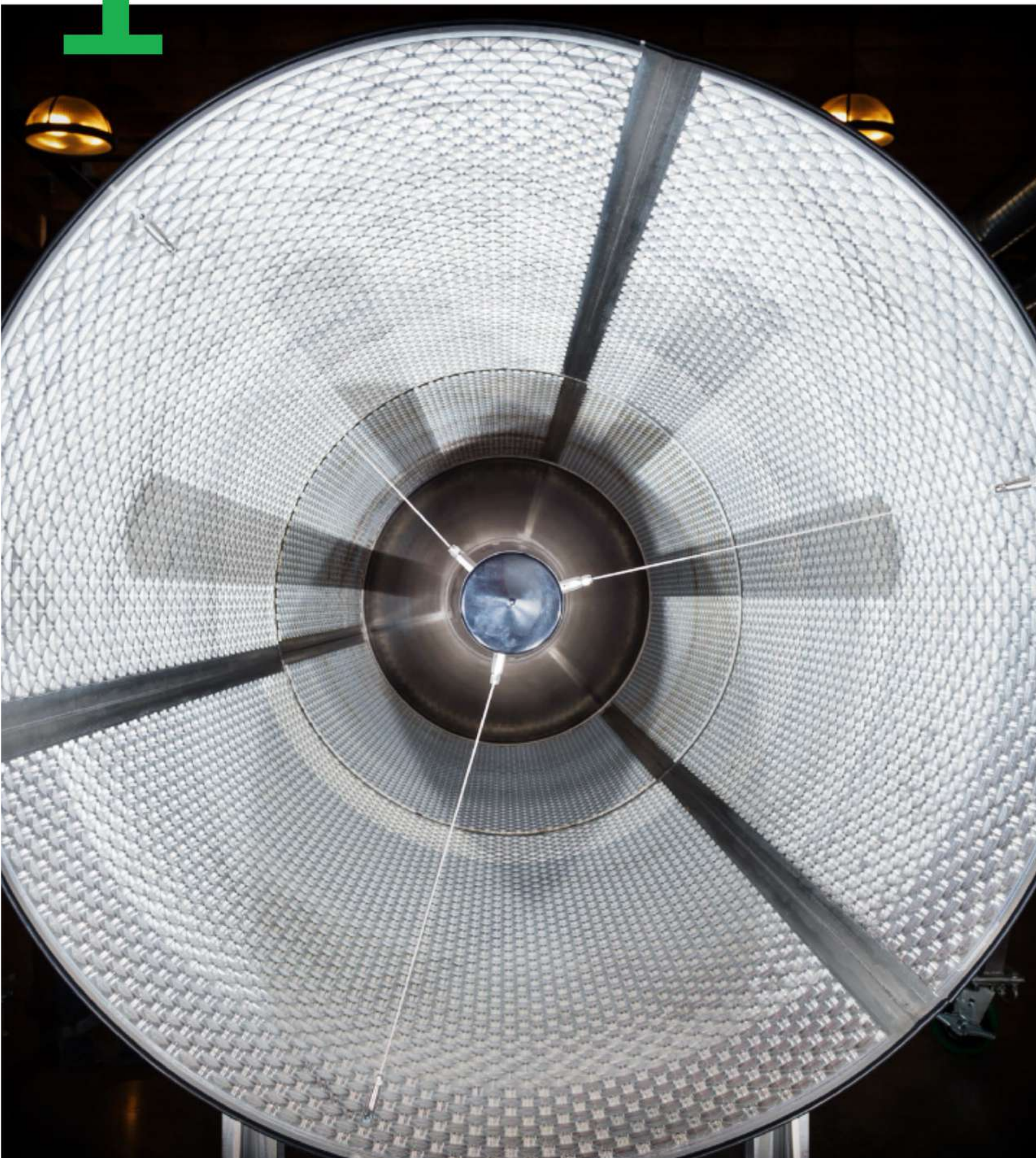


1.1 ABL

Founded in 2017, ABL's mission is to develop truly simple, reliable, and low-cost launch vehicles for the small satellite industry. We believe that:

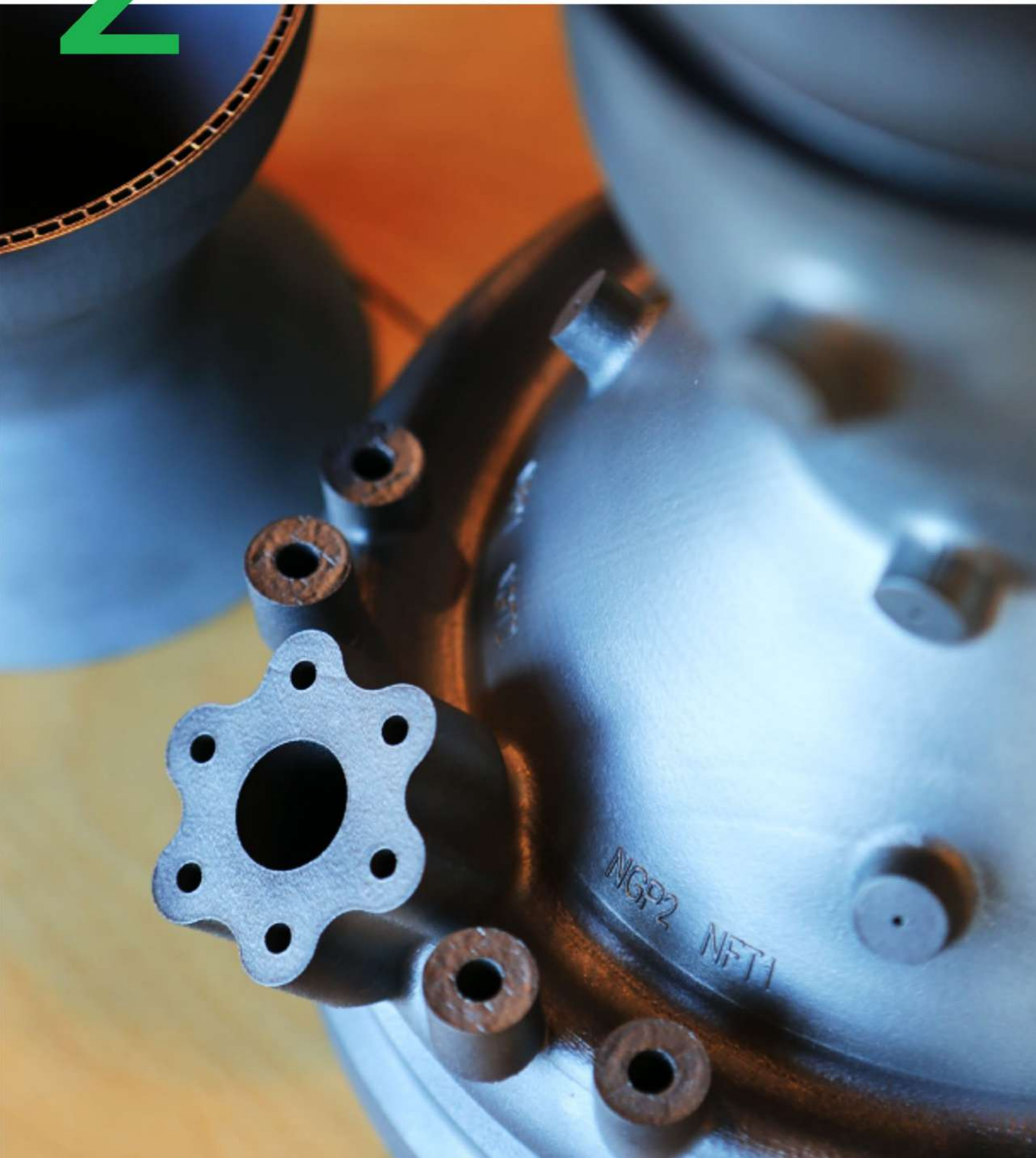
- recent innovations in electronics have enabled unprecedented capabilities in low-cost small satellites
- the deployment of thousands of these satellites over the next decade will fundamentally improve life on Earth
- the technology required to launch these payloads to orbit quickly and at a low cost has existed for decades
- despite this, the launch vehicle industry has continued to pursue eye-catching but unnecessarily complex architectures
- a truly low-cost, high-cadence, and flexible launch service is required to unlock an even greater wave of space applications

Based in El Segundo, California, we are a low-overhead team of dozens of engineers who draw our experience from the last decade of disruption in launch. We occupy two facilities in El Segundo totaling 60,000 sqft, with additional test sites distributed across the United States. ABL's flagship vehicle is RS1, with a maximum capacity of 1,350kg to LEO – small enough to simplify development, manufacturing, and operations, but large enough to deliver per-satellite launch cost at a fraction of a smaller vehicle. We prioritize relentless execution to satisfy our customers' needs above all else, and take pride in maintaining a high rate of progress in our technology development.

Our vehicle interstages are painted with a black-and-white checkered telemetry pattern in a tribute to the early days of the U.S. space program, when such patterns were used to enable observers to visually measure the roll rate and orientation of a vehicle as it flew downrange. When we studied Mercury Redstone 3, the first crewed U.S. space mission, we were inspired by the simplicity on display. Mercury Redstone took off from a flat concrete pad, lifted by a crane onto a short launch stool, and fueled through flexible tubing. We use the paint job to remind ourselves how much can be accomplished with simple technology. That vehicle put a human being into space 20 years before the first spreadsheet software was invented and with zero computers onboard the spacecraft. We have better tools at our disposal now, but we choose to use them to make our rockets simpler instead of more complex.

Figure 1: Development Stages and Fairing

2 RS1 Launch Vehicle



2.1 Launch Vehicle Overview

RS1 is a two-stage, ground-launched vehicle. Both stages use liquid oxygen (LOX) and rocket propellant (RP-1) as propellants. RS1 is also provisioned to use Jet-A. The vehicle's primary structure is entirely metallic, employing high-strength, reliable aluminum alloys. RS1 utilizes a common dome tank architecture to minimize structural mass. Tank barrels are grid-stiffened with a proprietary isogrid design. The front end of the vehicle includes a custom-designed payload adapter fitting and a metallic biconic fairing with acoustic protection.

E2 engines are turbopump-fed, gas generator cycle engines, and propel Stage 1 and Stage 2 of RS1. The gas generator cycle was selected for its reliability, tunability, and significant flight heritage. Additive manufacturing is used in select engine components, which are subject to rigorous material property validation and other quality control requirements. Engine components are carefully selected based on flight heritage and proven reliability. The upper stage engine employs a proprietary skirt extension to increase exo-atmospheric performance.

RS1 components and pressurization systems are optimized for simplicity, enabling rapid production and simple operation. Stage, fairing, and payload separation devices are non-pyrotechnic to enable simple handling procedures, minimize payload shock environments, and increase mission assurance.

RS1 avionics systems are highly modular and rigorously tested to ensure reliability. RS1 is provisioned for both classic and autonomous flight terminations systems to provide flight safety, as range safety protocols require. Avionics systems employ hardware redundancy and fault-tolerant software design to ensure high levels of reliability.

To support transportation and handling operations, all RS1 assemblies can be packaged into standard shipping containers.

Table 1: RS1 Overview

Item	Unit	Stage 1	Stage 2
Total Length	ft	50	5.4
Diameter	ft	6	6
Propellants	-	LOX and RP-1 or Jet-A	LOX and RP-1 or Jet-A
Feed system	-	Turbopump	Turbopump
Engine Cycle	-	Gas Generator	Gas Generator
Engine Thrust	lbf	12,100 (sea-level)	13,000 (vacuum)
Engine Quantity	-	9	1
Total Thrust	lbf	109,000 (sea-level)	13,000 (vacuum)
Pitch Control	-	Thrust Vector	Thrust Vector
Yaw Control	-	Thrust Vector	Thrust Vector
Roll Control	-	Thrust Vector	Cold Gas

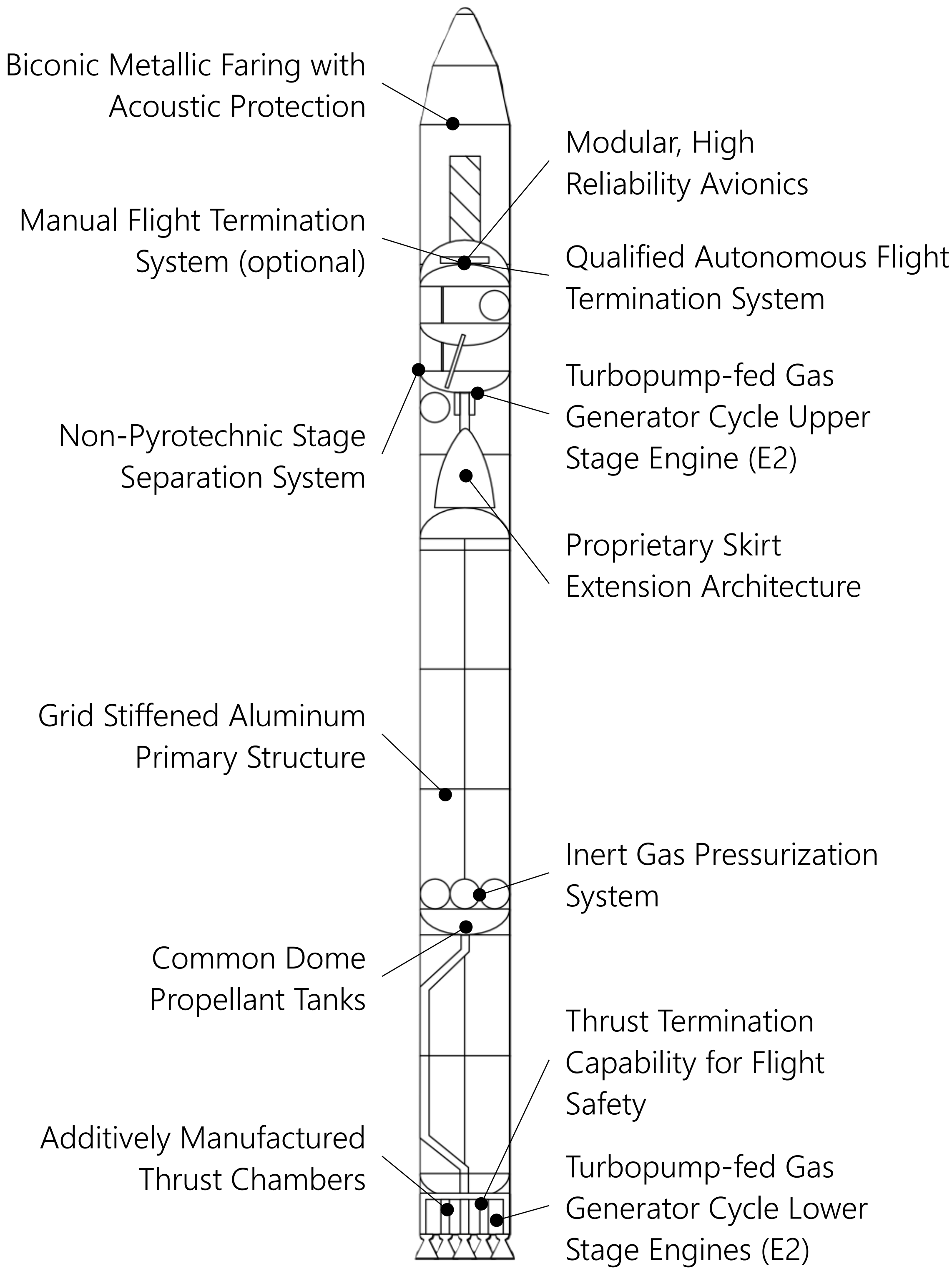


Figure 2: RS1 Launch Vehicle Architecture

2.1.1 Engines

As in our other systems, ABL employs simple, proven architectures in our E2 engines. The engines use a gas generator cycle and are fed with turbopumps, which provides a high-reliability engine system. The upper stage and lower stage engines share similar designs, minimizing part count and complexity.

ABL uses additive manufacturing methods to print a limited number of engine components, including the thrust chamber. This targeted use of additive manufacturing allows complex internal fluid passageways to be incorporated. Strict process control is implemented on all printed parts, which are manufactured per ABL's in-house specification (ABL-SPEC-13). This ensures reliability of the parts manufactured with advanced methods.

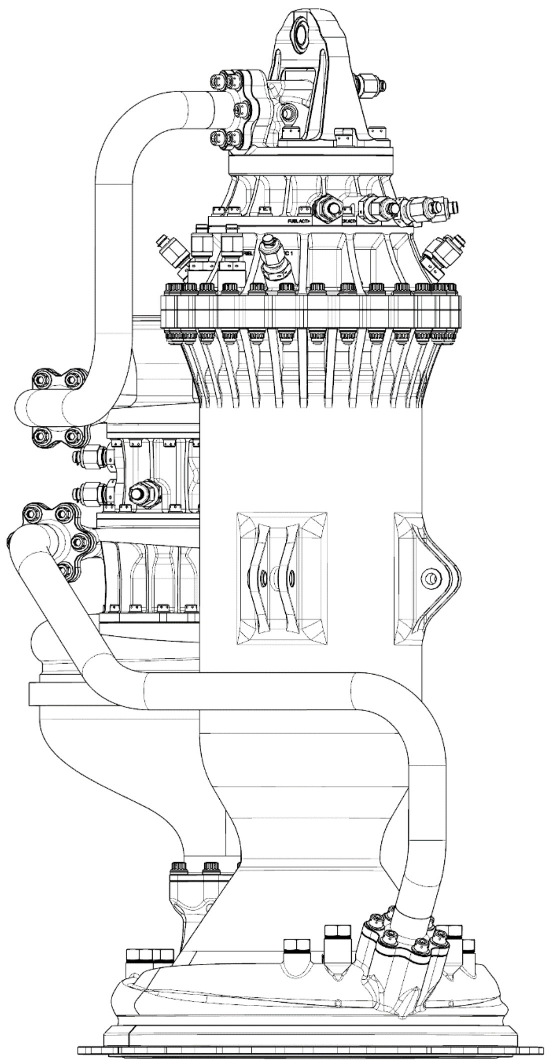


Figure 3: E2 Upper Stage Engine

2.1.2 Guidance Navigation and Control (GNC) and Mission Assurance

Preliminary flight trajectory optimization is executed in a 3 degree-of-freedom (3DOF) simulation environment to scope a mission. With moderate fidelity, these simulations provide a rapid, first order simulation of vehicle performance. 3DOF analysis is particularly useful for preliminary mission design where iteration is expected and can be performed rapidly on customer request.

For detailed mission planning, ABL uses a high-fidelity 6 degree-of-freedom (6DOF) simulation implemented on a hardware-in-the-loop (HITL) test bed to verify mission design and guarantee mission assurance. These tools provide high fidelity performance modeling and run on a real-time computer. HITL extends testing beyond the software implementation to include flight-like avionics hardware. The full avionics suite is integrated on the testbed, allowing guidance algorithms to run on flight hardware. Multiple test cases simulate corner-case flight conditions, on top of which Monte Carlo methods are layered to perform robust testing. Strong system modeling allows ABL to simulate missions and execute data review in a flight-like manner.

Every RS1 launch vehicle also undergoes vehicle HITL testing prior to launch to verify all mission configurations and parameters.

2.2 Performance Capability

RS1 performance capability is presented in Figure 4 for maximum and minimum inclination missions. RS1 supports launch out of any FAA-licensed launch site. For most missions, the RS1 second stage performs two engine burns. The second stage can also perform additional burns to allow for multi-altitude payload deployments during a single mission. RS1 is capable of deploying 1000kg to a 500km Sun-Synchronous Orbit.

ABL recognizes the expanding market of small satellites beyond low earth orbit (LEO) to medium earth orbit (MEO) and even geostationary earth orbit (GEO). RS1 is designed to access the higher altitude orbits of MEO and geostationary transfer orbit (GTO). This capability includes rigorous mission design protocol, as well as provisions for longer coasts between Stage 2 burns (for example, higher capacity batteries).

While MEO and GTO performance are more mission-dependent and require mission-specific analysis, RS1 can carry approximately 750 kg to an elliptical 8,000 km MEO orbit and 400 kg to GTO. Customers interested in these orbits are encouraged to contact ABL for feasibility analysis.

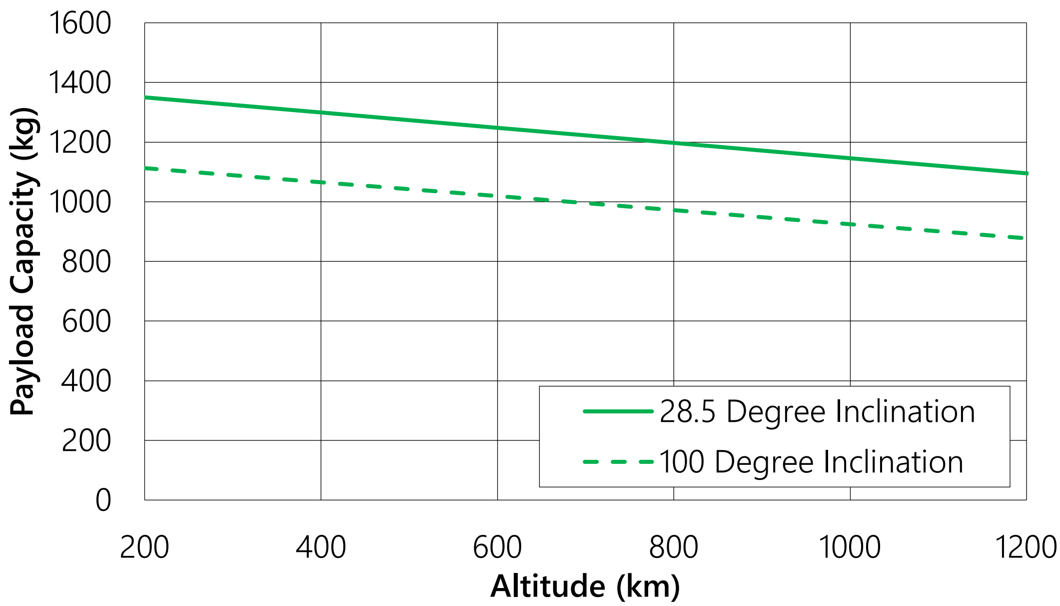


Figure 4: RS1 Performance Capability

2.3 Orbital Injection Accuracy

Orbital injection accuracies are presented in Table 2. The standard (± 7.5º) tolerance for the Right Ascension of the Ascending Node (RAAN) is based on a 1-hour launch window, which is ABL's baseline operation. Significantly tighter RAAN accuracy can be achieved with an instantaneous launch window, which ABL offers with additional mission planning.

Table 2: Orbital Parameter Accuracy

Perigee [km]	± 15
Apogee [km]	± 15
Inclination [deg]	± 0.15
RAAN [deg]	± 0.2 to ± 7.5

2.4 Deployment

RS1 uses a cold gas thruster system to control attitude and body rates. Table 3 presents standard deployment attitude and body rates for a LEO mission. Mission-specific payload injection accuracy bands are calculated during nominal pre-flight mission analysis by ABL.

Table 3: Deployment Attitude and Body Rate

Parameter	Angular Error [deg]	Rate Error [deg/s]
Roll	±2.0	±0.1
Pitch	±0.5	±0.1
Yaw	±0.5	±0.1

2.5 Radio Frequency

The RS1 launch vehicle transmits and receives data in the following frequency bands. Specific frequencies vary by mission and in some instances are range dependent.

Table 4: RS1 Radio Frequency System characteristics

Data Type	Mode	Antennas	Band	Frequency [MHz]
GPS	Receive	2	L-Band	L1: 1575.42 L2: 1227.60
Telemetry	Transmit	2	S-Band	2200.5 - 2394.5
FTS Telemetry FTS Command	Transmit Receive	2 2	UHF	400.0 – 460.0

2.6 Qualification

ABL developed an internal qualification specification based on a tailored version of SMC-S-016. The RS1 launch vehicle and all components are qualified per this specification, ABL-SPEC-27. This specification can be made available as necessary.

2.7 Regulatory

ABL launches are licensed through the FAA Office of Commercial Space Transportation per 14 CFR Parts 413, 415 and 417. For flight safety systems, ABL uses a tailored version of RCC 319-14 (ABL-SPEC-28).

2.8 Supply Chain

ABL procures parts from established, proven suppliers, who comply with strict quality control measures as defined in ABL's Standard Terms & Conditions and Quality Clause Attachment. ABL suppliers are AS9100 or ISO 9000 certified, as appropriate. Internal manufacturing is performed to strict quality control standards, and procurement, assembly, and test data can be provided to customers on request for each item in the RS1 Bill of Materials.

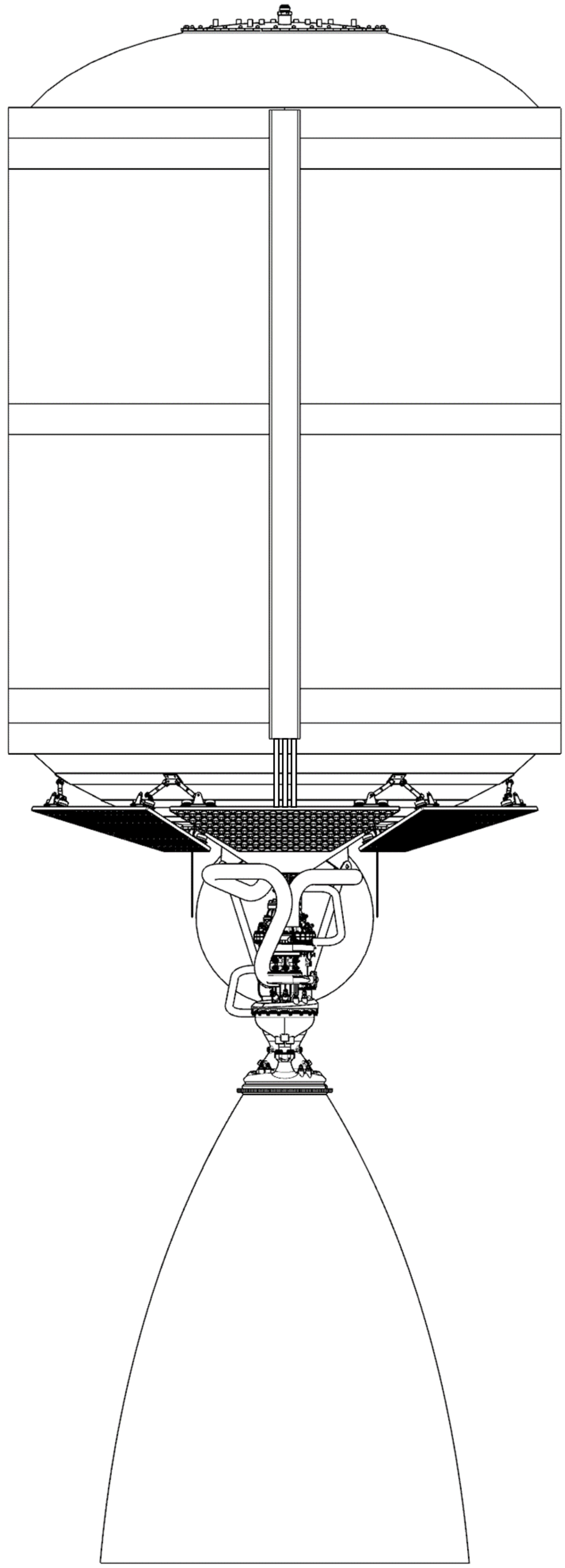


Figure 5: RS1 Stage 2

2.9 Reference Mission Timeline

Table 5 represents a reference timeline for a mission in which Stage 2 performs one burn before payload insertion. Stage 2 subsequently executes a Collision Avoidance Maneuver and a deorbit burn at a safe time after payload separation. For higher altitude orbits or multi-manifest missions, RS1 Stage 2 executes multiple burns. This allows the stage to enter elliptical transfer orbits and then circularize once in the higher orbit.

Table 5: Reference Mission Timeline

Mission Time [m:s]	Event
-0:02	Stage 1 Startup
0:00	Missile Lift Off
1:18	Maximum Dynamic Pressure (MaxQ)
2:58	Main Engine Cut Off (MECO)
3:00	Stage Separation
3:04	Stage 2 Startup 1
3:16	Fairing Separation
7:59	Second Engine Cut Off (SECO)
8:37	Payload Deploy
10:00	Collision Avoidance Maneuver (CAM)
15:00	Deorbit Burn

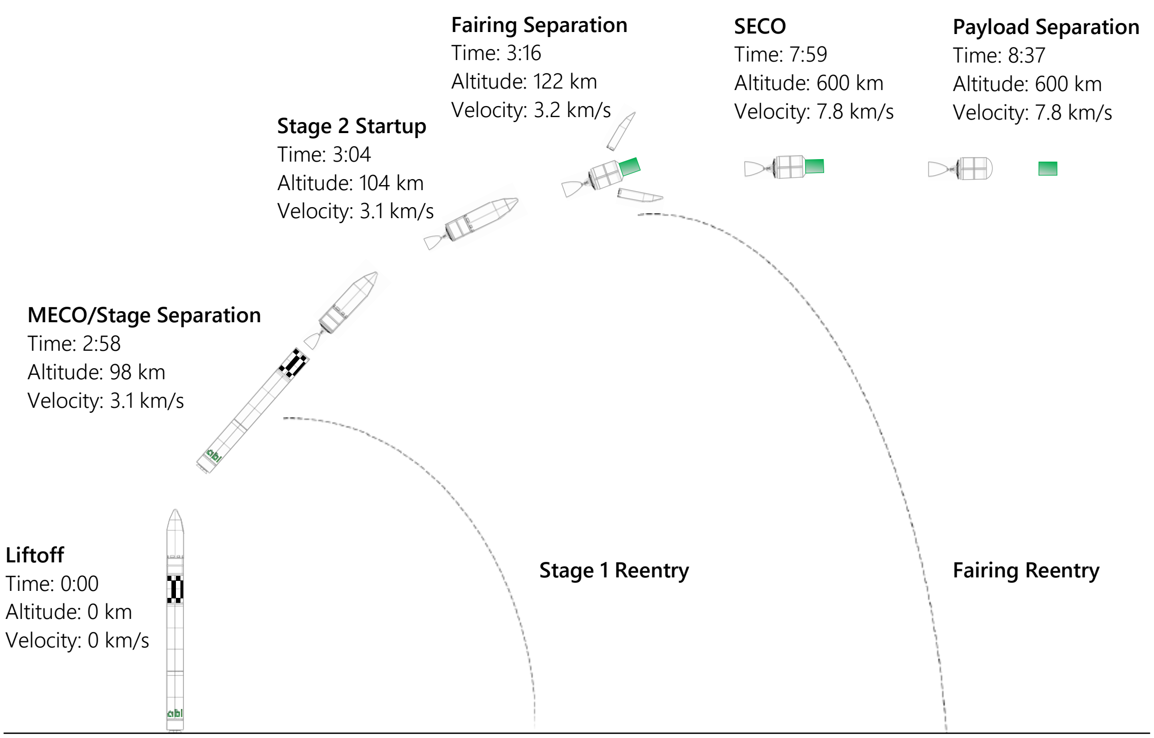
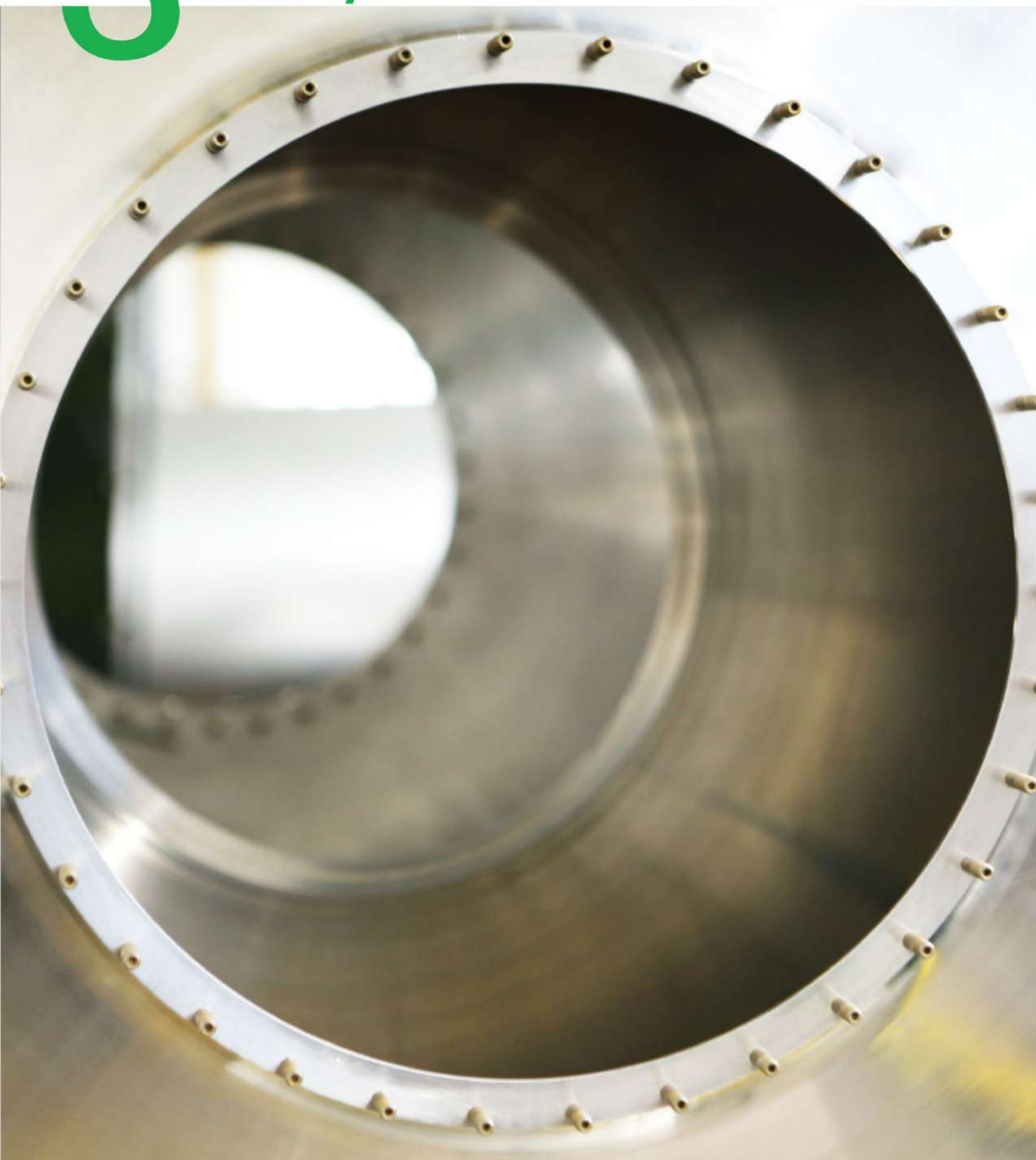


Figure 6: Reference Direct Insertion Mission Profile

3 Payload Accommodations



3.1 Payload Envelope

RS1 uses a simple metallic, biconic fairing to shield the payload from aerodynamic buffeting and heating during ascent. Internally, the fairing is provisioned with acoustic protection provisions. The fairing is a two-part assembly and separates along a longitudinal seam. Non-pyrotechnic devices are used for fairing separation, which limits shock loads. The fairing is jettisoned after the aero-heating rate is below 1,135 W/m^2.

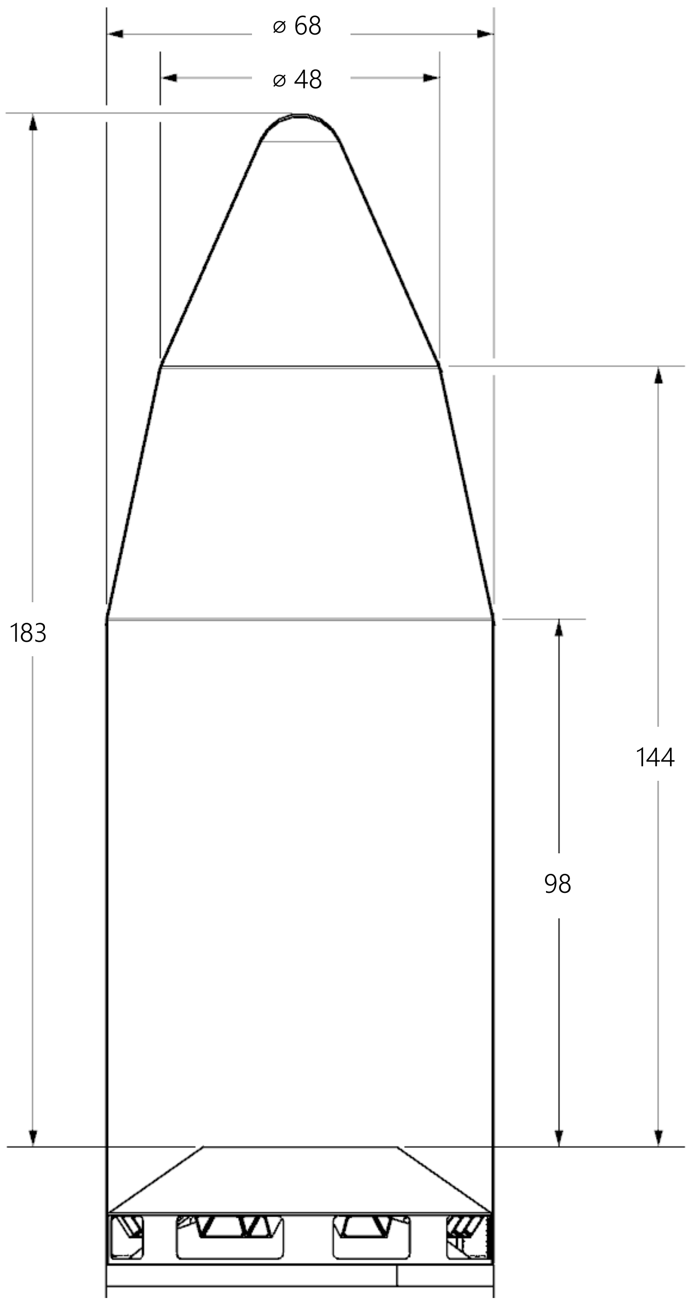


Figure 7: RS1 Payload Fairing Usable Volume Envelope (all values in inches)

3.1.1 Payload Mechanical Interfaces

The RS1 payload adapter fitting (PAF) is designed to interface with a standard 38.81-inch bolt circle, with 60 equally spaced fastener holes. Generally, ABL provisions for the customer to provide the payload separation system that interfaces with the RS1 PAF. Common small satellite separation systems that can be accommodated are:

- Planetary Systems Lightband
- Ruag Clamp Band Separation Systems
- Dassault Payload Separation Systems

If required, ABL can provide the separation system. Additionally, the PAF can be modified to accommodate any separation system with a mounting diameter between 12 inches and 38.81 inches.

3.1.2 Cubesat Bay

The RS1 PAF is provisioned to carry 3U and 6U Cubesats in the patent pending Cubesat Bay. Cubesat dispensers are integrated to the underside of the PAF, mechanically isolating the secondary payloads from the primary payload. The primary payload environmental seal further isolates the Cubesat Bay from the primary payload, keeping the primary payload environment undisturbed post-encapsulation.

With this design, Cubesats are fully isolated from the primary payload. Doors in the fairing permit cubesat integration after primary payload encapsulation, as late as L-5. Separate interfaces and mechanical separation eliminate mission planning conflicts with the primary payload.

The Cubesat Bay is designed such that cubesat specifications and operations have no impact on the primary mission.

3.1.3 Cubesat Dispensers

ABL utilizes standard 3U and 6U cubesat dispenser architectures, with a spring energized deployment. Customers may use ABL's standard dispenser or utilize any commercially available and qualified dispenser that conforms with RS1 standards.

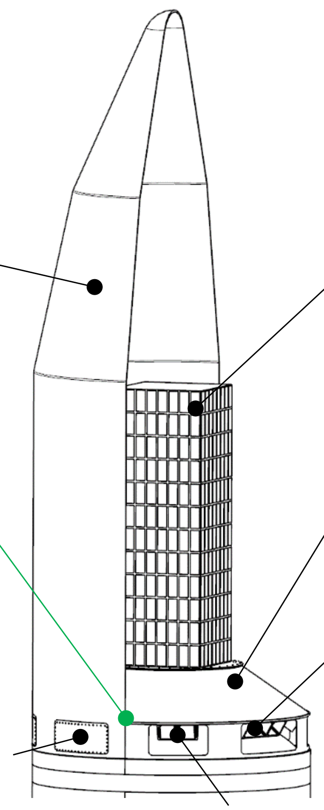


Figure 8: Payload Fairing with Cubesat Bay

3.2 Electrical Interface

3.2.1 Primary Payload

RS1 provides a standard set of electrical interfaces to primary payloads. On the pad, the primary payload is supplied with power (28V, 5A) and ethernet data connections. The primary payload data connection is isolated from all vehicle data and systems. The primary payload data connection feeds directly to the customer mission control area. Specific connector type and electrical pinout schema are provided to the customer with the RS1 Interface Control Document (ICD) during mission planning.

Nominally, in-flight payload data and power are not provisioned. However, payload data can be connected to the RS1 telemetry system and transmitted during flight, as an optional service. In this case, the data is not monitored by ABL, except for total telemetry bandwidth measurement. If a primary payload requires in flight power, the customer should notify ABL, as customer power systems can be implemented as well.

The RS1 Vehicle Controller connects to the primary payload separation system to provide separation control and monitoring.

3.2.2 Cubesat Secondary Payloads

The RS1 Vehicle Controller connects to all secondary cubesat payload dispenser systems to provide separation control and monitoring. RS1 and ground systems do not provide power or data connectivity to the secondary cubesat systems.

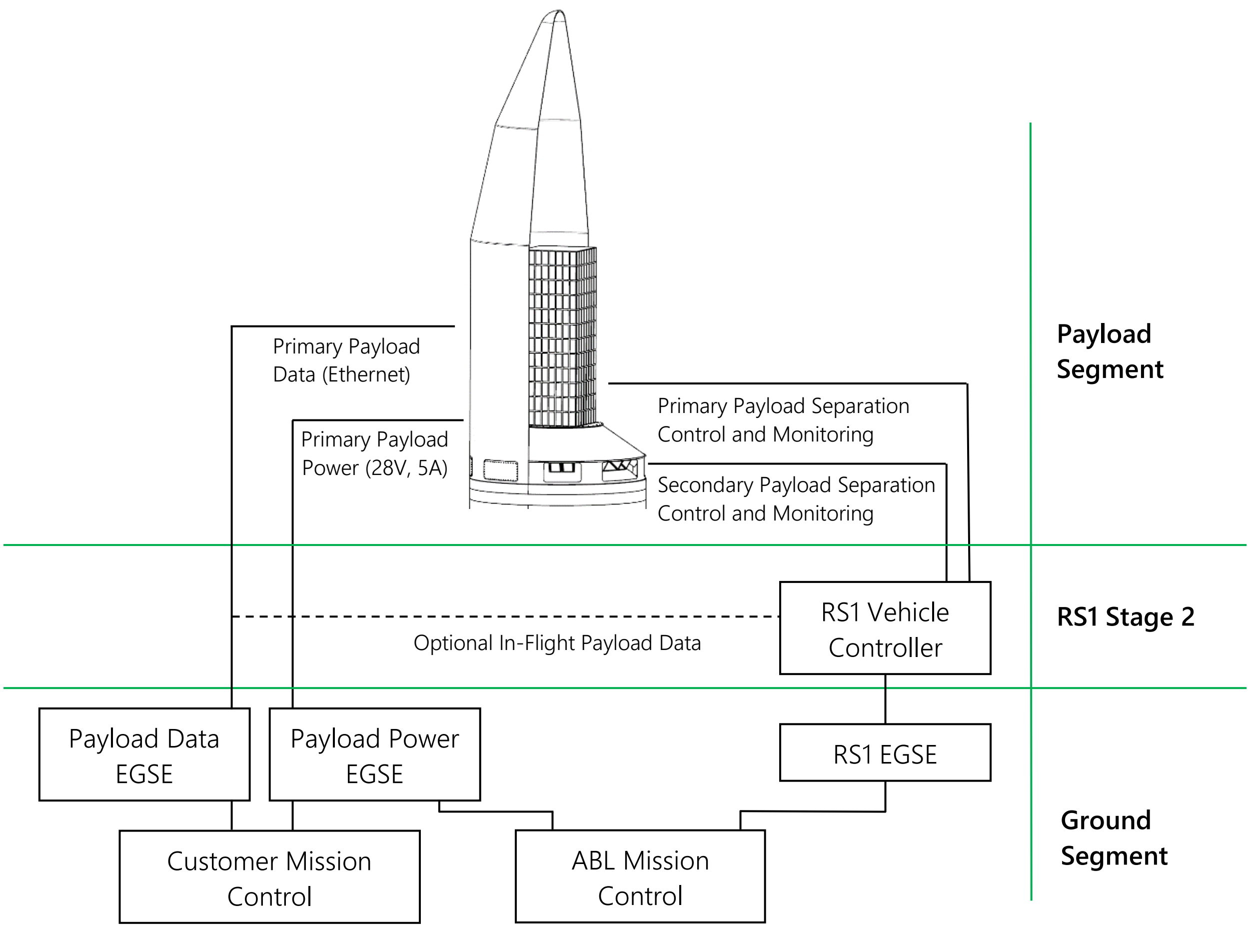


Figure 9: Payload Power and Data

3.3 Environments

Characterizing payload environments is critical for spacecraft design and mission assurance. Most environments are mission-dependent and require test and flight data to accurately determine frequencies and magnitudes. ABL gathers acoustic, dynamic, and shock data during all component, ground, and flight tests. This data can be provided on request during mission planning. For design and feasibility analysis purposes, design reference environments are presented below. Mission environments will not exceed the references presented, except as mutually agreed by all parties during mission planning.

3.3.1 Acceleration Loads

During ground operations and in flight, the payload is subjected to axial and lateral accelerations. The axial direction is in line with the RS1 longitudinal axis. The lateral direction is orthogonal to the longitudinal axis. These loads are enveloped by the values presented in Table 6. Loads with a positive sign are compressive.

Table 6: Flight Load Factors

	Lateral [g]	Axial [g]
Ground Handling	±1	±2
Flight	±2	+6/-1.5

Figure 10 illustrates the approximate acceleration profile during a single-burn mission with 1,350kg deployed to a 200km circular orbit. While each mission has a unique acceleration profile, this trend is representative of the maximum acceleration payloads will experience.

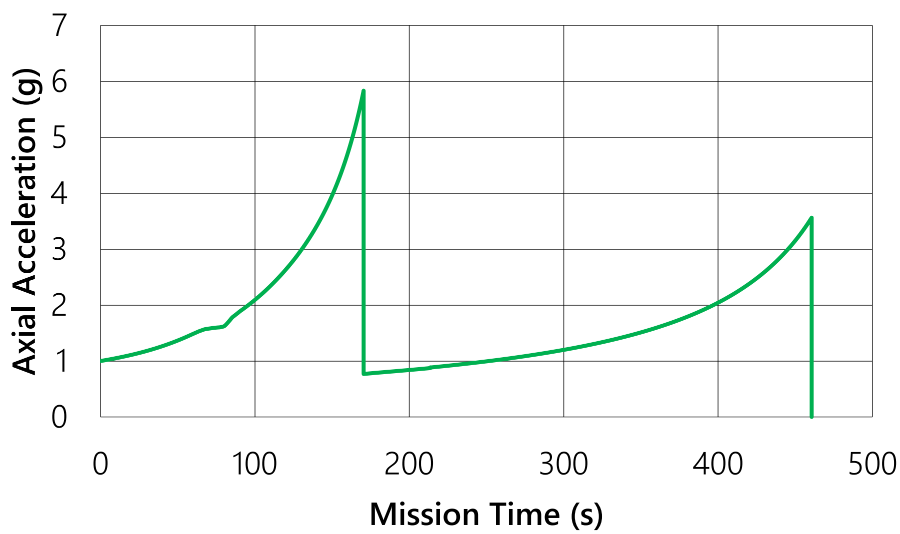


Figure 10: Reference Mission Acceleration Profile

3.3.2 Random Vibration

Random vibration is generally a driving load condition on the launch vehicle. The RS1 random vibration environments will not exceed NASA's General Environmental Verification Standard (GEVS) (GSFC-STD-7000). ABL maintains spacecraft loads below this limit using component tuning, isolators, and structural design.

Table 7: NASA GEVS Vibration Test Environments

Frequency [Hz]	PSD [g2/Hz]
20	0.013
50	0.030
800	0.030
2000	0.013

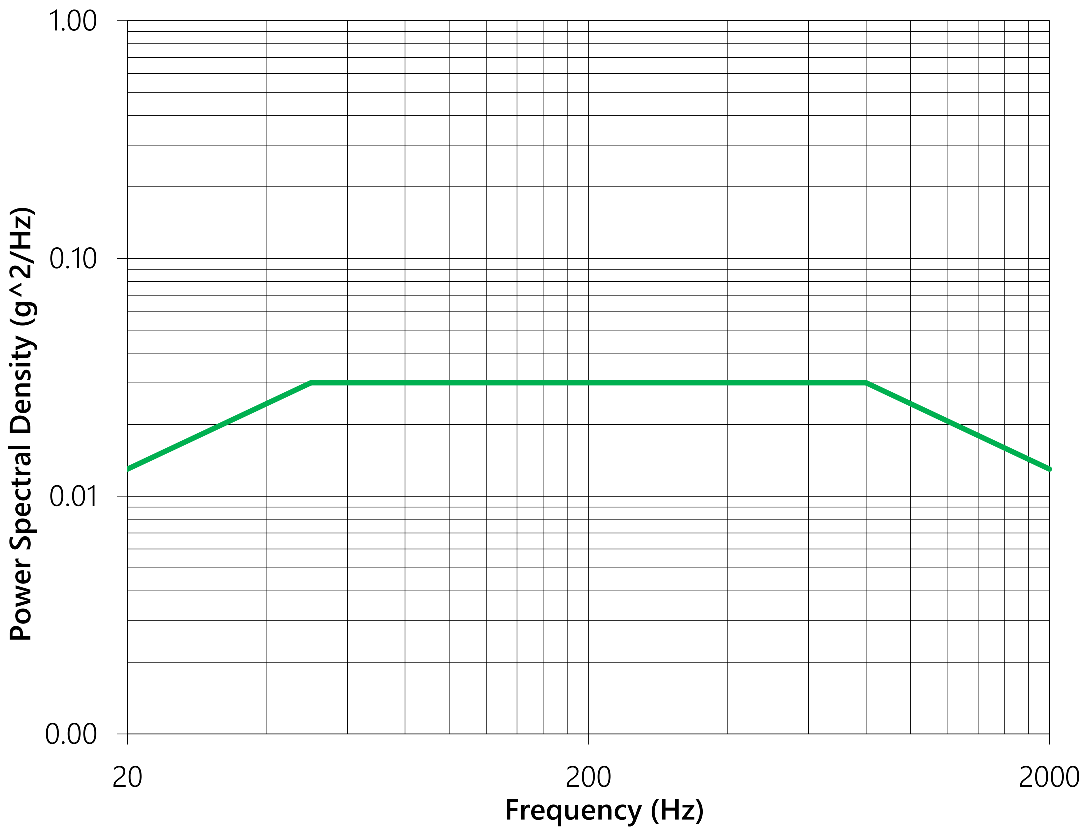


Figure 11: NASA GEVS Vibration Test Environments

3.3.3 Acoustic Loads

RS1 utilizes acoustic protection within the biconic fairing to maintain the Overall Sound Pressure Level (OASPL) below 135dB for the duration of the mission through liftoff and ascent.

3.3.4 Shock Loads

RS1 utilizes non-pyrotechnic separation devices for all vehicle separation events, which limits the shock loads imparted to the payload. The highest shock loads for the payload come from the payload separation system and are unique to the system and mission. Figure 12 presents an approximate shock response spectrum for a typical primary payload separation device.

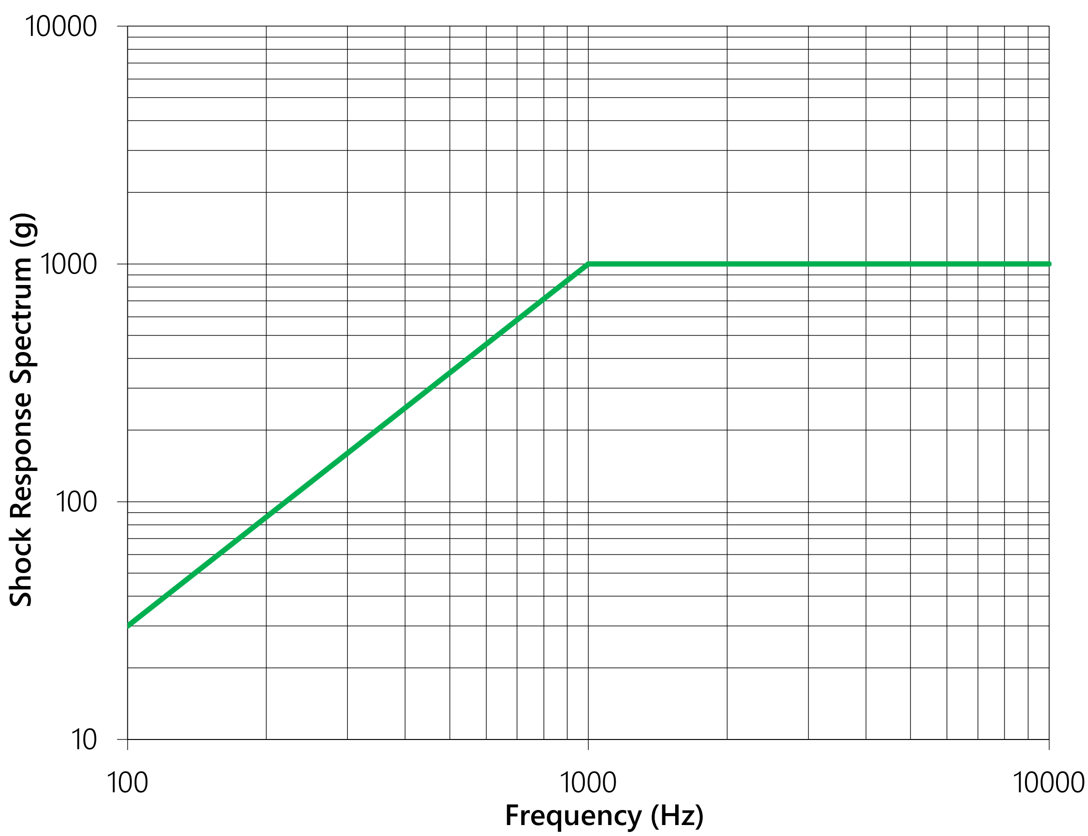


Figure 12: Approximate Shock Response for Payload Separation

3.3.5 Fairing Pressure Environment

During ascent, an overpressure in the fairing of about 0.15 psi above external pressure is maintained. The maximum depressurization rate is 0.5 psi/s, which occurs during transonic flight. Excluding transonic flight, the fairing depressurization rate is generally 0.25 psi/s throughout the mission.

3.3.6 Thermal and Humidity Environments

Spacecraft thermal and humidity environments are tightly monitored and controlled while ABL has custody of the spacecraft. Payload processing and fairing encapsulation is performed in a Class 100,000 cleanroom. Once encapsulated, the spacecraft is supplied with a clean, dry air supply. Air temperatures are maintained above the dew point at all times. A dry nitrogen purge can also be supplied instead of air.

Table 8: Payload Thermal and Humidity Environments

State	Environment		
	Temperature	Humidity	Cleanliness
Spacecraft Processing	70° ± 5°	50% ± 10%	Class 100,000 (ISO 8)
Roll Out Transportation	70° ± 5°	50% ± 10%	Class 10,000 (ISO 7)
Vertical on Pad	70° ± 5°	50% ± 10%	Class 10,000 (ISO 7)

3.3.7 Radio Frequency Environment

The RS1 radio frequency environment is characterized in Table 4. All primary and secondary payloads must pass testing per SMC-STD-461 for radiated emissions and susceptibility. Generally, it is advised that payloads are powered off during launch to reduce risk of RF interference.

3.4 Payload Center of Gravity

The primary payload center of gravity (CG) critically affects the loading of the payload adapter fitting and launch vehicle. Primary payloads must maintain the center of gravity within the axial and lateral limits outlined in Figure 13 and Figure 14 below. Axial CG offsets are measured from the separation plane. Lateral CG offsets are measured from the vehicle centerline.

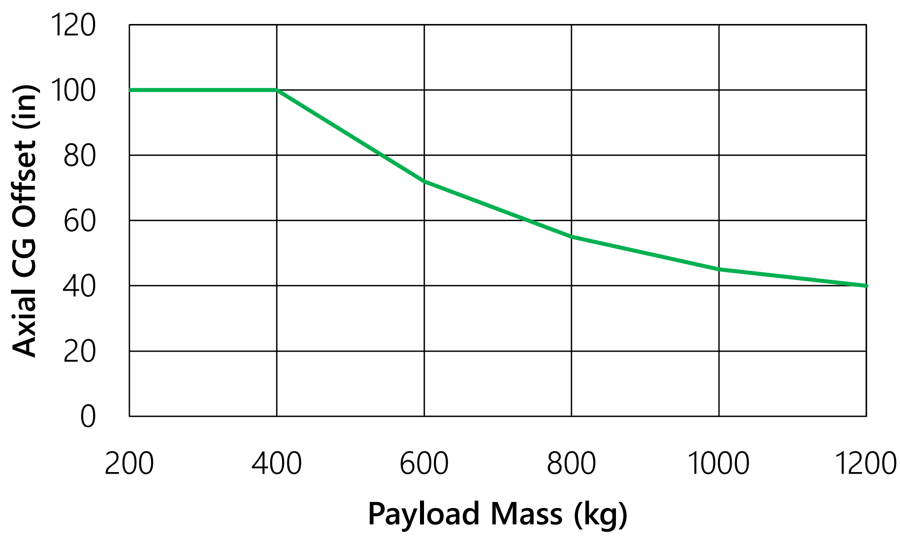


Figure 13: Primary Payload Axial Center of Gravity Limits

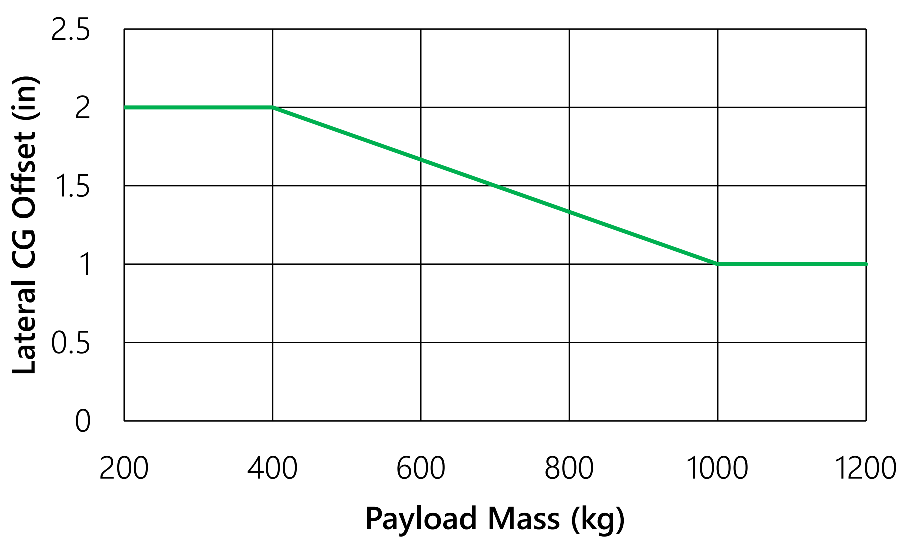


Figure 14: Primary Payload Lateral Center of Gravity Limits

3.5 Payload Requirements

The payload requirements for primary and secondary payloads are outlined in Table 9. Secondary cubesat payloads are carried in the Cubesat Bay and are mechanically and environmentally isolated from the primary payload.

Table 9: Payload Requirements

	Primary Bay Payloads	**Cubesat Bay Payloads**
Resonance and First Natural Frequency	The 1st lateral resonant frequency must exceed 10 Hz. The 1st axial resonant frequency must exceed 25 Hz.	The 1st resonant frequency must exceed 50hz
Random Vibration	The payload must withstand random vibration at the levels presented in Figure 11.	Primary payload testing regime recommended.
Acceleration Loading	The payload must withstand acceleration loads presented in Table 6.	Primary payload testing regime recommended
Mass Properties	The payload mass must be reported within +/- 5 lbm.	Nominal masses expected, higher masses acceptable with ABL approval (1U: 1.33kg, 3U: 4kg, 6U: 12kg)
Center of Gravity	The center of gravity location must be provided within +/- ¼ in in both the axial and lateral directions. The center of gravity must meet the limits presented in Figure 13 and Figure 14.	No center of gravity positioning requirements exist.
Radio Frequency Transmission	Payloads are nominally powered off and not transmitting during launch. If a customer requests the payload to be powered on during launch, an RS1 compatibility test must be executed.	Payloads must be powered off and not transmitting during launch.
Grounding and EMC	All payload interfaces must be electrically conductive to less than 0.1 Ω per unit area.	

3.6 Payload Safety

ABL follows AFSPCMAN 91-710 Range Safety User Requirements, as well as regulations in FAA 14 CFR 417, as well as certain other specifications and range requirements. Customer flight and ground systems must adhere to the requirements of these documents. Critical safety requirements include:

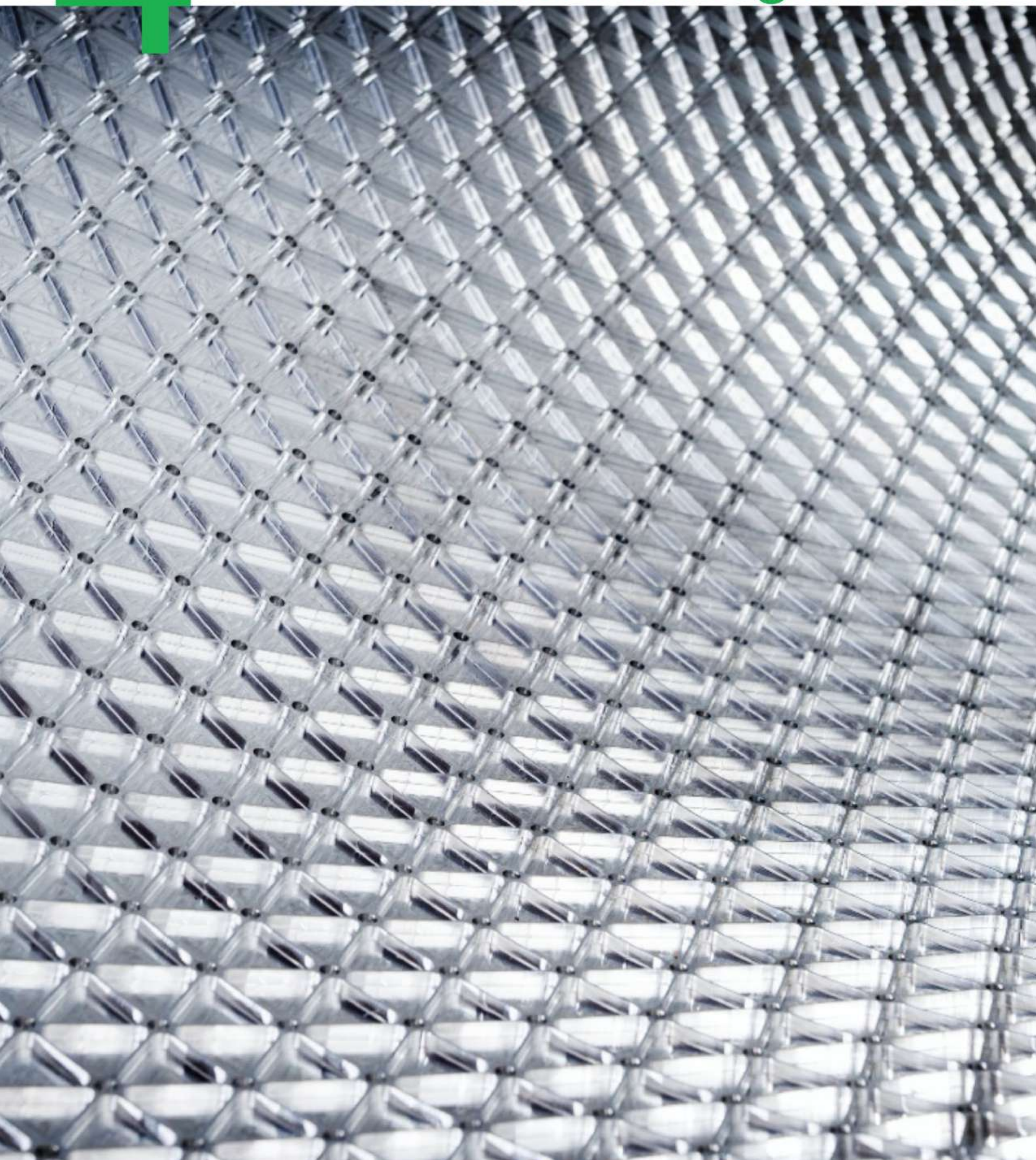
- **Payload Batteries.** Battery overcharge protection is required to mitigate explosion risk.
- **Pressure Vessels.** Payload pressure vessels must adhere to ATR-2005(5128)-1 Operational Guidelines for Spaceflight Pressure Vessels. Customers should coordinate with ABL for pressurization timelines. Pressure vessels should have relief mechanisms to protect against burst.
- **Propulsion Systems.** Payload propulsion systems must meet the requirements of AFSPCMAN 91-710 and their general characteristics must be communicated to ABL in the Payload Data Package.
- **Ground Support Equipment.** Ground support equipment should adhere to safety standards of 14 CFR 417. Any equipment that is loaded should have the limit load clearly marked. Lift points for all equipment should be marked. Electrical protection against battery overcharge is required. Relief valves are required on all pressurized fluid systems.
- **Pyrotechnic and Explosive Devices.** Generally, ABL does not handle payloads with pyrotechnic or explosive devices. If a payload has a pyrotechnic device, ABL can handle it with appropriate customer coordination.

3.3 Payload Data Package

For mission planning, both primary and secondary payload customers must submit a Payload Data Package to ABL. The report should contain the following:

- **Computer-aided Design (CAD) Model.** The customer provides a CAD model of the payload that accurately represents the enveloping outer geometry of the payload and the separation system. Acceptable file formats are STEP or Parasolid.
- **Finite Element Model.** The customer supplies a finite element model of the payload that accurately represents the payload stiffness and mass properties. Acceptable file formats are ANSYS Workbench or FEMAP.
- **Mass Properties Report.** The customer supplies a report that documents the total mass, center of mass, and moments of inertia about the center of mass.
- **Analysis and Test Report.** The customer supplies a report that indicates the payload modes, as well as all analysis and testing to satisfy the requirements outlined in Table 9.
- **Payload Flight Trajectory.** The post-deployment flight trajectory of the payload is required by ABL to design the vehicle flight trajectory and launch window.
- **Radio Frequency Data.** If the customer intends to transmit any radio frequency while on the launch pad, the frequencies and durations must be declared.
- **EMC Data.** Electromagnetic compatibility test results are required to show that payload emissions are within the acceptable ranges.
- **Safety Data.** Evidence of compliance with all safety regulations outlined herein..
- **Licensing Data.** The customer must provide all licensing data required for both launch (FAA) and orbit (FCC). Licensing data may be provided later in the launch campaign as it becomes available, but is required before the Launch Readiness Review.

4 Mission Management



4.1 Mission Planning

ABL supports a wide range of small satellite mission profiles, from multi-launch constellation deployments to rapid responsive launch of single payloads. Because each customer's needs are different, ABL assigns a dedicated mission manager to each launch. Through this liaison, ABL's customers have a single point of contact with ABL's technical team to ensure all requirements are met.

Standard commercial launches are generally planned over six to ten months. Launches can be single payloads or a combination of multiple spacecraft. ABL also supports a variety of non-traditional launch capabilities including rapid responsive launch and deployable, field-operable launch. For details on these capabilities, please contact ABL directly.

4.2 Commercial Launch Timeline

Figure 15 illustrates a standard mission planning timeline for a primary payload. Secondary cubesat payloads are planned and integrated on a shorter timeline.

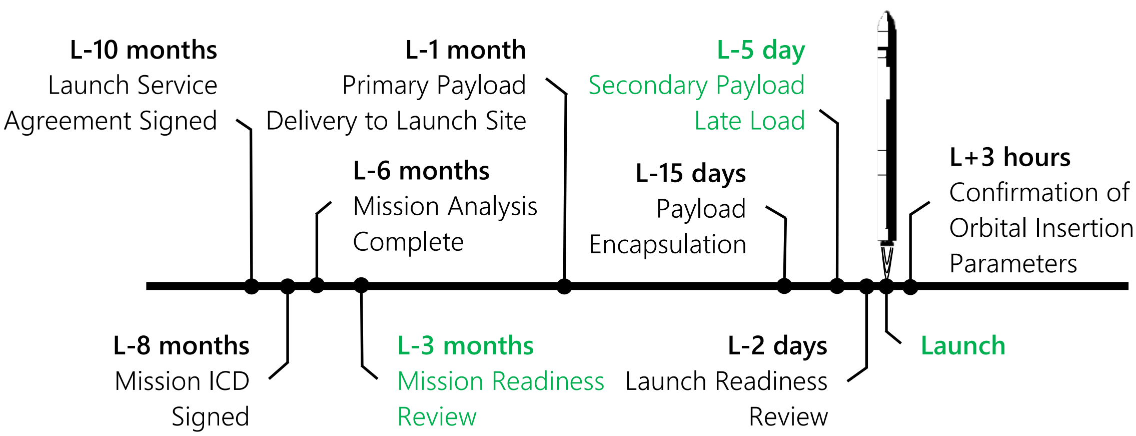


Figure 15: Reference Mission Planning Timeline

4.3 Tactical Responsive Missions

To enable government space resiliency efforts, ABL supports Tactical Responsive Missions (TRM) using RS1 deployed to distributed launch sites. Under TRM protocols, ABL can execute mission design from a blank slate for an unknown payload in three days. For a pre-planned mission employing pre-integrated payloads, launch can be executed in one hour.

4.4 Standard Services

As part of a launch service agreement, ABL performs a standard set of customer services. The details of these services are defined in the mission-specific Statement of Work.

- **Mission Analysis.** ABL performs Monte Carlo trajectory analysis to verify performance, as well as separation and recontact analysis. The results of a standard Combined Loads Analysis (CLA) and heating analysis are used to verify spacecraft loads.
- **Interface Control Document.** ABL creates and maintains an Interface Control Document (ICD) that defines all connections, interfaces and coordinated operations between the customer and ABL. As part of this effort, ABL also maintains record of all verifications for the ICD.
- **FAA Launch License.** ABL coordinates and secures an FAA Launch License with customer and mission specific inputs.
- **Payload Processing.** ABL provides ISO 8 payload processing facilities with temperature and humidity control.
- **Payload Management.** On the launch pad, ABL provides primary payloads with power and data connections (isolated from the vehicle).
- **Payload Separation.** ABL provides separation control and monitoring for all primary and secondary payloads.
- **Orbital Insertion.** After the mission concludes, ABL provides the customer with separation confirmation, a state-vector, and all orbital insertion parameters.

4.5 Non-Standard Services

In addition to ABL's standard services, additional optional services can be arranged and included in the Launch Service Agreement Statement of Work.

- **In-Flight Data.** Primary payload data signals can be routed through the vehicle avionics to provide real-time spacecraft telemetry during flight.
- **Custom Analysis.** ABL can perform spacecraft-specific CLA and thermal analysis.
- **Payload Transport.** ABL can arrange transport of the spacecraft to the launch site.
- **Payload Vibration Testing.** ABL can coordinate and execute payload vibration testing.
- **Pyrotechnic and Explosive Devices.** Nominally, payloads are assumed not to carry pyrotechnic devices. ABL can handle payloads with pyrotechnic devices with advanced coordination.
- **Remote Payload Encapsulation.** The ABL fairing and payload adapter fitting can be transported to customer facilities for encapsulation and shipped as an integrated unit to the launch site. The provides protection for sensitive payloads.

- **Rapid Launch.** For customers with time-sensitive missions, ABL offers Tactical Responsive Mission (TRM) protocols designed for government missions.

4.6 ABL and Customer Information Exchange

To ensure mission success, ABL and the customer must share detailed technical information. Table 10 illustrates an example timeline and structure for information flow between ABL and a primary payload customer. Secondary cubesat payloads have simpler, accelerated timelines.

Table 10: Mission Information Flow

Time	ABL to Customer	Customer to ABL
L-10 months	Signed Launch Service Agreement	
	Draft Mission ICD Standard CLA Results Standard Thermal Results	Payload Data Package
L-9 months	Preliminary Licensing Feedback	ICD Edits and Feedback
L-8 months	Signed Mission Interface Control Document (ICD)	
L-6 months	Preliminary ICD verifications Monte Carlo Trajectory, Separation and Recontact Analysis	Payload Launch License Inputs Detailed Payload Processing Schedule
L-3 months	Mission Readiness Review	
L-1 month	RS1 Readiness Confirmation	Primary Payload
L-15 days	Payload Encapsulation	
L-2 days	Launch Readiness Review	
L+3 hours	Orbital Insertion Parameters	--

4.7 Insurance

All aspects of ABL launches are insured by premier underwriters in the space insurance market. ABL is responsible for pre-launch and third-party liability coverage, while customers are responsible for insuring the value of their payload. ABL can assist with the placement of launch insurance policies on request.

- **Pre-launch insurance.** Covers losses during transportation and testing operations through ignition.
- **Launch insurance.** Covers losses during the launch operation, from ignition through satellite separation, and in some cases extending through the in-orbit testing phase.
- **Third-party liability (TPL) insurance.** Covers damage to third parties due to launch activity and is statutorily required.

5 Launch

5.1 Launch Overview

ABL approaches launch differently. All ground systems are modular and containerized, which enables the entire launch system to be mobile and deployable. The RS1 launch system requires only a flat pad and local propellant commodities to achieve orbital launch.

For commercial launch operations, ABL can operate from all FAA-licensed launch sites. Customers can expect a local payload processing facility for fairing encapsulation, as well as a customer data viewing area.

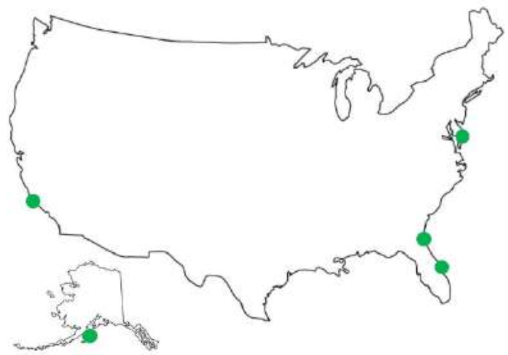


Figure 16: United States Commercial Launch Sites

Table 11 outlines the coordinates and accessible inclinations from United States launch sites. ABL can launch from international launch sites as required.

Table 11: United States Launch Sites

Site	Lat. [deg]	Lon. [deg]	Min Inc. [deg]	Max Inc. [deg]
Camden County, GA	N 30° 55' 39"	W 81° 30' 53"	31	58
Cape Canaveral, FL	N 28° 27' 30"	W 81° 31' 42"	28.5	57
Kodiak, AK	N 57° 26' 09"	W 152° 20'16"	59.6	110.2
Vandenberg AFB, CA	N 34° 34' 34"	W 120°37' 56"	57	104
Wallops Island, VA	N 37° 56' 24''	E 75° 27' 59''	38	60

5.2 Launch Site

Figure 17 illustrates the typical launch configuration for the RS1 deployable launch system. The ground system can connect either to mobile tankers (depicted) or integrate with local launch site bulk storage. At sites with compatible existing infrastructure, ABL can utilize fixed infrastructure assets to complement our deployable system.

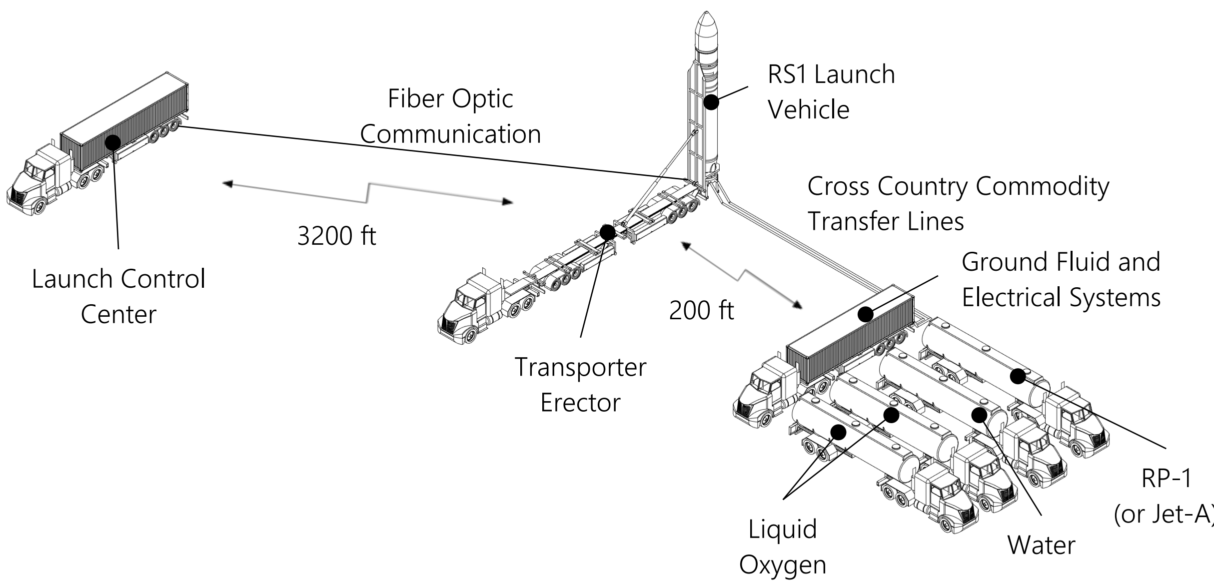


Figure 17: Launch Site Configuration (note: distances between vehicles not to scale)

5.3 Launch Overview

To support government space resiliency efforts, RS1 launch systems can be deployed to a distributed array of launch sites. The RS1 vehicle is ruggedized for containerized transport and long-duration storability. This capability allows any flat pad globally to be utilized as an orbital launch pad. Launch license restrictions typically limit this functionality to government customers, but ABL can also provide deployable orbital launch capability to commercial customers who hold an FAA Launch Site Operator's license.

5.4 Launch Integration Facilities

ABL's launch integration facilities are optimized for high-cadence launch with multiple customer payloads onsite. Figure 18 illustrates how RS1 vehicles flow through the launch integration facility, in conjunction with customer payloads. Two isolated customer payload integration bays provide confidential and secure areas for customers to process and checkout spacecraft. Both bays open to a common payload mating clean room, where secondary cubesat payloads are also integrated.

On the launch vehicle side of the building, dedicated areas for each stage provide space for final checkouts and vehicle HITL testing. Stage mate is performed in a central aisle, after which the forward end of the vehicle is moved into the common payload clean room for payload mate. After RS1 is integrated into a full launch system, it is transported aft first to the launch pad.

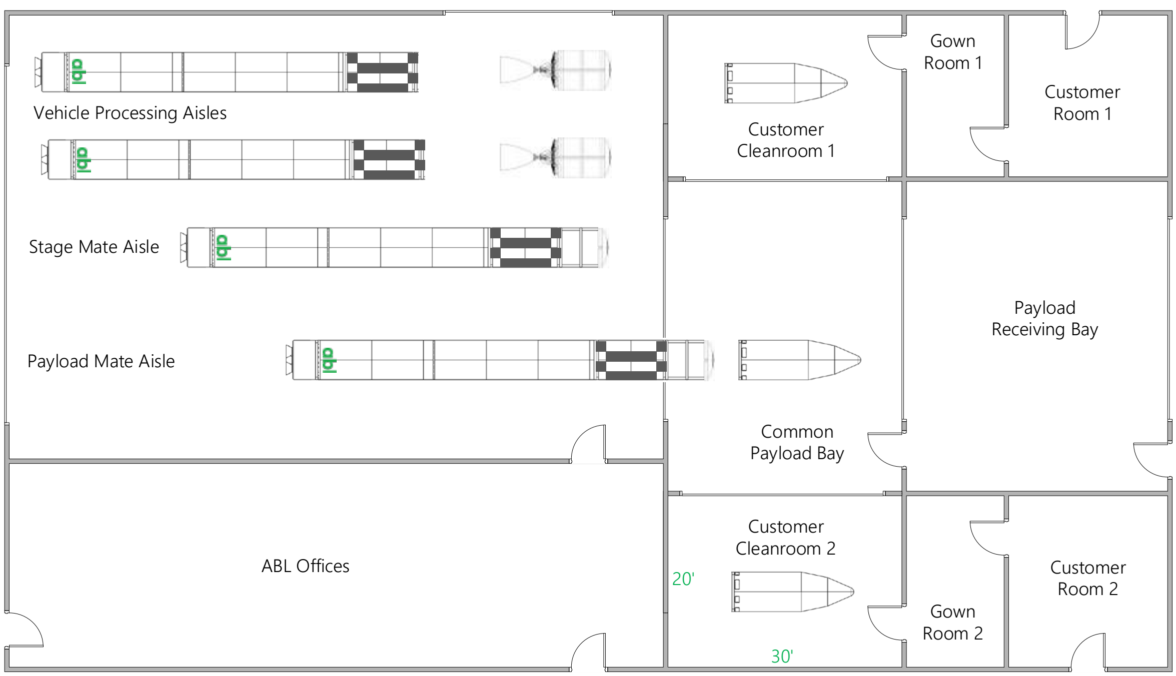


Figure 18: Launch Integration Facilities

5.5 Launch Operations

ABL executes launch operations with a small, efficient launch team. The Launch Director serves as the central point of command for the operation. All Go/No-Go decisions run through the Launch Director. In the Launch Control Center, the Launch Conductor manages two controllers who perform the detailed actions required to load propellant and launch RS1. On the pad, the Ground Conductor leads the ground team responsible for setting the launch mount, after which they fall back to secure the blast danger area for launch.

The Mission Manager interfaces with the customer to verify spacecraft readiness and launch acceptability. Similarly, the Range Safety Director interfaces with the FAA to verify compliance and range safety.

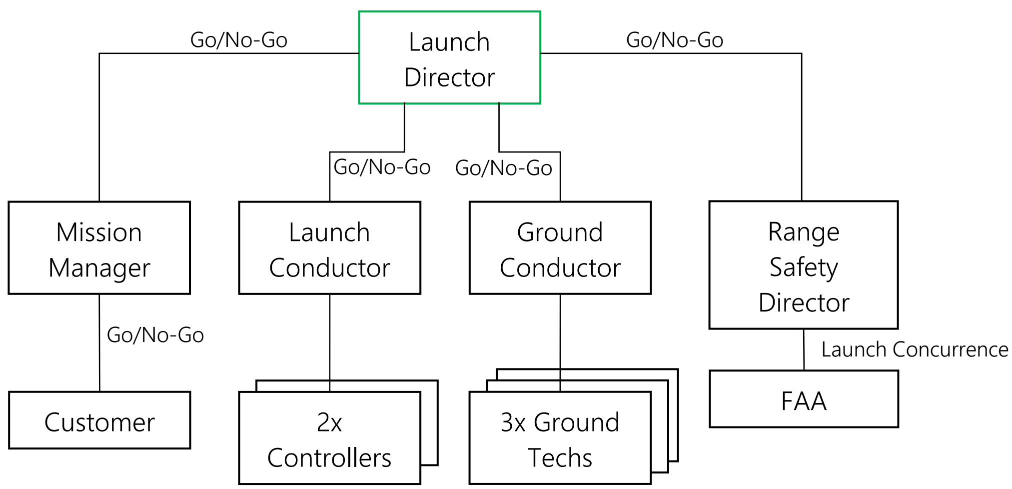


Figure 19: Launch Team Organization

5.6 Launch Campaign Timeline

Table 12 illustrates a standard launch campaign timeline. While each commercial mission is different, ABL adheres to a strict launch timeline to enable high-cadence and on-time launches. ABL can accommodate customers that require more time onsite for payload processing, as necessary.

Table 12: Reference Launch Campaign Timeline

Event	Date
Primary Payload Arrives at to Launch Site	L-30 days
Launch Vehicle Arrives at to Launch Site	L-21 days
RS1 Unpacking and Inspection	L-20 days
RS1 Integrated System Checkouts	L-19 days
Primary Payload Encapsulation	L-15 days
Stage Mate	L-10 days
Payload Mate	L-9 days
End to End Flight Safety Test	L-7 days
Vehicle HITL	L-6 days
Secondary Cubesat Payload Late Load	L-5 days
Flight Readiness Review	L-4 days
Pad Fluid and Electrical System Checkouts	L-3 days
Pad Radio Frequency Checkouts	L-3 days
Propellant and Gas Bulk Storage Verification	L-3 days
Launch Readiness Review	L-2 days
Roll Out to Pad	L-2 days
Lift Vertical	L-1 day
Launch	L-0

5.7 Day of Launch Operations

ABL executes a rapid "load-and-go" style launch operation. Propellant and gas commodities are loaded quickly through high-capacity systems to minimize the duration the launch vehicle remains loaded on the pad, reducing risk.

To enable rapid launch, the vehicle and ground systems undergo extensive testing prior to launch day. This consists of a series of HITL and dry-run sequences to verify system functional integrity and timing. Additionally, stringent leak checks are executed on all fluid systems to ensure a successful propellant load operation.

In addition to managing the vehicle, ABL executes other required day-of-launch mission verifications. These includes upper level wind assessments to tune loads alleviation algorithms, as well as Monte Carlo mission simulations.

Ultimately, these efforts provide assurance that once propellant load begins, RS1 will successfully achieve orbit.

Table 13: Nominal Day of Launch Timeline

Event	Time
Weather Balloon Release	T-480:00 min (ongoing)
Final Local Area Notice and Clear	T-120:00 min
Initiate Air, Sea and Land Surveillance	T-75:00 min
Final Vehicle Self Integrity Test	T-60:00 min
Final Telemetry Verification	T-60:00 min
Final Range Safety Verification	T-55:00 min
Final Flight Weather Condition Verification	T-55:00 min
Verify Battery Power	T-45:00 min
Set Blast Danger Area Hard Down	T-45:00 min
Obtain Launch Concurrence	T-40:00 min
Start Inert Gas Load	T-35:30 min
Start Propellant Load	T-20:30 min
Verify Final Launch Commit Criteria	T-10 min
End Inert Gas Load	T-5:30 min
End Propellant Load	T-5:30 min
Start Terminal Count	T-5 min
Launch	T-0

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