ABL Payload User's Guide

ABL SPACE SYSTEMS COMPANY

ABL Payload User's Guide

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ABL OVERVIEW

ABL Space Systems (ABL) was founded in 2017, and the rapid hardware development capability and focused business approach have quickly positioned the company as a leader in the small launch market. ABL's launch vehicle RS1 is a two-stage, ground-launched rocket. The vehicle is deliberately simple and designed for high-rate manufacturing and streamlined launch operations.

Based in El Segundo, California, ABL already occupies several facilities with end-to-end manufacturing capabilities in-house, including 3D printing, precision machining, forming, and welding. ABL's highly-verticalized engineering approach allows for a heightened control over both schedule and quality.

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 a per-satellite launch cost at a fraction of a smaller vehicle. In addition, ABL offers a high degree of flexibility via GS0, a 100% containerized launch solution for responsive deployment with minimal existing ground infrastructure.

ABL's mission is to develop simple, reliable, and low-cost launch vehicles for the small satellite industry.

MISSION CAPABILITIES

Orbital Capabilities

With multiple launch sites, ABL can deliver to a wide range of orbits in order to meet customer needs. See Figure 0-1 for an overview of orbital capabilities. For orbits outside of the ranges below, please contact ABL directly.

Table 0-1: Orbital Capabilities

Launch Site	Available Orbits
Cape Canaveral Space Force Station, FL	Mid-inclination, GTO
Vandenberg Space Force Base, CA	Mid- to High-inclination and polar orbits
Pacific Spaceport Center, AK	Mid- to High-inclination and polar orbits
SaxaVord Spaceport, UK	High-inclination and polar orbits

Performance

RS1 utilizes a relightable second stage engine, which can deliver payloads to many unique orbits. As a reference, most missions will require two second stage burns. With this two-burn mission design, RS1 is capable of deploying 970kg to a 500km Sun-Synchronous Orbit (SSO). RS1 performance capability for a range of mission inclinations is presented in Figure 0-1. Please contact ABL to discuss any specific performance needs that are outside of the orbits presented.

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 700 kg to an elliptical 8,000 km MEO transfer orbit and 320 kg to GTO. Customers interested in these orbits are encouraged to contact ABL for feasibility analysis.

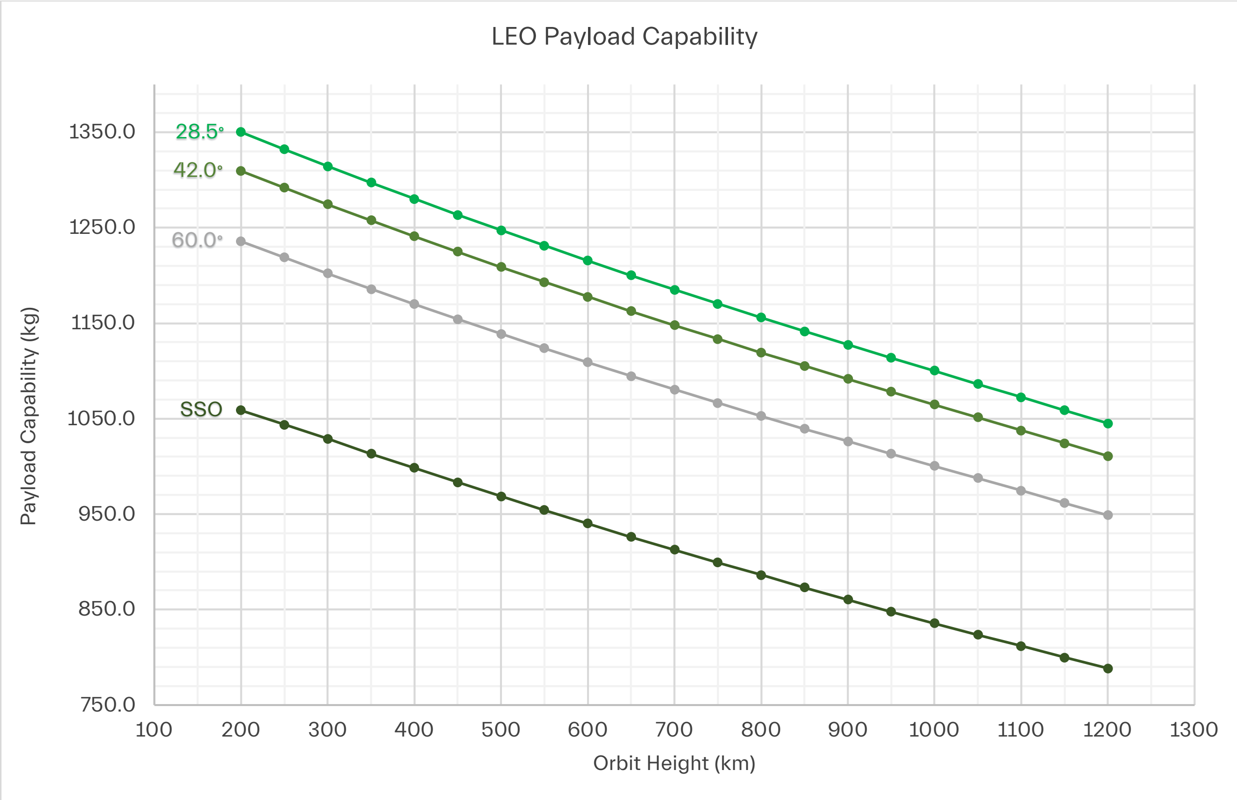

Figure 0-1: RS1 LEO Payload Capability

Mission Profile

The RS1 is a two-stage to orbit launch vehicle with stage separation occurring at approximately 160 seconds into flight. Second Stage Engine Cut Off (SECO) is specific to each mission, but in a standard reference mission SECO-1 will occur at approximately ~508 seconds at a 200km altitude. Payload separation occurs once Stage 2 reaches the desired orbital parameters for the payload. Please see Figure 0-2 for a summary of major events and their timing for a standard reference mission.

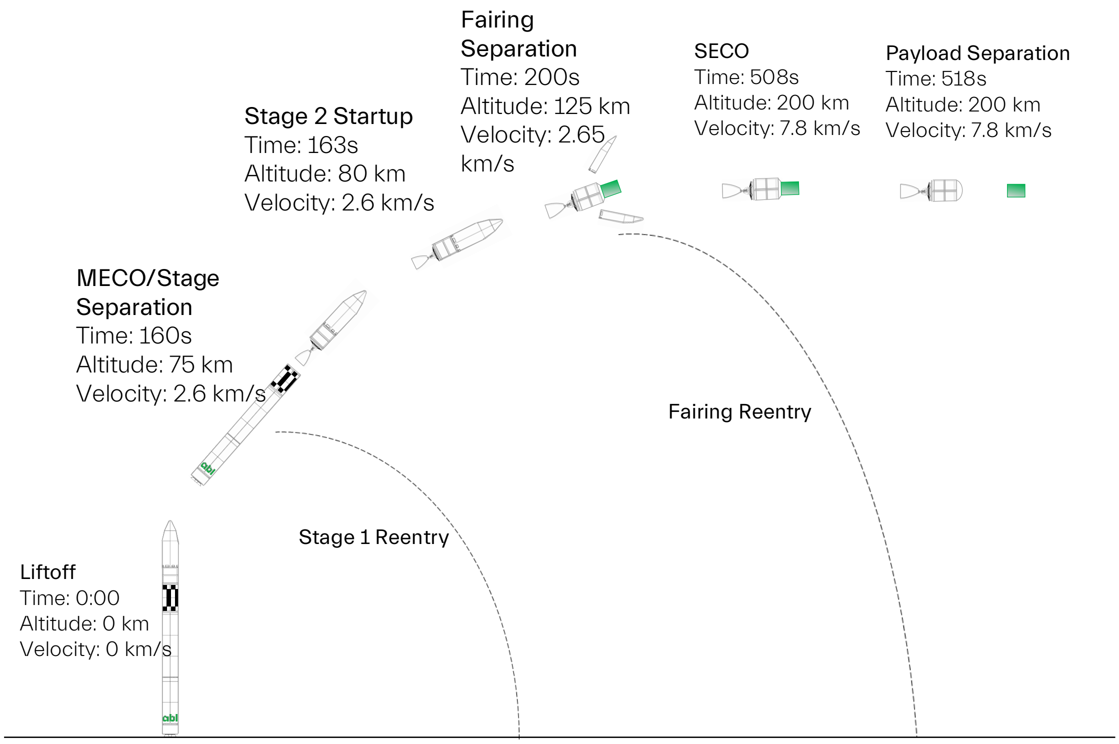

Figure 0-2: Reference mission timing of major events

Insertion Accuracy

Orbital injection accuracies are presented in Table 0-2. The standard (± 7.5°) 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 0-2. Orbital Parameter Accuracy

Perigee [km]	± 15
Apogee [km]	± 15 LEO, ± 275 GTO
Inclination [deg]	± 0.15
Argument of Perigee [deg]	± NA LEO, ± 0.3 GTO
RAAN [deg]	± 0.2 to ± 7.5

Deployment Accuracy

RS1 uses a cold gas thruster system to control attitude and body rates. Table 0-3 presents standard deployment attitude and body rates for a three-axis stabilized deployment. RS1 can support other deployment methods, and mission-specific payload injection accuracy bands are calculated during nominal pre-flight mission analysis by ABL.

Table 0-3. Attitude and Body Rates for a Three-Axis Stabilized Deployment

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

RS1 LAUNCH VEHICLE

RS1 is a two-stage, ground-launched vehicle (Figure 0-1) that uses nine E2 Sea Level engines on the first stage and one E2 Vacuum engine on the second. RS1 is six feet in diameter and 88-feet long when fully integrated. Both stages use liquid oxygen (LOx) as oxidizer and kerosene as propellant. 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 an isogrid design. The front end of the vehicle includes a custom-designed payload adapter fitting and a metallic bi-conic fairing with acoustic protection.

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 termination 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.

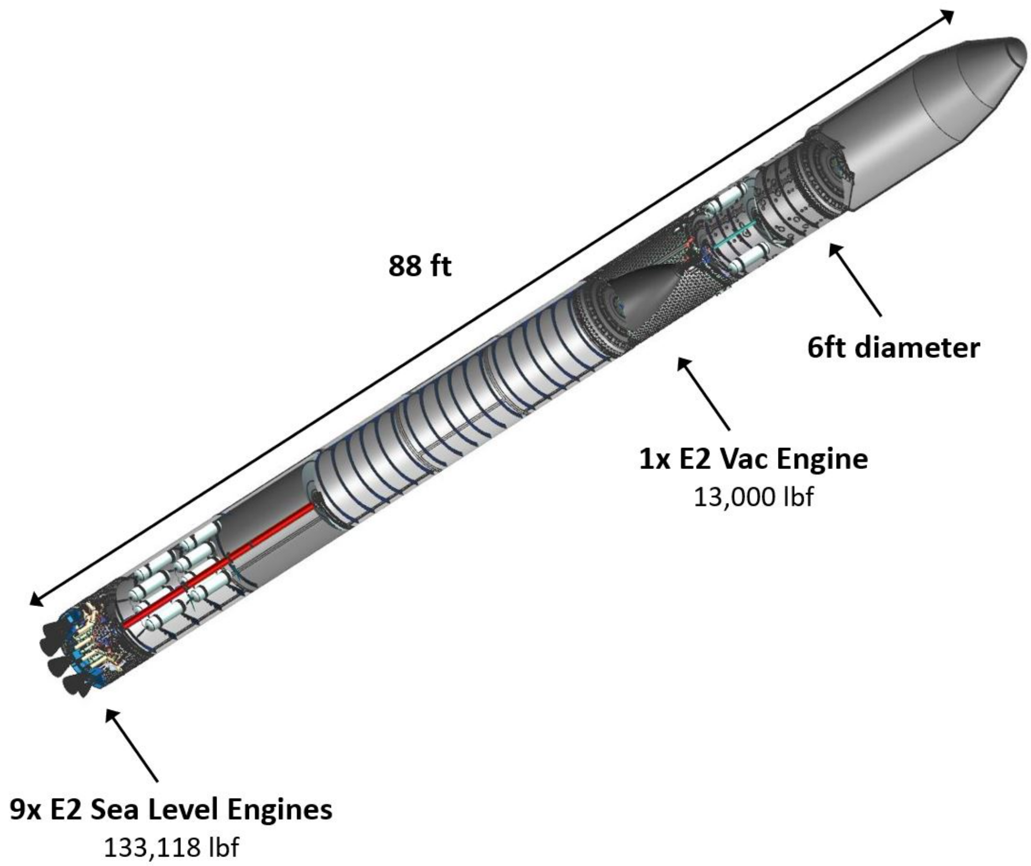

Figure 0-1: RS1 Overview

Table 0-1. RS1 Overview

Item	Unit	Stage 1	Stage 2
Total Length	ft	50	5.4
Diameter	ft	6	6
Propellants	-	LOx and Kerosene	LOx and Kerosene
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	133,118 (sea-level)	13,000 (vacuum)
Pitch Control	-	Thrust Vector	Thrust Vector
Yaw Control	-	Thrust Vector	Thrust Vector
Roll Control	-	Thrust Vector	Cold Gas

Coordinate System

The launch vehicle (LV) coordinate system is defined as:

LV Body Axis:

- +X: LV roll axis, directed through the LV fairing nose
- +Y: LV pitch axis, completes a right-handed coordinate system
- +Z: LV yaw axis, directed opposite of the LV raceway

The LV coordinate system origin is 90 inches aft of the exit plane formed by the stage 1 engine nozzles (Figure 0-2).

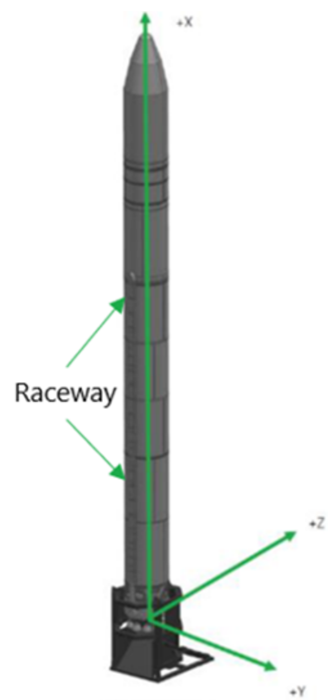

Figure 0-2. LV Coordinate System

Engines

ABL developed the E2 engine (Figure 0-3) from a clean sheet with a focus on simplicity to meet the requirements of the RS1 launch vehicle. E2 is a gas generator cycle engine and produces 13,000 lbf (vac) of thrust. RS1 utilizes E2 on both stages to capture manufacturing economies of scale. Stage 1 utilizes nine sea level optimized E2 engines, while Stage 2 uses one vacuum optimized E2 engine.

Figure 0-3: E2 Sea Level Engine

Additive manufacturing is used in select engine components to structurally optimize components and reduce manufacturing steps to rapidly produce components. This targeted use of additive manufacturing allows complex internal fluid passageways to be incorporated without the need for complex joining processes. Strict process control is implemented on all printed parts, which are subject to rigorous material property validation and quality control requirements. This ensures reliability of the parts manufactured with advanced methods.

All E2 engine components are designed in-house, including the turbopump, main propellant valves, thrust chamber assembly, and gas generator, which gives ABL complete control over the engine architecture and upgrade roadmap. ABL machines and prints most E2 engine parts in-house, minimizing the design-manufacturing feedback loop. This provides tight control over production schedule and the ability to readily scale engine manufacturing.

Avionics

The RS1 avionics system combines proven off-the-shelf components and simple ABL designs. Beyond minimizing technical risk, the team has focused on tailoring redundancy for different aspects of the system to minimize failure modes and comply with the FAA and Range licensing frameworks.

Figure 0-4: Avionics manufacturing bay at ABL headquarters

Guidance, Navigation, and Controls (GNC)

ABL's guidance, navigation, and control (GNC) architecture is typical of a modern LV system. RS1's navigation state is a blended combination of both Global Navigation Satellite System (GNSS) and inertial measurement unit (IMU) sensor data. The actuation systems used are Thrust Vector Control (TVC) and a cold gas Reaction Control System.

Flight algorithms are designed to allow simple adjustments to the mission profile and launch site location with minimal configuration parameters. RS1 has been designed to be robust to high altitude winds to increase launch availability and simplify day-of-launch analysis.

Mission Design

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.

Stage and Fairing Separation Systems

The RS1 stage separation event occurs shortly after the termination of the first stage thrust. RS1 stage separation is accomplished by six equally spaced mechanisms around the circumference of the vehicle. Each mechanism is comprised of a pneumatically-actuated mechanical latch and a pneumatic pusher. All stage separation mechanisms are designed, built, and tested in-house.

RS1 uses split spool devices and springs for fairing separation. Before fairing separation occurs, the fairing halves are held together and to Stage 2 via several electrically-actuated hold down and release mechanisms (HDRMs). The HDRMs are non-pyrotechnic release mechanisms which are commercially available and have many years of flight heritage across several active launch vehicles. Fairing separation is then initiated by actuating the HDRMs, and four in-house spring-based pushers passively act to separate the fairing halves, which rotate and fall away from the vehicle via hinges near the base of the fairing.

PAYLOAD ACCOMMODATIONS

Payload Envelope

As a standard, RS1 uses a metallic, milled 80-inch (2.032m) diameter bi-conic fairing to shield the payload from aerodynamic buffeting and heating during ascent. The fairing is provisioned with acoustic protection provisions with ample clearance for dynamic movement of the fairing and payloads during the ascent. The fairing is a two-part assembly and separates along a longitudinal seam using low shock pneumatic and fully testable actuators.

In addition, ABL offers an expanded fairing option of 108” for customers that need a larger envelope.

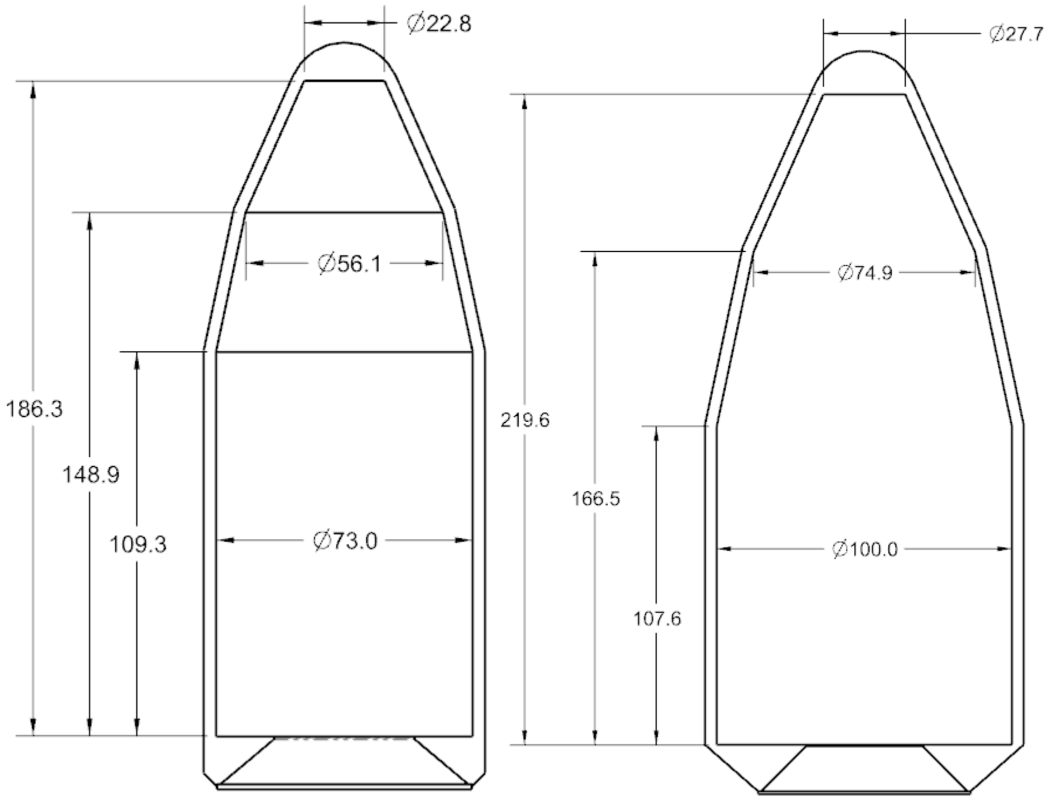

Figure 0-1: RS1 Dynamic Envelopes for 80” Hammerhead (left) and 108” XL Fairing (right) Options

Mechanical Interfaces

Primary Payload Interfaces

The RS1 Payload Attach Fitting (PAF) is designed to be adaptable with standard interface ring diameters up to a 38.81-inch bolt circle. This interface is directly compatible with most separation release systems from Planetary Systems Corp, RUAG, Moog, and other commercial or ABL-custom built secondary adapters. ABL can procure the payload separation system that interfaces with the RS1 PAF as a non-standard service, upon request.

The 38.81-inch PAF interface is referenced below in Figure 0-2.

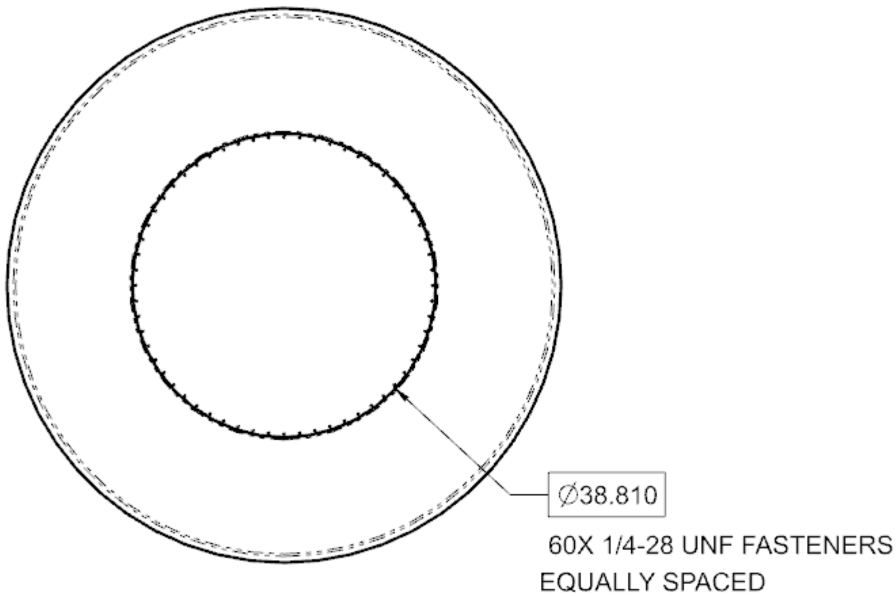

Figure 0-2: PAF 38.81 Inch Mechanical Interface

Secondary Payload Interfaces

The RS1 PAF is compatible to host all commercially available CubeSat dispensers. A customized ABL-built or commercially available secondary structure will be used to accommodate the installation of the CubeSat dispensers.

Electrical Interfaces

Payload to RS1 Electrical Interfaces

The RS1 Flight Computer provides the signals to separate the payloads. The deployment signals can be provided via un-regulated 28V or regulated 10V circuits with various pulse widths and current limiting resistors installed as required. These circuits are routed from the Flight Computer to the payload via direct connection or through an interface panel on the PAF. The RS1 Flight Computer commands both primary and redundant deployment signals simultaneously or can offset signal timing as required.

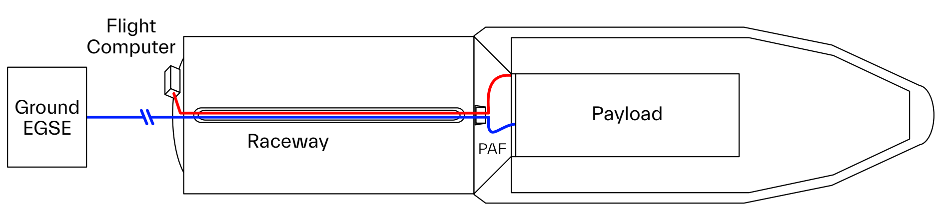

Figure 0-3: RS1 Electrical Interfaces

Payload Separation Indication

The RS1 flight computer will monitor the separation switches or loop-back (break-wire) signals upon separation from the PAF or dispenser. These circuits are routed from the payload deployment system to the flight computer on Stage 2. This configuration is mission-unique depending on the separation systems utilized and the number of payloads and will be defined in the mission Interface Control Document (ICD).

Payload to Ground Electrical Interfaces

The RS1 provides a customizable electrical interface for primary payloads requiring power, battery charging, telemetry, and other command/control functions via a maximum of 75 twisted/shielded pairs (22 gauge) for signal data, 12 twisted pairs (20 gauge) for lower current transmission and 5 twisted pairs (16 gauge) for higher current transmission. This umbilical interface uses an Amphenol R27 quick disconnect connector that is built-in to the RS1 launch mount and a 184-wire umbilical cable that runs to the primary payload electrical ground support equipment accommodation that is housed in a smaller environmentally and physically controlled container called the Payload T-0 EGSE Container (PTEC). The PTEC has a junction box connector for payload EGSE racks. Additional conveyances can be provided to route communication signals via copper, fiber, etc. to off-pad facilities. A terminal block is provided that can be used to re-configure the umbilical circuit wires as required for the payload servicing.

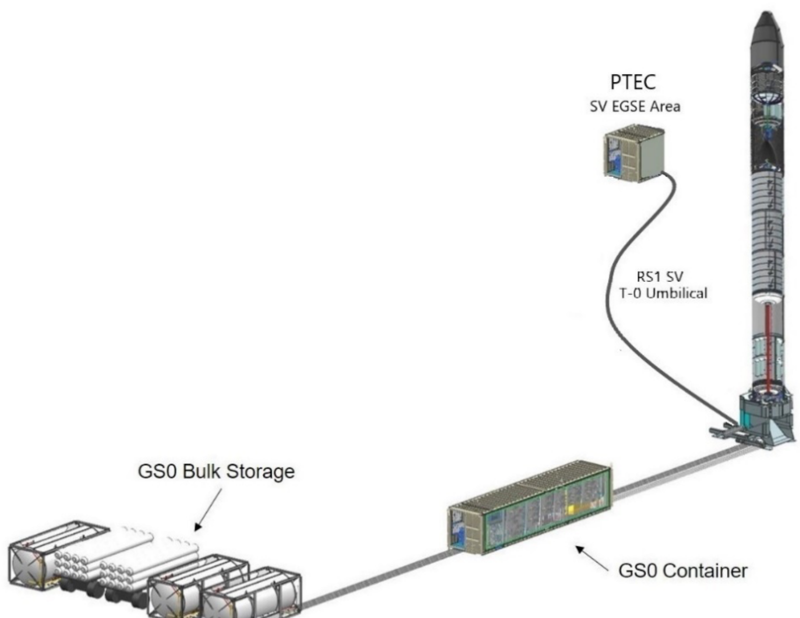

Figure 0-4: Payload – Ground Electrical Interface

ENVIRONMENTS

Characterizing payload environments is critical for payload 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.

Ground Environments

Payload thermal and humidity environments are tightly monitored and controlled while ABL has custody of the payload. While in the payload processing facility, the processing environment temperature will be maintained between 60° to 80° Fahrenheit during operations where the payload is present, and the processing environment humidity will be maintained between 35% to 65% relative humidity.

Payload processing and fairing encapsulation is performed in an ISO 8 (Class 100,000) cleanroom, although higher cleanliness levels are possible ISO 7 (Class 10,000) upon request. Once encapsulated, the payload is supplied with a clean, dry air supply or a low-flow GN_2 purge until final mate to the RS1 vehicle. Once mated to the LV, a GN_2 purge is initiated and maintained until launch. Temperatures are always maintained above the dew point.

Once the Encapsulated Assembly (EA) is mated to the LV, the fairing purge is maintained via the LV umbilical and the environment is monitored remotely via launch control displays.

Table 0-1. Payload Thermal and Humidity Environments

	Environment		
State	Temperature	Humidity	Cleanliness
Payload Processing	70° ± 10°	50% ± 15%	ISO 8 (Class 100,000)
Roll Out Transportation	70° ± 10°	50% ± 15%	ISO 8 (Class 100,000)
Vertical on Pad	70° ± 10°	50% ± 15%	ISO 8 (Class 100,000)

Flight Environments

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 0-2. Loads with a positive sign are compressive.

Table 0-2. Flight Load Factors

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

Figure 0-1 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.

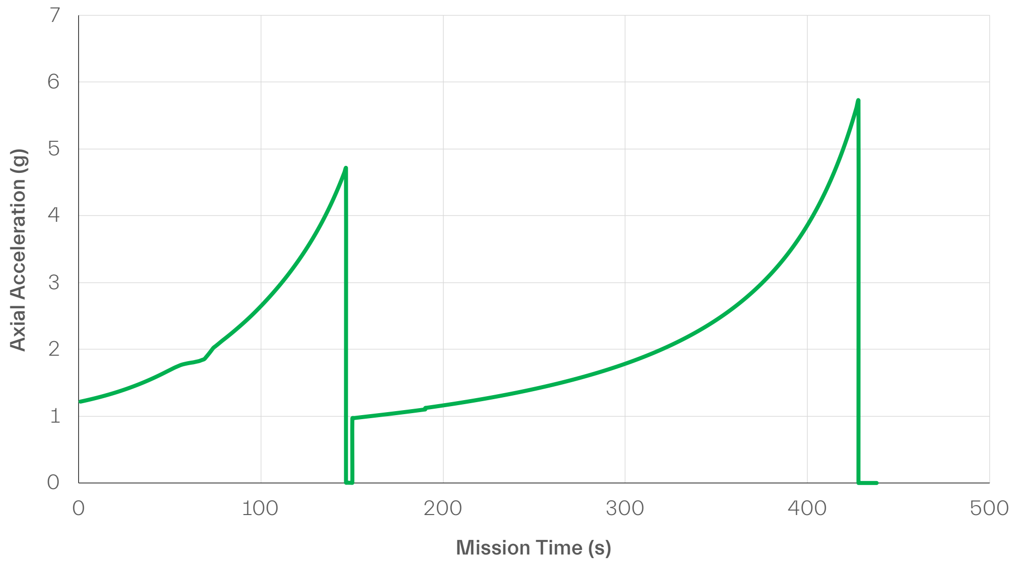

Figure 0-1. Reference Mission Acceleration Profile

Random Vibration

Random vibration is generally a driving load condition on the LV. The RS1 random vibration environments will not exceed NASA's General Environmental Verification Standard (GEVS). ABL maintains and validates these levels through analysis, testing, flight data, and component/isolator design.

Table 0-3. NASA GEVS Protoqualification Levels

Frequency [Hz]	PSD [g2/Hz]
20	0.026
50	0.16
800	0.16
2000	0.026

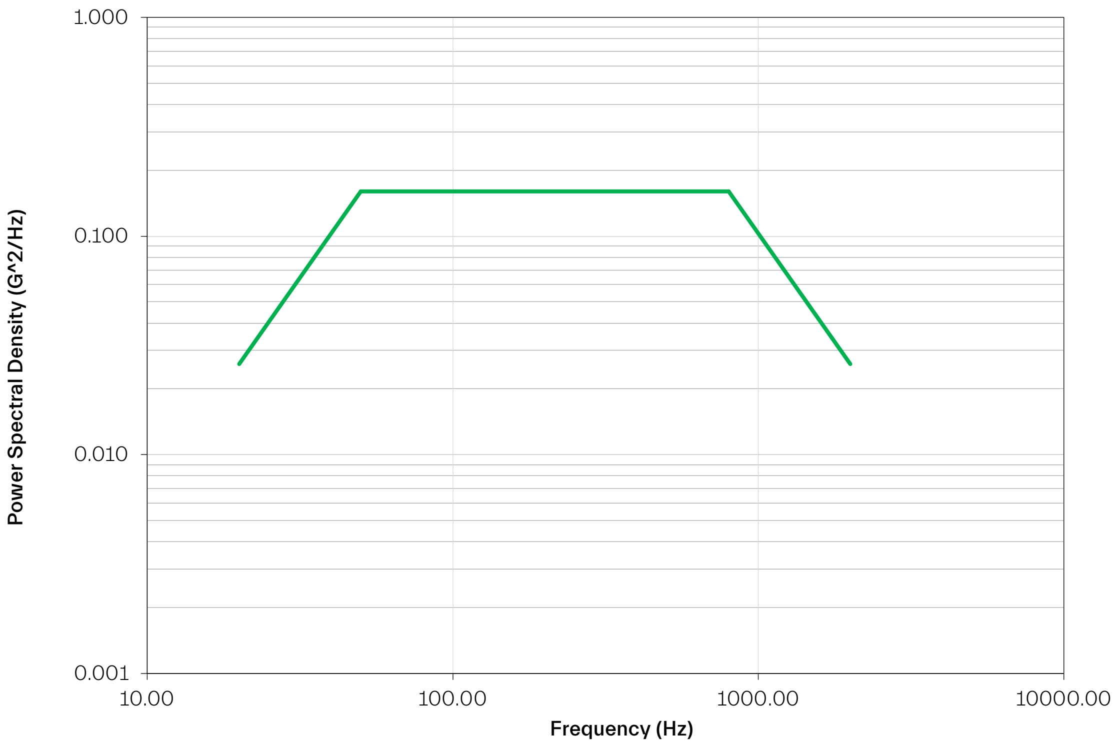

Figure 0-2: NASA GEVS Random Vibration Protoqualification Levels

Acoustic Loads

RS1 utilizes acoustic protection within the bi-conic fairing to maintain the Overall Sound Pressure Level (OASPL) below 135dB for the duration of the mission through liftoff and ascent. The P95/50 acoustic environment levels are shown in Table 0-4, with an OASPL of 129.5dB for the empty PLF and OASPL of 132dB for a 50% full PLF.

Table 0-4: Maximum Flight-Level Payload Acoustic Environment

Freq (Hz)	SPL (dB)	50% full SPL (dB)
16	116.1	119
20	116.8	119.8
25	117.5	120.4
31.5	118.1	121.1
40	119.0	122
50	119.5	122.4
63	119.7	122.6
80	119.5	122.4
100	119.1	121.9
125	118.2	121
160	117.9	120.7

200	116.3	119
250	113.2	115.8
315	111.1	113.6
400	110.0	112.4
500	111.1	113.4
630	112.2	114.3
800	104.4	106.5
1000	105.6	107.5
1250	106.9	108.6
1600	99.4	100.9
2000	97.0	98.4
OASPL	129.5	132.4

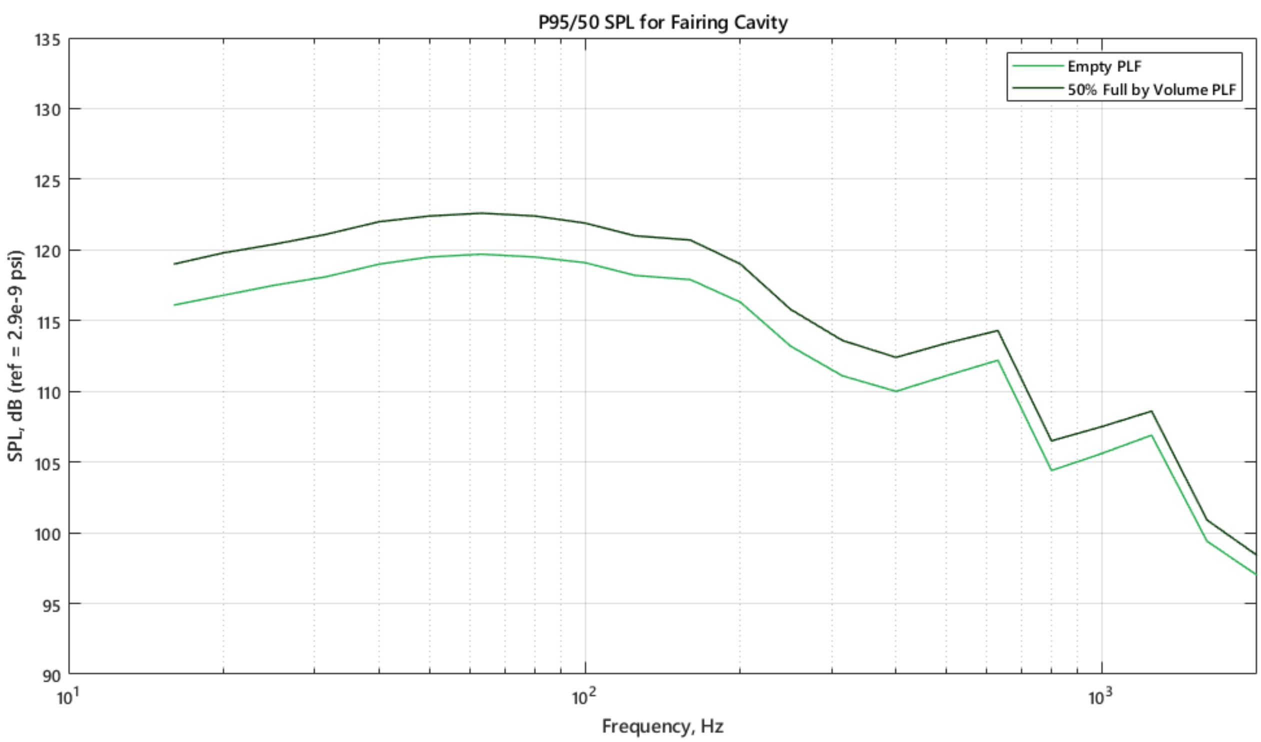

Figure 0-3: P95/S0 SPL for Fairing Cavity

Shock Loads

Four events during RS1 flight create shock loads: liftoff hold down release, stage separation, fairing separation, and payload separation.

RS1 utilizes non-pyrotechnic separation devices for all vehicle separation events, which limits the shock loads imparted to the payload. Figure 0-4 presents an approximate shock response spectrum for a typical primary payload separation device.

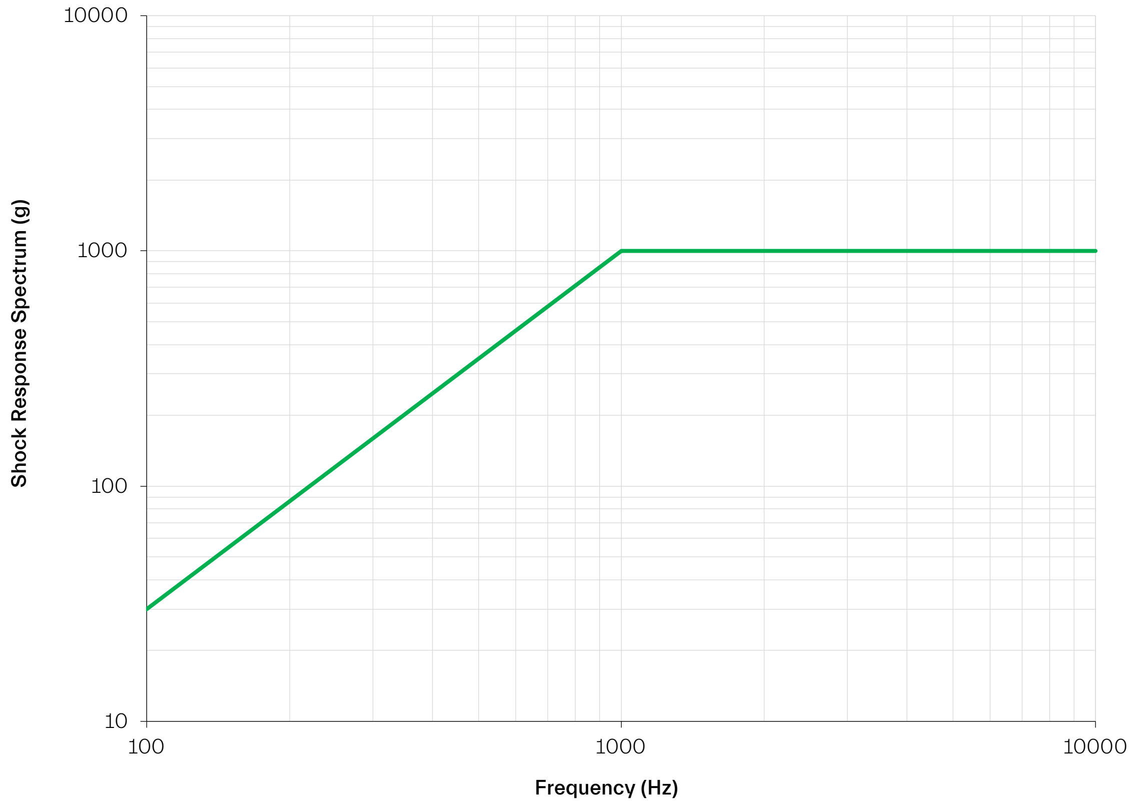

Figure 0-4: Approximate Shock Response for Payload Separation

Radio Frequency

The RS1 launch vehicle transmits and receives data in the frequency bands specified in Table 0-5. Specific frequencies vary by mission and in some instances are range dependent.

Table 0-5: 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 Command	Transmit/Receive	2	UHF	400.0 – 460.0

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.

Fairing Internal Pressure

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.

Payload Thermal

The payload fairing heats minimally during ascent, and the temperature that the payload is exposed to will remain below 90°C. Mission-specific thermal analysis can be performed using payload thermal models upon request.

On orbit, certain trajectories may benefit from an RS1 Stage 2 roll during coast to ensure even solar heat flux across the payload. Attitude pointing and roll control of up to 2 deg/s can be provided if thermal analysis demonstrates that this is required.

Free Molecular Heating

RS1 fairing deployment occurs when free molecular aero-thermal heating is less than 1,135 W/m^2. This is a time-based determination from 6DOF simulations and Monte Carlo methodology.

Payload Environmental Compliance

The payload requirements for primary and secondary payloads are outlined Table 0-6.

Table 0-6. Payload Requirements

Resonance and First Natural Frequency	The 1st lateral resonant frequency must exceed 10 Hz. The 1st axial resonant frequency must exceed 25 Hz.
Random Vibration	The payload must withstand random vibration at the levels presented in Table 0-3.
Acceleration Loading	The payload must withstand acceleration loads presented in Table 0-2.
Mass	Preliminary mass must be reported to within +/- 5lbm For Cubesats, nominal masses expected, higher masses acceptable with ABL approval (1U: 1.33kg, 3U: 4kg, 6U: 12kg)
RF 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.

MISSION MANAGEMENT

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 launches can be single payloads or a combination of multiple payloads. 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.

ABL's Mission Integration process envelopes all payload services as they pertain to LV and mission planning, design, analysis, development, production, integration, and testing. ABL's mission management team is trained and well-versed in working with both dedicated and rideshare missions and will collaborate with the customer to ensure that compatibility between the payloads and the LV (and between other payloads, in the case of rideshare missions) is a smooth and timely process.

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 CLA and heating analysis are used to verify spacecraft loads.
- **Interface Control Documentation.** ABL creates and maintains an 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 payloads with environmental control until T-0.
- **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.

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 payload telemetry during flight.
- **Additional Analysis.** ABL can perform additional cycles for CLA and thermal analysis.
- **Payload Transport.** ABL can arrange transport of the payload to the launch site.
- **Separation System.** ABL can provide a range of compatible separation systems for payloads upon request.
- **Payload Adapter Fitting Customization.** Customized mechanical fittings can be provided by ABL should the payload not fit the standard payload adapters offered.
- **Advanced Orbit Planning** ABL can perform on-orbit thermal management maneuvers or provide custom orbital planning including orbit spacing between payloads or a change of orbital altitudes or planes for multiple payloads.

- **Launch Pad T-0 Umbilical Connection.** ABL can provide a separate, secure Customer EGSE room located at the launch pad as well as day-of-launch umbilical connections to the payload. Payload telemetry can be monitored from the control room.
- **Payload Fueling.** ABL can assist with procurement as well as support fueling activities at the payload processing facilities, including hazardous operations.
- **Rapid Launch.** For customers with time-sensitive missions, ABL offers responsive launch options.

Customer Requirements

Table 0-1 gives an example timeline of customer deliverables that ABL will require from authority to proceed (ATP) to launch. The requirements timeline is subject to change in accordance with mission and customer requirements.

Table 0-1: Example timeline of deliverables from both parties

Time	Customer to ABL
ATP	Contract Signature
ATP+2 weeks	Mission/Orbit Specifications Payload Questionnaire and Specifications (such as CAD)
ATP+2 months	Payload CLA Model (if applicable)
ATP+3 months	Mission Specific ICD edits Preliminary Payload Layout Design
L-10 months	Preliminary Payload Processing/Range Safety Inputs
L-8 months	Payload Thermal Model (if applicable)
L-7 months	Electrical and Mechanical fit checks
L-6 months	Mission ICD signed Payload Test Plan(s)
L-4 months	Launch License Inputs Daily Payload Processing Schedule Final Mass Properties
L-45 days	Payload License Confirmations Payload Readiness Confirmation As-measured Mass Properties FAA Cross-waivers signed
L-30 days	Payload arrives at launch site or processing facility
L-2 days	Launch Readiness Review

Insurance

All aspects of ABL launches are insured by premier underwriters in the space insurance market. ABL is responsible for third-party liability coverage, while customers are responsible for insuring their payload.

Payload Safety

ABL follows AFSPCMAN 91-710 Range Safety User Requirements, 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 Questionnaire.
- **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 requires appropriate advance customer coordination.

ABL can provide guidance on documentation required to meet Range requirements and will coordinate with the Customer on compliance well in advance of launch.

FACILITIES

ABL's headquarters are located in El Segundo, CA, in close proximity to the test facilities at Mojave Air and Space Port and Edwards Air Force Base further described in Section 7.5 below. ABL’s headquarters and test site locations allow for easy access to the test sites for ABL engineering and operations staff, and also serve to enable quick iteration and turnaround times during test campaigns.

In addition, ABL is activating multiple launch sites as depicted in Figure 0-1 below.

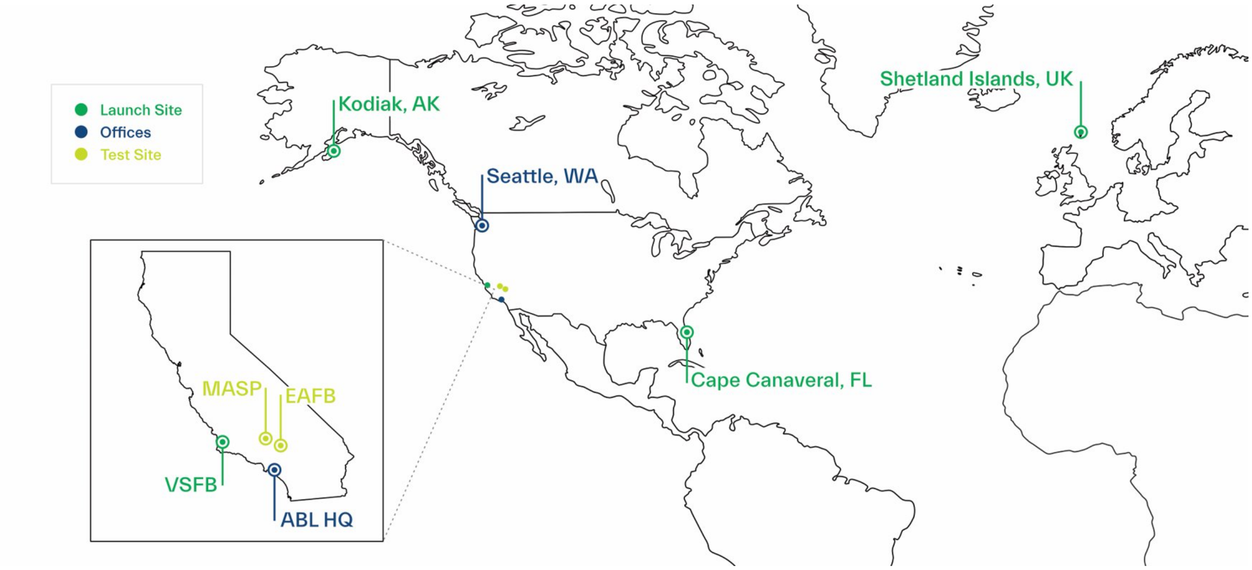

Figure 0-1: ABL launch sites, offices, and test facilities

ABL Headquarters

The ABL campus in El Segundo includes four buildings, totaling 80,000 square feet of manufacturing and test space. The El Segundo campus contains all design engineering, fluid system and avionics integration, environmental testing, tank manufacturing, and LV integration. In addition, the campus contains a large, state-of-the-art machine shop, capable of producing the company's most complex parts, and areas for ground system fabrication, storage, and refurbishment.

Launch Sites

RS1 and GS0 are designed to be packaged into standard shipping containers and operated from a flat concrete pad of 150' x 50'. This capability dramatically reduces the time and cost of activating new launch sites. ABL can operate from both dedicated and shared launch pads, doubling launch capacity at each range, with fairing capsulation occurring from a local payload processing facility.

Table 0-1 outlines the coordinates and accessible inclinations from both domestic and international launch sites.

Table 0-1. United States Launch Sites Details

Site	Lat. [deg]	Lon. [deg]	Min Inc. [deg]	Max Inc. [deg]
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 Space Force Base, CA	N 34° 34' 34"	W 120°37' 56"	57	104
Saxavord Space Centre, UK	N 60° 49 '04"	W 0°45'40.7"	90	SSO

Vandenberg Space Force Base (VSFB) LC-576E

ABL has secured LC-576E on the northern area of VSFB as a dedicated, long-term launch facility. LC-576E's unique location offers ideal access for integration and distance from other launch sites and strategic assets on base. This site enables access to SSO and polar orbits.

Cape Canaveral Space Force Station (CCSFS) Station and Kennedy Space Center (KSC)

ABL has structured an agreement with Space Florida, a Florida state government organization, to conduct RS1 launch operations from LC-46 at CCSFS. This site is similar in configuration to VAFB SLC-576E. This site enables ABL to launch payloads to mid-inclinations, as well as Geostationary Transfer Orbit (GTO).

SaxaVord Space Centre, UK

ABL was selected in partnership with Lockheed Martin Corporation as the launch service provider for the United Kingdom Pathfinder Launch Program to be launched from the SaxaVord Spaceport located in Unst, Shetland. Operating from SaxaVord, ABL can support missions to Sun-Synchronous, Polar and High Inclination orbits.

Kodiak, Alaska

ABL has entered into a formal agreement with Alaska Aerospace Corporation for launch of RS1 from Pacific Spaceport Complex (PSC) in Kodiak, Alaska. Pacific Spaceport Complex currently has six active launch pads, two suitable cleanrooms, and is capable of handling hazardous fueling operations.

Ground Systems (GS0)

ABL's GS0 ground system is fully independent and self-sufficient, providing orbital launch capability from any flat 150' x 50' concrete pad globally. Any air base or similar facility can be used as an orbital launch site.

For commercial applications, GS0 represents a differentiator in ABL's ability to scale launch sites. All aspects of the GS0 launch system are fabricated in ABL's factory, enabling strict process control and oversight. Importantly, this enables ABL to serially produce launch site infrastructure in the same way the company produces launch vehicles. ABL can rapidly create launch infrastructure and deploy it to fixed, FAA-approved launch sites for increased orbital launch capacity.

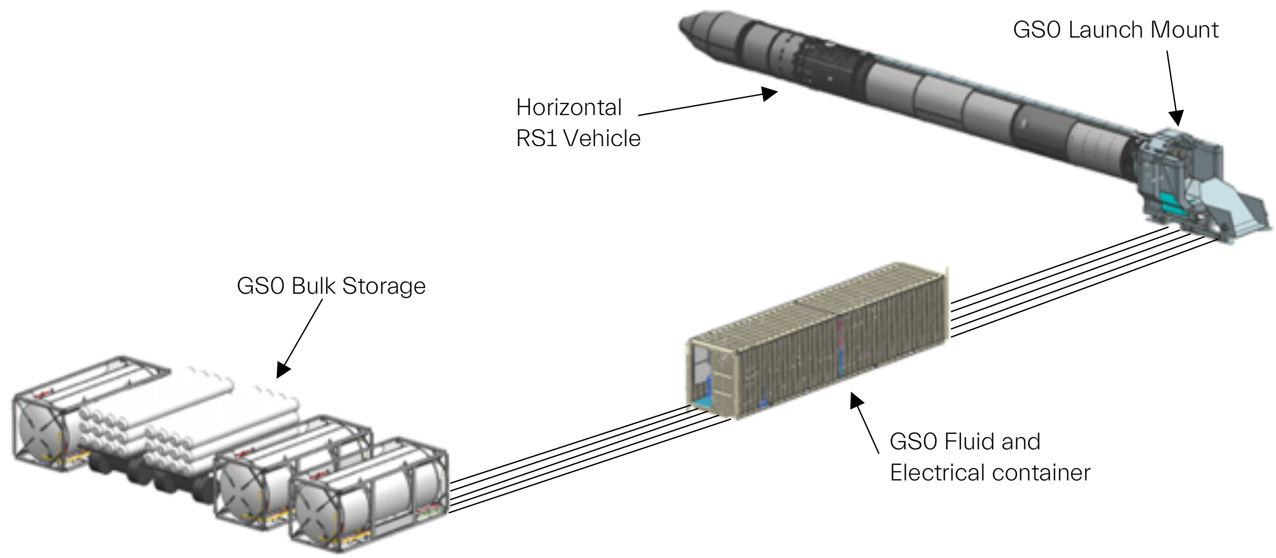

Figure 0-2. GS0 system layout

Payload Processing Facilities

For payload processing at various sites, ABL ensures that all facilities meet the following requirements:

- ISO 14644 Cleanroom; ISO8 certified
- Certified Crane available for use
- Adequate ceiling/hook height clearances
- Adequate space for GSE, Payload, PAF, PLF, and tables
- Gowning room, garments, and supplies
- Adequate power for integration activities
- Adjacent office facilities with desks, phone lines, internet connectivity, and a printer
- Compatibility with security requirements
- Ability to support hazardous operations

ABL will also provide a storage area for crates and containers after they are unloaded. ABL maintains a standard tool and GSE list for integration needs and will ensure that all necessary tools/equipment are calibrated properly and available for use during integration. Appropriate safety equipment will be obtained for hazardous operations.

Test Facilities

ABL's Production Test site is located at the Mojave Air and Spaceport, shown in Figure 0-3. This facility currently includes two active engine test bays, as well as a Stage 2 test stand and a Stage 1 test stand. This facility allows for rapid test setup and execution of all engine acceptance tests leading up to launch.

ABL also has a test facility located at Edwards Air Force Base. This facility is a Development Test Site and includes an area for general testing, including structural proof testing.

Figure 0-3: ABL Test Site at MASP with Integrated E2 Cell (left) and E2 Powerhead Cell (right)

LAUNCH OPERATIONS

ABL begins the deployment of the GS0 ground systems at approximately L-25 days. The launch stool is secured, bulk commodities are staged, and racks for mission control are installed. Ground system activation and checkouts will occur up until L-10 days and happen in parallel with RS1 stage checkouts. Payload arrival and processing can also begin as early as L-30 days, but notionally could occur as late as L-12 days.

Once S1 and S2 are mated (at approximately L-10 days), the LV is mounted to the launch stool and integrated checkouts take place, including vehicle HITL tests. At L-5 days, the LV performs a static fire test with a burn duration of 5 seconds. Post-test, the vehicle is brought back to horizontal, and the Encapsulated Assembly is mated to RS1 at L-4 days. The Launch Readiness Review is conducted at L-2 days as the final review before launch.

Table 0-1 illustrates a standard launch campaign timeline. While each mission is different, ABL adheres to a strict launch timeline to enable high-cadence and on-time launches. As arranged in advance, ABL can accommodate customers that require more time onsite for payload processing.

Table 0-1. Reference Launch Campaign Timeline

Event	Date
GS0 Deployment Begins	L-25 days
LV Arrives at to Launch Site	L-21 days
RS1 Unpacking and Inspection	L-20 days
RS1 Integrated System Checkouts	L-19 days

Payload Integration Start	L-15 days
Stage Mate	L-10 days
Encapsulation	L-9 Days
Operational Dry-Runs	L-7 days
Static Fire Test	L-5 days
Mate EA to RS1	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
Launch	L-0

Payload Processing

ABL's standard payload arrival time at the payload processing facility is at L-30 days; however, this can be tailored to the customer's specific schedule. Depending on the payload processing facility used, ABL will coordinate for appropriate payload standalone processing and fueling and PAF integration and encapsulation rooms.

Payload Encapsulation

Once final mechanical and electrical mate between the payload and PAF is complete, the entire Payload and PAF assembly is broken over from vertical to horizontal. The fairing interior and exterior will be cleaned and staged in the airlock on a mobile cradle. When the payload/PAF assembly is ready, the fairing will be staged into the cleanroom and aligned for horizontal encapsulation. Alignment and encapsulation occur via a cradled rail assembly which is attached to the PAF breakover fixture.

When encapsulation is complete, the Encapsulated Assembly (EA) is connected to an HVAC/GN_2 purge and transported and mated to RS1 at the pad.

Security

ABL can accommodate the security requirements for the payload while present at the launch site. This includes 24/7 video monitoring of key areas, card access control to facilities for approved personnel only, and 24/7 security patrols that walk the entire site periodically. Additional requirements can be discussed and arranged in coordination with ABL.

Countdown 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 include upper-level wind assessments to tune loads alleviation algorithms, as well as Monte Carlo mission simulations.

Flight Operations

Liftoff and Ascent

A reference timeline for a sample mission in which Stage 2 performs a single burn, deploys the payload, and subsequently executes a Collision Avoidance Maneuver and a deorbit burn at a safe time after payload separation is shown in Table 0-2. For higher altitude orbits or multi-manifest missions, RS1 Stage 2 executes multiple burns.

Table 0-2. Reference Mission Timeline

Mission Time [m:s]	Event
-0:02	Stage 1 Startup
0:00	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

Payload Separation and Reporting

After reaching the spacecraft injection orbit and attitude, the vehicle will issue redundant payload separation commands to initiate separation of the payload.

ABL understands the importance of locating a payload quickly post-deployment and as such, ABL's standard time for post-deployment delivery of the state vector and orbital parameters is within deployment + 45 minutes, with an emphasis on providing the data as soon as possible. To do this, ABL considers ground station planning with the mission-specific trajectory to ensure coverage during payload deployment. If payload deployment does not occur in view of a ground station, or there is a ground station issue, the RS1 vehicle will store the information on-board until the next available opportunity to transmit to the ground.

Collision Avoidance

RS1 will provide adequate time between payload separation and any maneuvers which could result in contamination to the payload, such as a collision avoidance maneuver.

Post Launch Reports

Post-launch, ABL provides a report that includes timing of all major events as well as actual versus predicted performance, orbital injection accuracy, and measurement of the environments in the Payload Fairing.

DOCUMENT REFERENCE

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List of Acronyms

Acronym	Definition
24/7	Twenty-four hours seven days per week
3DOF	Three Degrees of Freedom
6DOF	Six Degrees of Freedom
ABL	ABL Space Systems

AFSPCMAN	Air Force Space Command Manual
AK	Alaska
ATP	Authority to Proceed
BEO	Beyond Earth Orbit
CA	California
CAD	Computer Aided Design
CAM	Collision Avoidance Maneuver
CCSFS	Cape Canaveral Space Force Station
CG	Center of Gravity
CLA	Coupled Load Analysis
EA	Encapsulated Assembly
EAFB	Edwards Air Force Base
EGSE	Electrical Ground Support Equipment
FAA	Federal Aviation Administration
FL	Florida
GEO	Geostationary Earth Orbit
GEVS	General Environmental Verification Standard
GN2	Gaseous Nitrogen
GNC	Guidance, Navigation, and Control
GNSS	Global Navigation Satellite System
GSE	Ground Support Equipment
GTO	Geostationary Transfer Orbit
HDRM	Hold Down and Release Mechanism
HITL	Hardware-in-the-Loop
HVAC	Heating, Ventilation, and Air Conditioning
ICD	Interface Control Document
IMU	Inertial Measurement Unit
KSC	Kennedy Space Center
LC	Launch Complex
LEO	Low Earth Orbit
LOx	Liquid Oxygen
LV	Launch Vehicle
MASP	Mojave Air and Space Port
MaxQ	Maximum Dynamic Pressure
MECO	Main Engine Cutoff
MEO	Medium Earth Orbit
MTO	Mass to Orbit
NASA	National Aeronautics and Space Administration
OASPL	Overall Sound Pressure Level
PAF	Payload Attach Fitting
PLF	Payload Fairing
PSC	Pacific Spaceport Complex

PSD	Power Spectral Density
PTEC	Payload T-0 EGSE Container
Q	Dynamic Pressure
RAAN	Right Assentation of the Ascending Node
RF	Radio Frequency
SECO	Second Stage Engine Cutoff
SEIP	Standard Electrical Interface Panel
SLC	Space Launch Complex
SMC	Space and Missile Systems Center
SPL	Sound Pressure Level
SSO	Sun Synchronous Orbit
SW	Space Wing
TPL	Third Party Liability
TRM	Tactical Responsive Mission
TVC	Thrust Vector Control
UHF	Ultra-high Frequency
UK	United Kingdom
VSFB	Vandenberg Space Force Base
WA	Washington