FIREFLY
AEROSPACE

PAYLOAD USER'S GUIDE

Overview

The goal of the Firefly Payload User's Guide is to provide summary information for preliminary mission planning for Payload Customers. The contents found herein are not intended to be mission specific and are subject to change. Firefly welcomes detailed design data such as payload-specific requirements and interfaces, and operational plans once a Launch Service Agreement is in place.

Contact Firefly

Please contact Firefly Aerospace Launch Services with inquiries into the suitability of the launch vehicle for your mission.

Launch Services	Firefly Aerospace Inc. 1320 Arrow Point Drive Suite 109 Cedar Park, TX 78613 E-mail: launch@fireflyspace.com Web: www.fireflyspace.com

Copies of this Firefly Payload User's Guide may be obtained from the Firefly website at the link above. Hard copies are also available upon request.

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1 Introduction

Welcome to the Payload User's Guide for the Firefly launch vehicles - we're glad you're here!

Firefly's mission is to make space accessible by providing our customers with reliable, economical, high- frequency launches for orbital services.

Our Alpha and Beta launch vehicles enable this vision. Come aboard.

1.1 Firefly's History

Firefly Aerospace Inc. ("Firefly") was founded to provide economical, high-frequency access to space for small payloads through the design, manufacture and operation of reliable launch vehicles. The Firefly team addresses the market's need for flexible access to space with a "simplest, soonest" approach to technology selection.

Firefly's engineering team is comprised of industry-proven leaders with experience in building both commercial launch vehicles and successful technology firms. Augmenting and rounding out this team are passionate young minds from the country's top engineering schools. To reduce risk and increase reliability, each vehicle is engineered with cross-industry design insights and leverages high maturity design elements and commercial off the shelf (COTS) components. Firefly's manufacturing process is highly vertically integrated. Propulsion, structures and avionics are designed, built and tested in-house. The technologies employed in our Alpha flagship vehicle provide a clear pathway for future incremental improvements in vehicle capability.

Firefly's facilities include a 20,000-square foot design campus in Cedar Park, Texas, just north of Austin, which houses the corporate headquarters, engineering staff, prototyping facilities and machine shop. The Firefly Briggs operations facility, a 200-acre test and production site, is a short drive north from the design campus. It hosts extensive and growing test and manufacturing capabilities. Briggs facilities house ground systems fabrication, a test control center, surface finishing/processing, composites fabrication and assembly production. Briggs is also home to the propulsion, structures and materials testing range, whose proximity to the design campus facilitates rapid transitions from paper to proven designs. Rapid development testing is optimized at low cost utilizing our in-house horizontal engine test, vertical stage test, and high-pressure component stands.

Firefly's first Alpha vehicle launch is scheduled for the third quarter of 2019. By the first quarter of 2021, Firefly plans to launch two Alpha vehicles per month given planned production capacity. The Firefly team is currently evaluating market demands to determine the first launch date of Beta.

2 Vehicle Overview

Firefly launch vehicles service the small-to-medium-sized satellite market. Alpha delivers 1,000 kg (2,204 lbm) to Low Earth Orbit (LEO) and the larger Beta launch vehicle delivers up to 4,000 kg (8,818 lbm) to LEO and smaller payloads to Geostationary Transfer Orbit (GTO). Firefly vehicles draw on well-established, historically-successful rocket technology, such as LOX/RP-1, pump-fed, regeneratively cooled engines.

In contrast, modern advances in aerospace composite materials enable rapid development of strong, lightweight primary structures such as propellant tanks. Use of Commercial Off-the-Shelf (COTS) components in avionics systems, such as the flight computer and communication system, allows for high-reliability, low-cost, and streamlined development. Proximity to technology centers in Austin, Texas facilitates support operations with all facets of design, testing, and production performed locally.

Figure 1 highlights the Alpha and Beta vehicle characteristics. More details of Alpha architecture are presented in Section 2.1; the Beta architecture is detailed in Section 2.2.

PERFORMANCE	ALPHA, α	BETA, β	UNITS
Payload (SSO, 500km)	630	3,000	[kg]
Payload (LEO, 200km)	1,000	4,000	[kg]
Payload (GSO)	n/a	400	[kg]
ARCHITECTURE			
GLOW (SSO, 500km)	54,000	149,000	[kg]
Number of Stages	2	2	
Total Length	29	31	[m]
Max Diameter	2.00	2.80	[m]
Structure	All Composite	All Composite	
PROPULSION			
Oxidizer	LOX	LOX	
Fuel	RP-1	RP-1	
Max Thrust (stage 1)	736	2,208	[kN]
Max Thrust (stage 2)	70	163	[kN]

Figure 1: Firefly Vehicles Overview

2.1 Alpha Architecture

Alpha is a two-stage launch vehicle capable of delivering 1,000 kg (2,204 lbm) of payload to 200 km (125 mile) Low-Earth Orbit. Firefly's entry-to-market vehicle, Alpha provides low-cost launch capabilities for the small satellite market. To learn more about Alpha, please see Table 1 and Figure 2.

Table 1: Alpha Characteristics

CHARACTERISTICS	STAGE ONE	STAGE TWO
Height	29 m (95 ft) including fairing and stages	
Diameter	1.8 m (6.0 ft)	
Material	Carbon composite	
Propellants	LOX/RP-1	LOX/RP-1
Propellant feed system	Turbopump	Turbopump
Engine name	Reaver 1	Lightning 1
Quantity of engines	4	1
Thrust (stage total vac)	736 kN (165,459 lbf)	70 kN (15,737 lbf)
Engine designer	Firefly	Firefly
Engine manufacturer	Firefly	Firefly
Restart capability	No	Yes, 1 restart
Max level of throttling	20%	20%
Tank pressurization (No.)	Heated helium (4)	Heated helium (1)
Dry mass	2,895 kg (6,382 lbm)	910 kg (2,006 lbm)
Max Gross Lift-Off Weight	54,000 kg (119,050 lbm)	
Payload mass	1,000 kg (LEO 28.5°, 200 km) 630 kg (SSO, 500 km)	

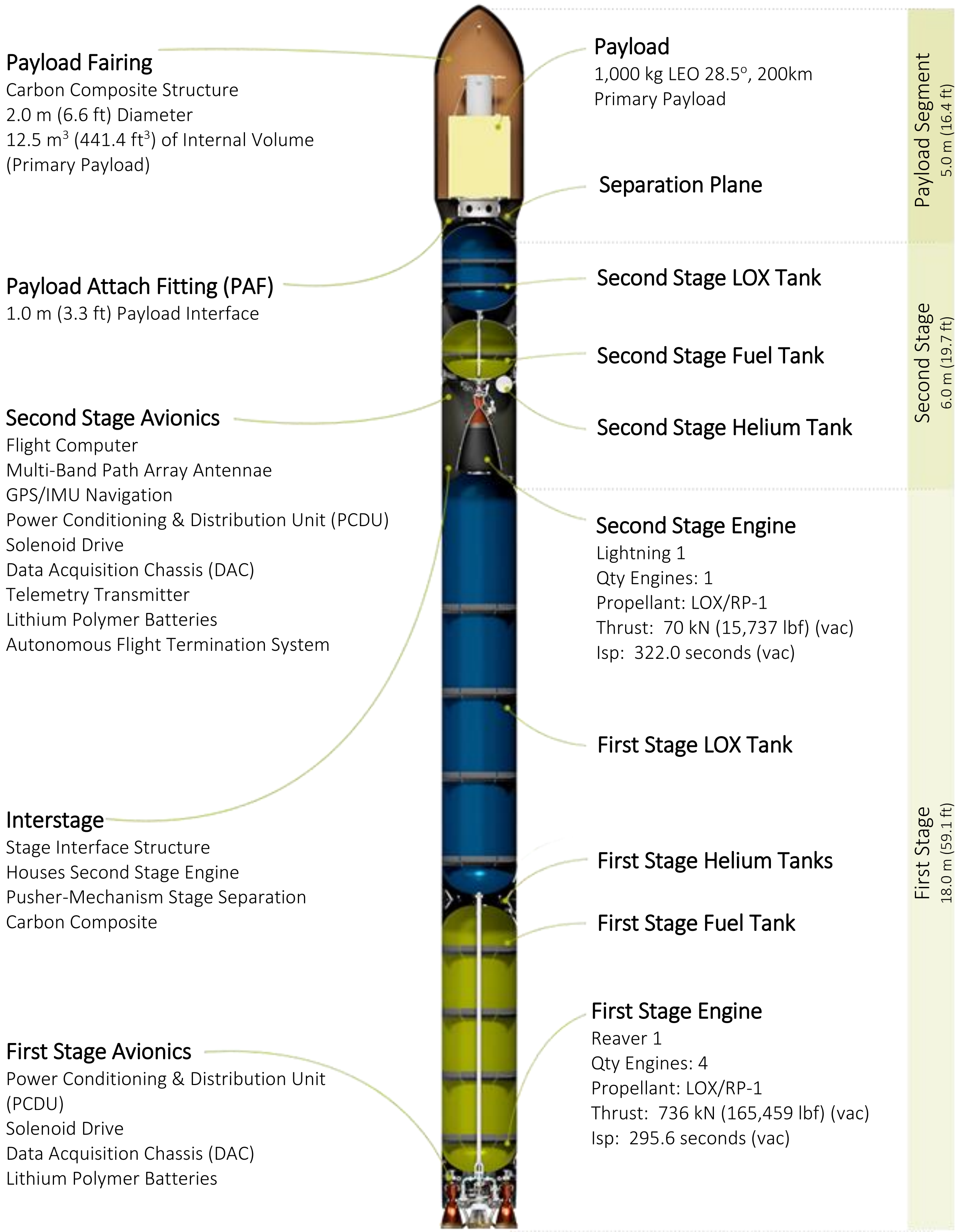

Figure 2: Alpha Overview

Figure 3 shows the definition of the axes for the Firefly Alpha vehicle. The X-axis is the roll axis for the vehicle, and the vertical axis for any vertically mounted satellite. The axes definitions in Figure 3 are used throughout this User's Guide to specify payload environments, loads, and test requirements.

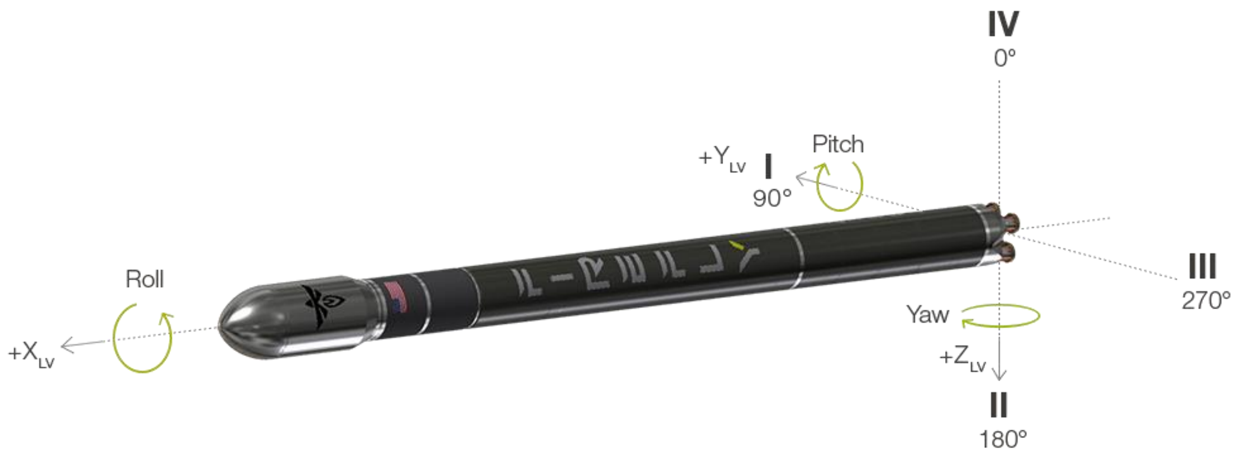

Figure 3: Alpha Vehicle Coordinate Frame

2.1.1 First Stage

First stage propulsion features four independent LOX/RP-1 engines. These pump-fed LOX/RP-1 engines yield 736 kN (165,459 lbf) (vac) thrust. This stage incorporates a carbon composite propellant tank with four helium pressurant tanks nested between the LOX and fuel tanks. Thrust vector control is provided by gimballing each thrust chamber. Flight termination is ordnance-based, with Autonomous Flight Termination Units located on Stage 2.

2.1.2 Alpha Second Stage

The second stage delivers the payload to orbit. It features a pump-fed, bell nozzle engine. Fueled by LOX/RP-1, this stage provides 70 kN (15,737 lbf) (vac) thrust. The all-composite structure includes a 2 m (6.6 ft) payload fairing baseline accommodation. A single helium tank provides ullage pressurant, attitude control, roll control, and settling. The engine is gimbaled using hydraulic actuators for thrust vector control.

2.1.3 Alpha Payload Fairing

The Firefly-developed payload fairing composite construction is 2 m (6.6 ft) in diameter by 5.0 m (16.4 ft) in height.

The fairing separates into two equal halves as shown in Figure 4. Figure 5 details the mechanical separation design.

Figure 4: Open Alpha Clamshell Fairing Concept

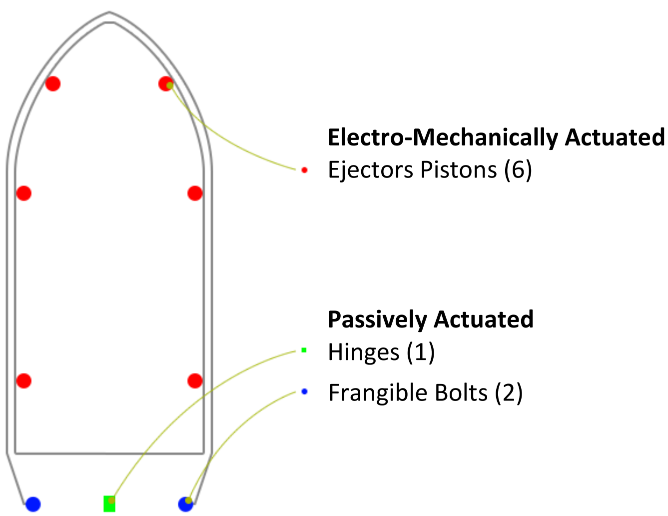

Figure 5: Baseline Alpha Fairing Separation Design

After the second stage burn, the second stage and payload are stabilized. Then the payload fairing separates, exposing the payload. Finally, each satellite is deployed from the Payload Attach Fitting (PAF). A typical direct inject flight profile is discussed in Figure 8 of Section 2.1.4

2.1.4 Alpha Performance

This section details the performance capabilities of the Firefly Alpha vehicle. Alpha can accommodate a wide range of payload requirements. Our team can provide performance trades to meet our Customers' needs. Figure 6 provides orbit delivery performance for inclinations typical of a launch from the East Coast of the United States. Figure 7 provides orbit delivery performance for inclinations typical of a launch from the West Coast of the United States.

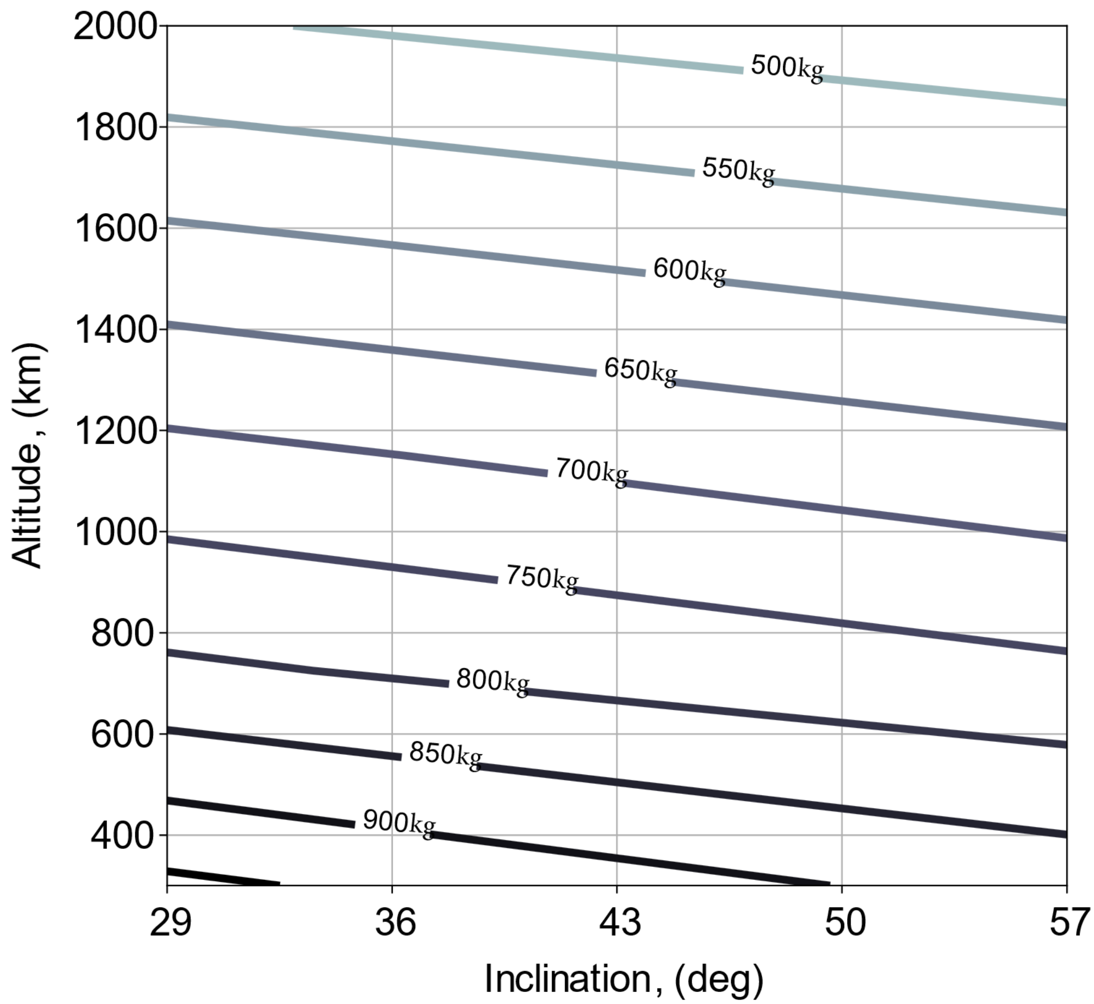

Figure 6: Alpha Performance
East Coast Launch

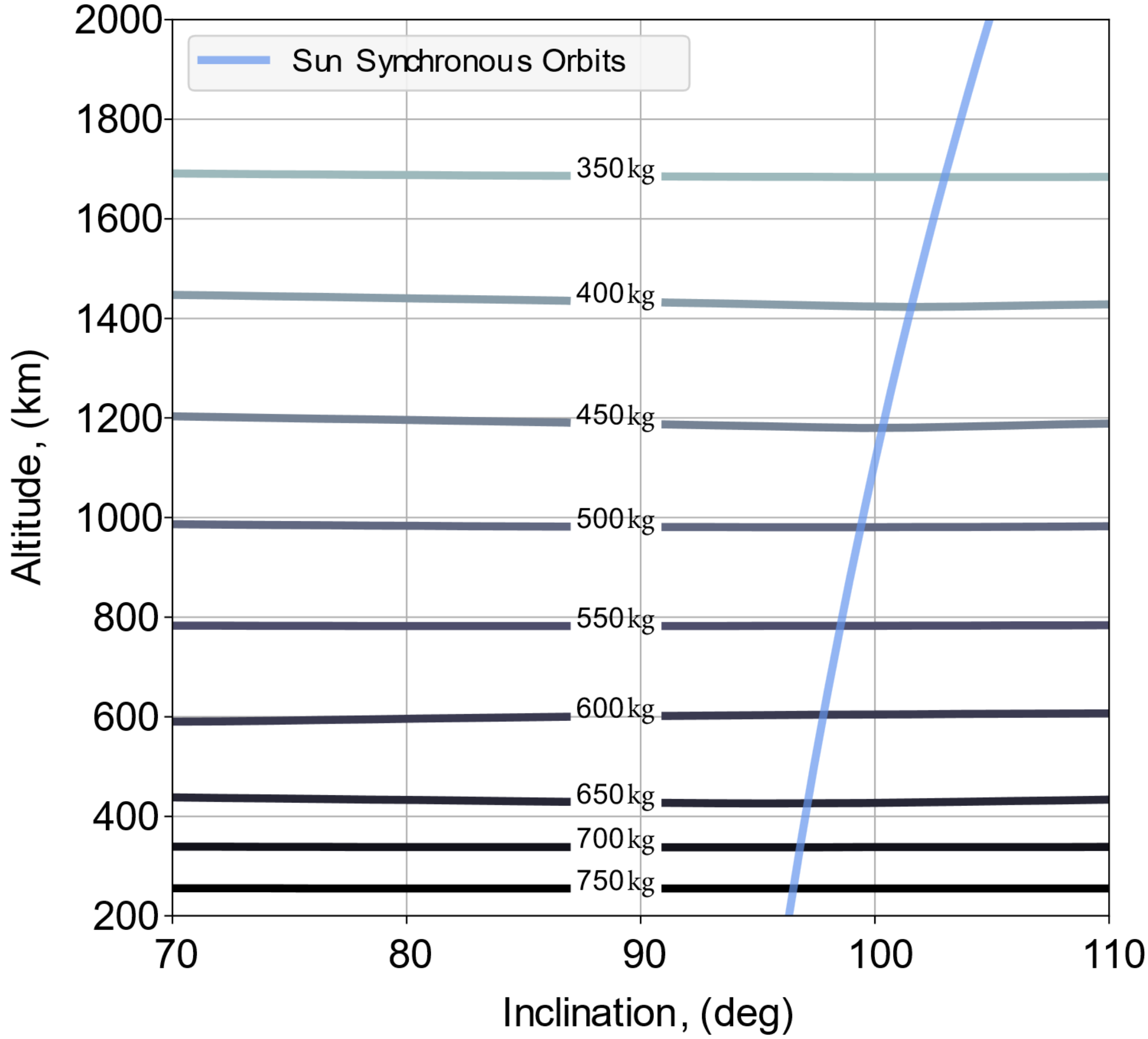

Figure 7: Alpha Performance
West Coast Launch

A representative flight profile of the Firefly Alpha launch vehicle is depicted in Figure 8. Most missions follow a similar profile, although the times and altitudes for key events may vary slightly.

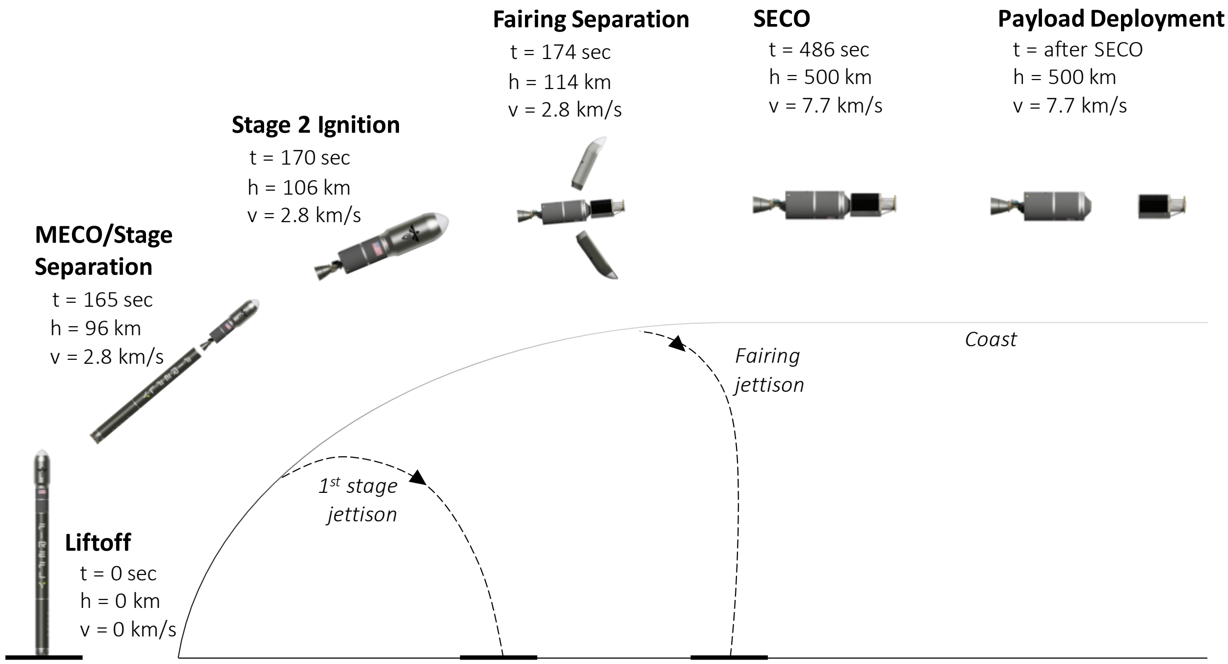

Figure 8: Example Alpha Direct Insert Flight Profile

As depicted above, payload deployment occurs approximately 500 seconds after liftoff. For multi-manifested missions and those requiring higher orbits, the Alpha second stage first inserts into a low elliptical transfer orbit, coasts to apogee, then initiates a second burn to circularize into the final orbit.

2.2 Beta Architecture

The Firefly Beta is a two-stage launch vehicle capable of delivering 4,000 kg (8,818 lbm) of payload to 200 km (125 mile) Low-Earth Orbit. The Beta vehicle can reach Geosynchronous Orbits.

The Beta vehicle also utilizes efficient technologies such as composite tanks and COTS components (e.g. Avionics electronics) and builds on the Alpha architecture discussed in Section 2.1. To learn more about the Beta vehicle, please see Table 2 and Figure 9.

Table 2: Beta Characteristics

CHARACTERISTICS	STAGE ONE	STAGE TWO
Height	31 m (102 ft) including fairing and stages	
Diameter	2.8 m (9.2 ft)	
Material	Carbon composite	
Propellants	LOX/RP-1	LOX/RP-1
Propellant feed system	Turbopump	Turbopump
Engine name	Reaver 1	Lightning 2
Quantity of engines	12	1
Thrust (stage total vac)	2,208 kN (496,378 lbf)	163 kN (36,643 lbf)
Engine designer	Firefly	Firefly
Engine manufacturer	Firefly	Firefly
Restart capability	No	Yes, 1 restart
Max level of throttling	20%	20%
Tank pressurization (No.)	Heated helium (4)	Heated helium (1)
Dry mass	8,960 kg (19,753 lbm)	950 kg (2094 lbm)
Max Gross Lift-Off Weight	149,700 kg (330,032 lbm)	
Payload mass	4,000 kg (LEO 28.5°, 200 km) 3,000 kg (SSO, 500 km) 400 kg (Geosynchronous Orbit, 28.5°)	

Payload Fairing
Carbon Composite Structure
2.8 m (9.2 ft) Diameter
22.6 m^3 (798.1 ft^3) of Internal Volume
(Primary Payload)

Payload
4,000 kg LEO 28.5°, 200km
Primary Payload

Payload Segment
6.5 m (21.3 ft)

Second Stage Engine
Lightning 2
Qty Engines: 1
Propellant: LOX/RP-1
Thrust: 163 kN (36,643 lbf) (vac)
Isp: 324.0 seconds (vac)

Second Stage
5.3 m (17.4 ft)

Second Stage Avionics
Flight Computer
Multi-Band Path Array Antennae
GPS/IMU Navigation
Power Conditioning & Distribution Unit (PCDU)
Solenoid Drive
Data Acquisition Chassis (DAC)
Telemetry Transmitter
Lithium Polymer Batteries
Autonomous Flight Termination System

Interstage
Stage Interface Structure
Houses Second Stage Engine
Pusher-Mechanism Stage Separation
Carbon Composite

First Stage
22.1 m (72.5 ft)

First Stage Avionics
Power Conditioning & Distribution Unit (PCDU)
Solenoid Drive
Data Acquisition Chassis (DAC)
Lithium Polymer Batteries

First Stage Engine
Reaver 1
Qty Engines: 12
Propellant: LOX/RP-1
Thrust: 2,208 kN (496,378 lbf) (vac)
Isp: 295.6 seconds (vac)

Figure 9: Beta Overview

2.2.1 Beta Performance

The performance capabilities of the Firefly Beta vehicle are detailed in this section. Beta will accommodate a wide range of payload requirements and our team can provide performance trades to meet our Customers' needs.

Figure 10 and Figure 11 provide the orbit delivery performance capabilities from LEO to Geosynchronous Transfer Orbit (GTO) for inclinations typical of a launch from the East Coast of the United States.

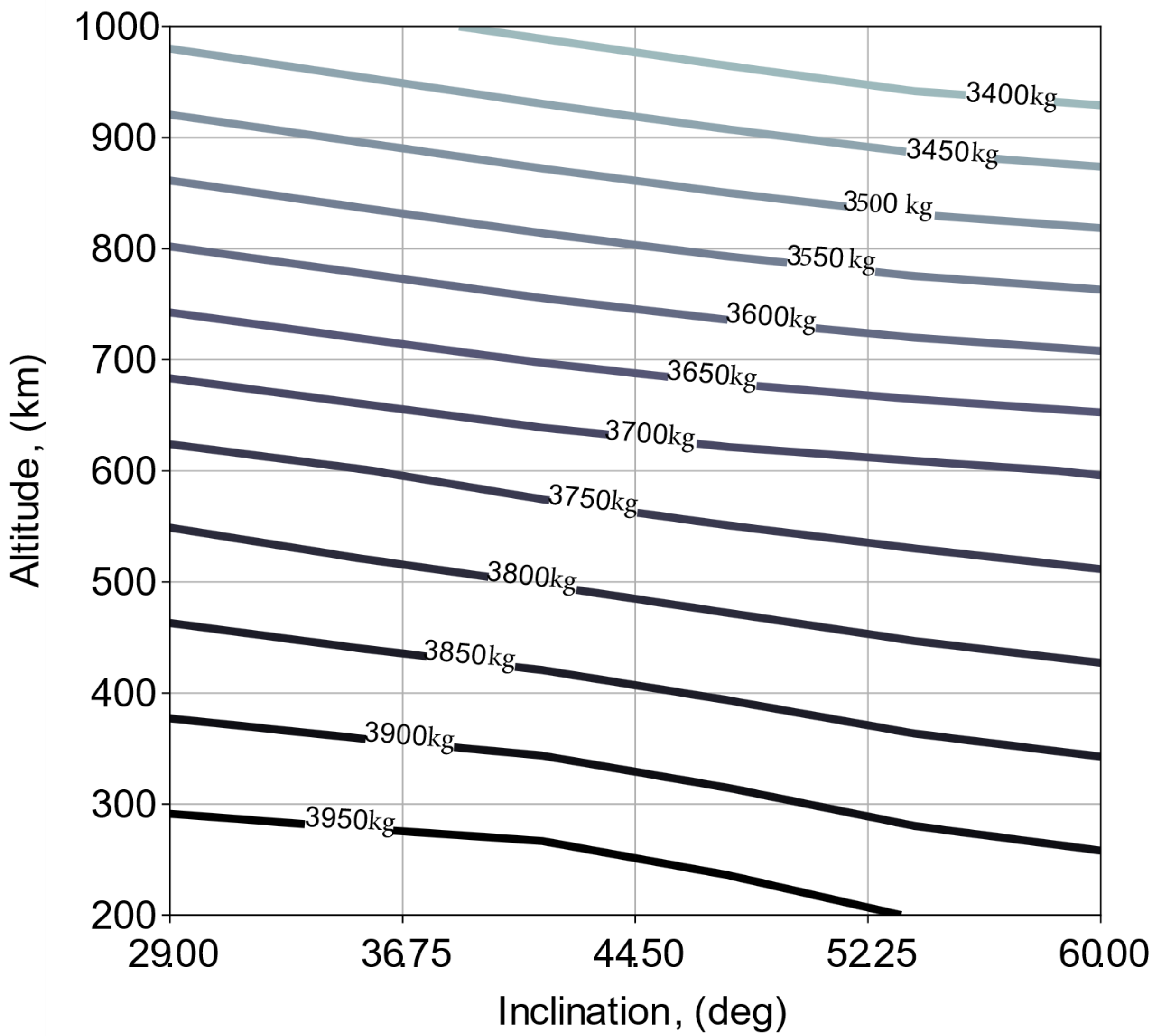

Figure 10: Beta Performance
East Coast Launch for lower altitudes

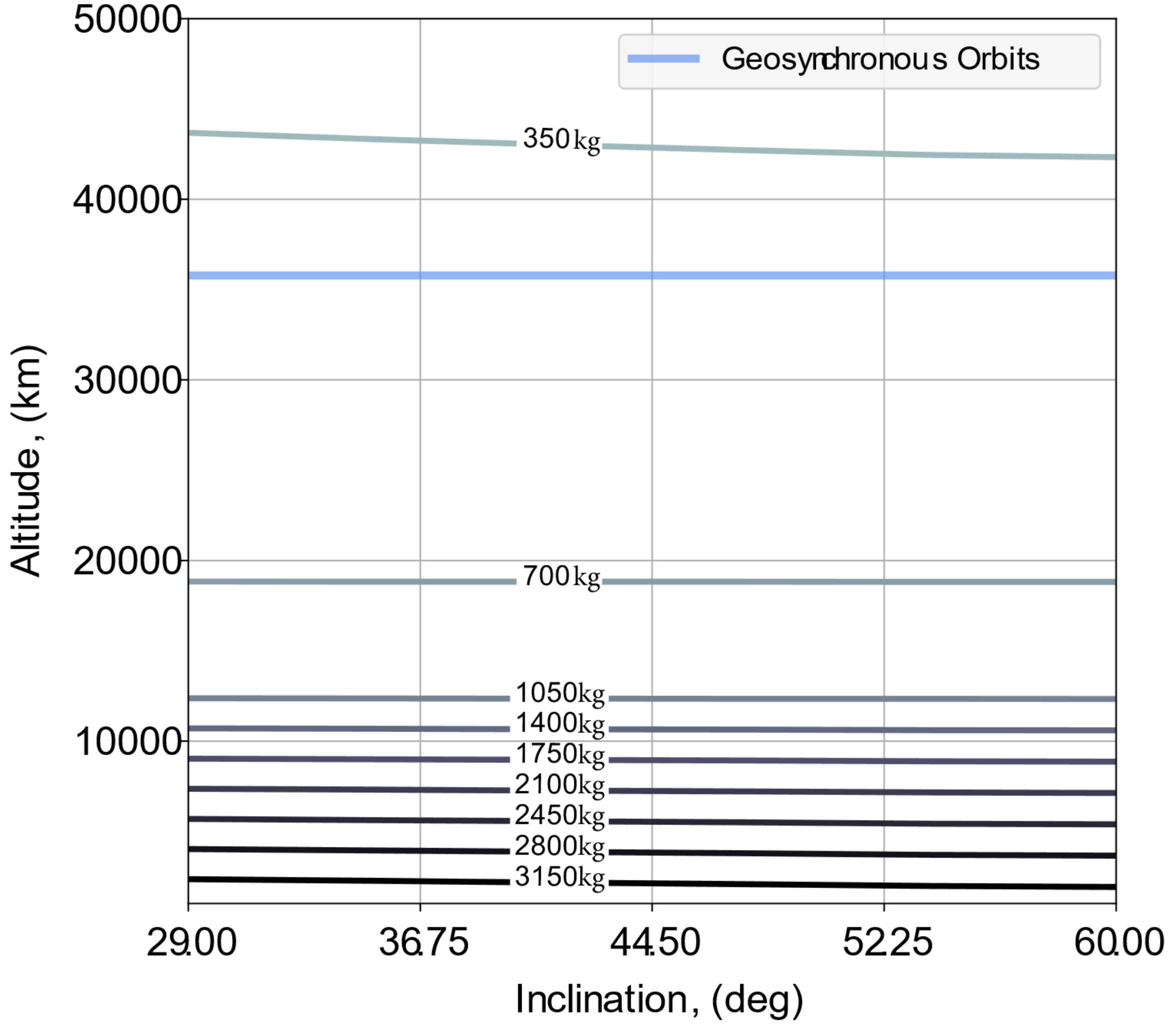

Figure 11: Beta Performance
East Coast Launch for higher altitudes

Figure 12 provides orbit delivery performance for inclinations typical of a launch from the West Coast of the United States, including Sun Synchronous Orbit insertions.

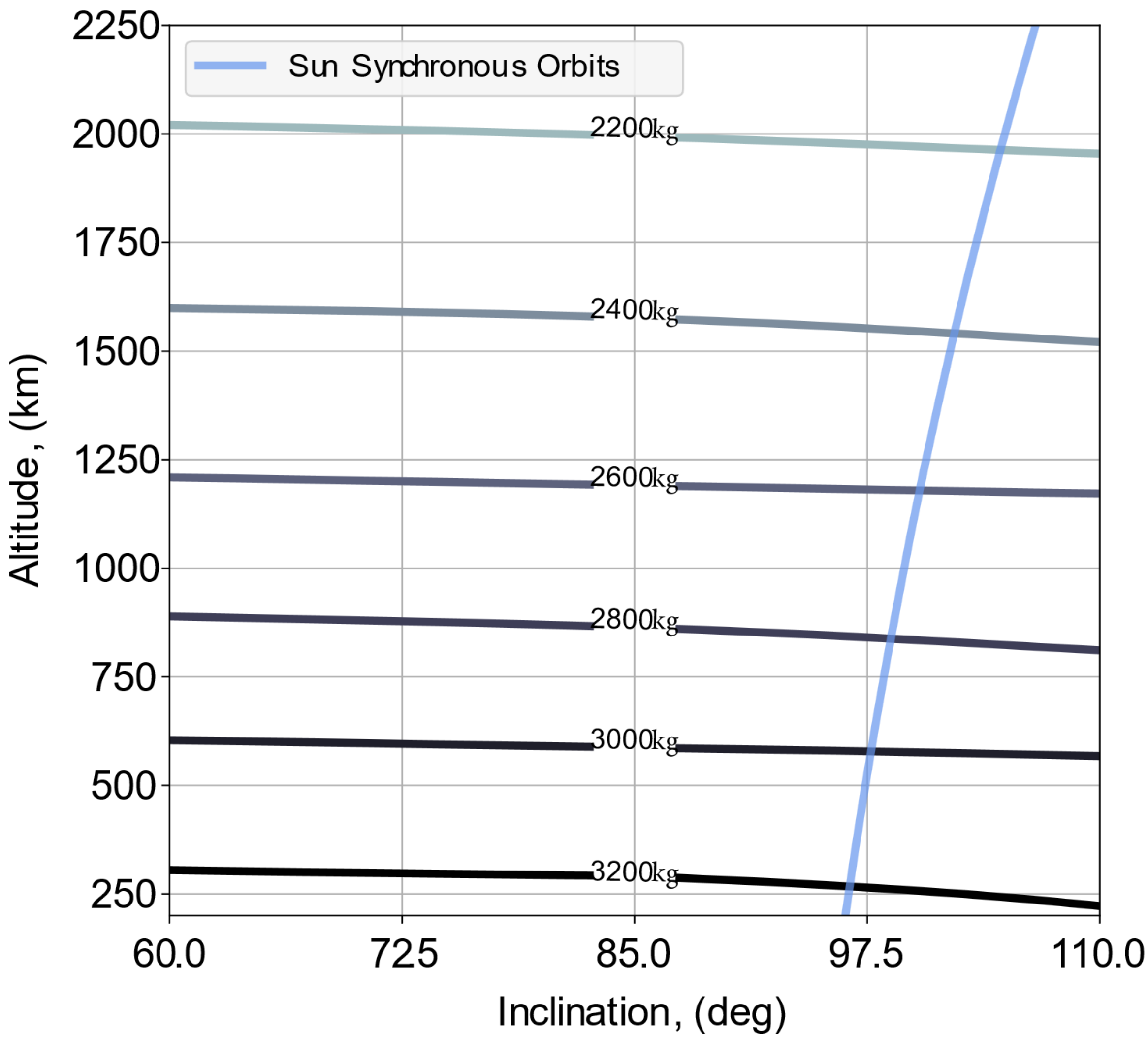

Figure 12: Beta Performance, West Coast Launch

2.3 Launch Services

Firefly aims to offer the lowest price and best value launch service to its Customers. The basic offering and price includes the standard services and provision in Table 3. Firefly also anticipates requests for non-standard services during early mission planning and may accommodate the services and provisions included below:

Table 3: Launch services

STANDARD SERVICES	NON-STANDARD SERVICES
• Payload access prior to fairing closure • Launch of the payload into the desired orbit • Customer support from the Payload Mission Manager, Ground support and Launch Operations resources and personnel needed to support Mission planning, integration and launch • ISO 8 (same as 100K) clean room payload and PAF integration space • Payload processing, integration and encapsulation within the fairing • Testing of payload interfaces at the launch site • Environmental conditions per contract agreement and payload health and monitoring requirements • Provisions for safety interfaces and protocols, pursuant to range regulations • Acquisition and maintenance of mission- required licensing for launch vehicle, including US FAA and State Department • Mission Simulation Test exercising operational readiness, vehicle resources and equipment and ground system support • Mission Dress Rehearsal for key launch team members • Post-flight launch services, including delivery of the Post-Flight Data Package, including payload separation confirmation, payload environment report and final orbit configuration • Separation system provided by Customer	• Payload access after fairing closure • Payload heating and/or dedicated thermal control during cruise phase (prior to payload separation) • Additional planning meetings • Additional Customer offices and payload checkout space • Increased cleanliness levels in payload checkout areas • Additional fueling services and provisions Additional launch documentation Hypergolic fueling of payload • RF transmission after encapsulation and before payload separation • Separation system provided by Firefly

2.4 The Firefly Advantage

Firefly is enthusiastic to discuss how to accommodate your mission. Select advantages of Firefly's launch vehicles include:

Availability - Firefly launch vehicles are mass produced to the highest quality standards. Mass production empowers industry change through regularly scheduled launches.

Reliability - Firefly launch vehicles are designed and built for reliability. Separation events are kept to a minimum of three: stage, fairing, and payload separation. Each launch vehicle runs through a regime of tests, starting at the component level, up to a full stage test prior to transportation to the launch site. Specific design choices have been made to ensure uncompromised reliability beginning at the architectural level, including, but not limited to those found in Table 4.

Table 4: Design choices for increased reliability

DESIGN CHOICE	DESCRIPTION
Environmental Qualification	Environmental qualification is performed on all Firefly- designed avionics with SMC-S-016 (Space and Missile Systems Center Standard – Test Requirements for Launch, Upper-Stage and Space Vehicles) as a baseline
Parts, Materials and Processes Plan	The Firefly-developed Parts, Materials and Processes Plan is used to standardize and establish reliability for Firefly designed hardware; The EEE parts baseline is Automotive Grade with extended temperature ranges
Pump-Fed Engine	Pump-fed engine enables tank design pressures for low operating strain
Coupled Loads Analysis	Coupled Loads Analysis with Vibroacoustic analysis ensures that the Firefly launch environment will not exceed the vibration requirements of the payload
Composite Materials	Composite materials enable monolithic parts with fewer structural joints, which leads to fewer failure points and leak paths
Commercial off the Shelf (COTS) hardware	With space launch vehicle heritage, COTS hardware is employed for many Avionics and Fluid System components, as well as prepreg carbon fiber to ensure consistent quality and robust material for Structures components

DESIGN CHOICE	DESCRIPTION
Autonomous Flight Termination	The Autonomous Flight Termination Unit (AFTU) is procured from a RCC-319-14/AFSPCMAN qualified manufacturer
Engine Material Selection	Engine Material Selection based on 50 years of US rocket heritage

2.4.1 Payload Insertion Accuracy

Precise pointing and orbit insertion are provided by an inertial navigation control module consisting of an IMU and GPS receiver on the upper stage of each vehicle. For a second-stage probability of command shutdown (PCS) of 99.7%, the following values represent the three-sigma (3σ) dispersions for a low-earth orbit direct insertion. Continued analysis may yield tighter tolerances as performance is refined.

- Perigee altitude: ± 5km Apogee altitude: ± 15 km Orbit inclination: ± 0.1^{o}

3 Mission Management

3.1 Mission Planning & Preparation

Firefly provides a single point of contact to guide every Customer through the entire mission planning and execution process. This Firefly point of contact, the Payload Mission Manager, remains the primary liaison for the entirety of the Firefly-Customer relationship. Customers can expect transparency and open communication throughout the entire process, with regular status reports.

One fit check meeting is foreseen during the mission preparation phase, typically to take place at Firefly's integration facilities at our Customers' convenience, combined with a meeting to finalize the payload to launch vehicle Interface Control Document (ICD). Activities and objectives of the Fit Check include the following activities:

- Assemble a comprehensive mass and volume representative model of the entire payload segment, including all payloads (in the event of multi-manifested launch configurations) and separation systems and adapters,
- Validate the mechanical and electrical interfaces, and
- Where possible, validate the operation of all separation systems

3.2 Launch Campaign Timeline

Each Firefly mission follows a standard timeline, starting with the initial Customer contact and finishing with the successful completion of the mission. Figure 13 depicts a typical timeline. All timings and milestones are counted before (-) or after (+) the Launch Date. Insertion data is provided as early as possible, with the final confirmation of launch performance and parameters delivered no later than three hours after launch. Please note that all dates in the figure are guidelines, and not firm constraints; more compact timelines may be possible depending on Customer circumstances.

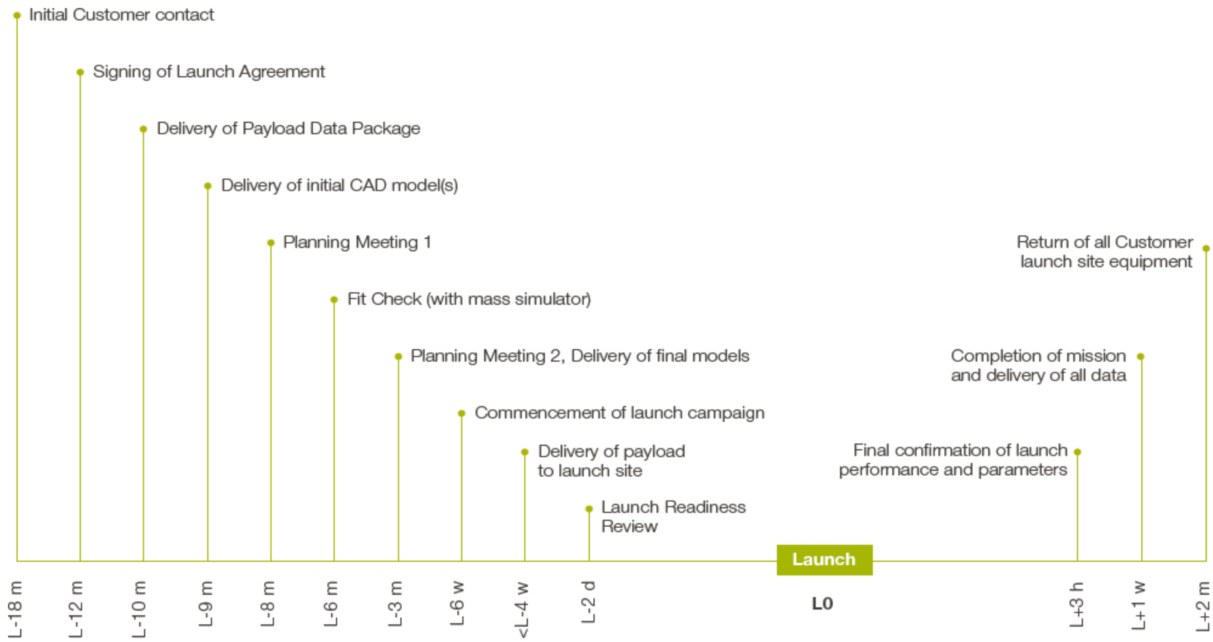

Figure 13: Typical Launch Event Timing

Figure 14 depicts a notional launch timeline as the launch date nears, and Firefly welcomes the opportunity to discuss adjustments for Customer needs. Additional or fewer days can be supported for payload operations depending on Customer needs. The current schedule carries two margin days post-payload mate to the launch vehicle.

The Mission Readiness Review (MRR) evaluates the status of the facilities, the launch vehicle, ground support, and payload in route to mission success. This review is the final review of the launch vehicle configuration and all hardware and software modifications needed to support spacecraft mission requirement. It is conducted before shipment of launch vehicle hardware to the launch site.

The Flight Readiness Review (FRR) ensures that safety systems and procedures are enabled and readied for mission success. The FRR examines previously performed tests, demonstrations, analyses, and audits that determine the overall system readiness for a safe and successful flight/launch and for subsequent flight operations. It also ensures that all flight and ground hardware, software, personnel and procedures are operationally ready. The Flight Safety Review is incorporated into the FRR. The review shall include vehicle hazards, the status of any applicable waivers and any other issues that contribute to flight risk.

The Launch Readiness Review (LRR) is the final prelaunch assessment of the integrated launch vehicle/payload system and launch-facility readiness for launch. It is the last critical review before launch.

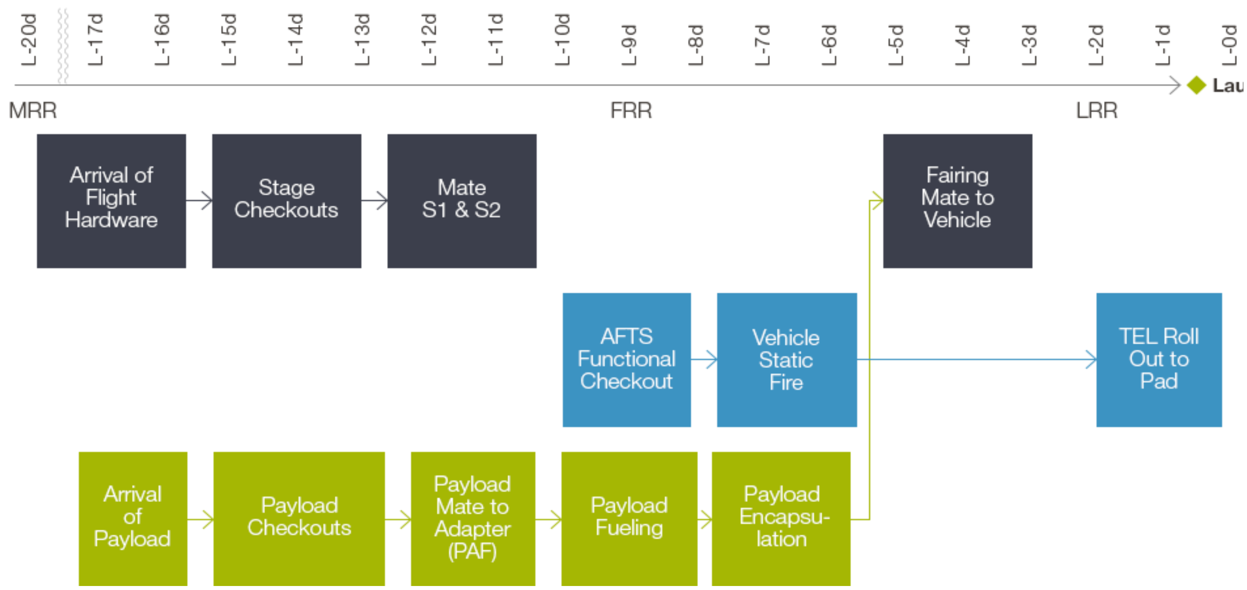

Figure 14: Notional Launch Campaign Timeline

An expected overall launch campaign duration is three weeks, with seven to ten days typically assigned to payload checkout and miscellaneous autonomous payload operations. An additional seven to ten days is typically required for payload to launch vehicle integration activities and final launch vehicle preparation activities (including fairing closure, transport to launch pad, and launcher erection). The Payload Mission Manager works with Ground Support to facilitate clear communication and coordinate launch site activities. Firefly aims to exceed Customer expectations during all phases of launch preparation.

3.3 Payload Integration Operations

Payloads interface with the launch vehicle by means of a structure called the Payload Attach Fitting (PAF) encapsulated by the payload fairing in the vertical position. Once integrated, the encapsulated payload is rotated to a horizontal orientation by means of a break-over fixture. The payload segment is then mated to the launch vehicle in the horizontal position. The payload is maintained in a horizontal, cantilevered position until the launch vehicle is rolled out to the pad and raised to the vertical position for launch.

4 Ground and Launch Operations

4.1 Launch Control Organization

Every Customer is provided a dedicated Payload Mission Manager, who reports directly to the Launch Director at the Range. Figure 15 shows the expected launch control organization and associated roles and is representative of the organization after the test flight phase is complete.

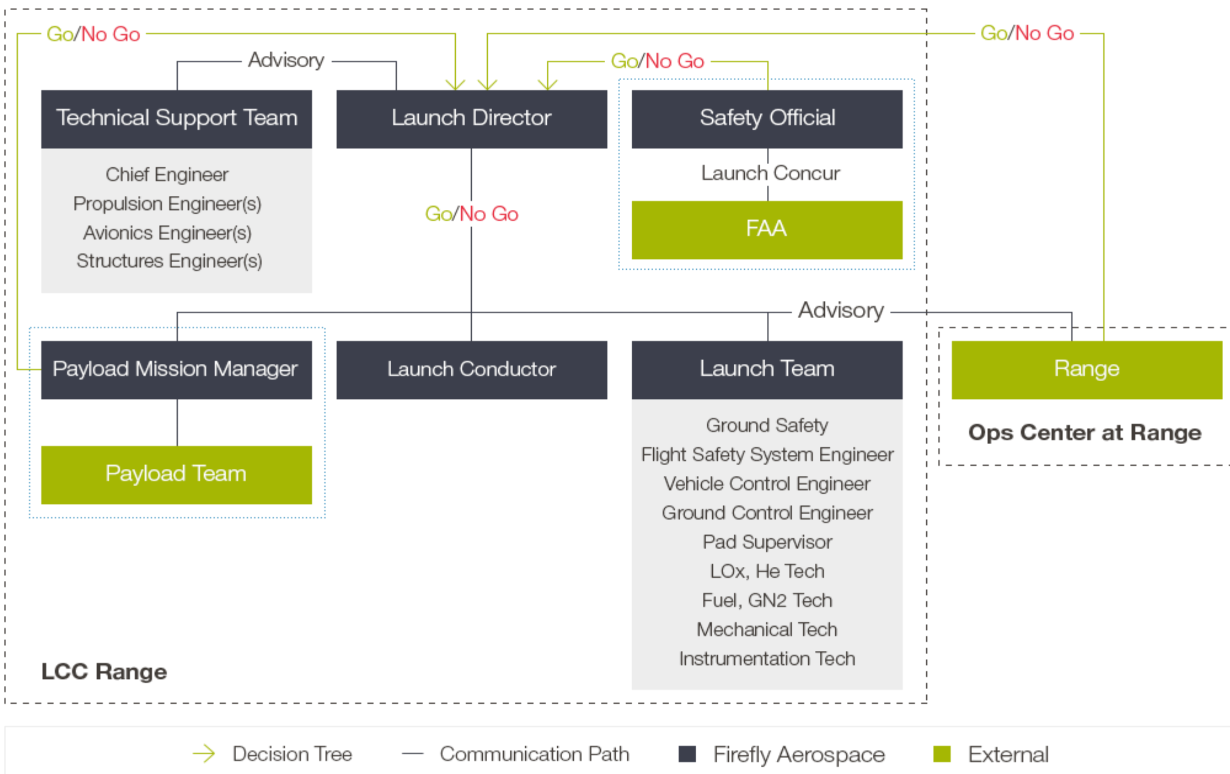

Figure 15: Launch Control Organization

4.2 Payload Processing

4.2.1 Payload Transport to Launch Site

The Firefly Payload Mission Manager works with Customers to coordinate transportation of payloads from the pickup location (Customer facility, airport, railway station, etc.) to the Firefly Payload Processing Facility (PPF). Please see Section 6.3.2 for PPF details. If accommodations are desired beyond the PPF, given advance discussion, Firefly can work with Customers to process the payload elsewhere.

The payload arrives at the Firefly PPF and is lifted from the transportation carrier by fork truck or overhead crane located within the airlock. The satellite shipping container is wiped down prior to being relocated into the clean room area, which provides a minimum processing area of 500ft^2. The satellite is removed from the shipping container with an overhead crane and mated to the PAF. Once the payload is fully assembled, checked out, and (if required) fueled, it is encapsulated by the fairing.

4.2.2 Encapsulation

After the payload is mated to the PAF and checkouts are complete, all contamination-critical hardware is inspected and, if necessary, cleaned prior to encapsulation. The payload is enclosed by the fairing in the vertical position. Upon payload encapsulation, a continuous supply of clean air is provided at a typical environment range as presented in Table 9. The air is supplied to the encapsulated payload through the air-distribution access door. A deflector can be installed within the fairing at the inlet to direct any airflow from sensitive payload components. The payload fairing with enclosed payload is rotated to a horizontal orientation by means of a break-over fixture. The PAF will be mated to the launch vehicle in the horizontal position. The payload will be in a horizontal, cantilevered position until the launch vehicle is rolled to the pad and raised to the vertical position. The air distribution access door is closed during the roll out to the launch pad with no climate control provided until arrival at the pad.

4.2.3 Fueling

Gaseous helium and nitrogen fluid panels are available in the Payload Processing Facility and main vehicle integration hangar. Nitrogen will be 99.99% pure per MIL-PRF-27401F, Grade B. Helium will be 99.995% pure per MIL-PRF-27407D, Grade A. Higher purities can be provided upon request.

Hypergolic fueling can be completed as a non-standard option and Firefly welcomes the discussion at initial mission planning meetings. Early missions that require fueling may take place at a third-party facility and then be transported to the launch site.

4.2.4 Fluid Checkout Panels

Gaseous helium and nitrogen fluid panels are available in the Payload Processing Facility and main vehicle integration hangar. Nitrogen is 99.99% pure per MIL-PRF-27401F. Grade B. Helium is 99.995% pure per MIL-PRF-27407D, Grade A. Higher purities can be provided upon request.

4.2.5 Cleanliness of Facilities

The Horizontal Integration Facility is maintained as a visibly clean, climate-controlled space at all times. As a standard service, the PPF clean room area will be certified and operated at ISO 8 (Class 100K FED-STD-209E) for payload encapsulation.

4.2.6 Customer Team Accommodation & Offices

Office type accommodation will be provided for Customer teams. This will typically consist of:

- office desks and chairs and
- a meeting area with a small meeting table and chairs.
- IT equipment is not provided as a standard service although adequate power and network/internet connections will be provided. Additional Customer office accommodations can be provided as desired.

4.2.7 Infrastructure

4.2.7.1 Power

The following Electrical Ground Support Equipment (EGSE) power sources are provided for payloads at the Payload Processing Facility (PPF) and launch equipment building: 120V/240V single phase, and 208V three phase, 60 Hz. 50 Hz accommodations May be made via frequency converters; this requirement should be included within the ICD requirements and discussed during initial meetings.

4.2.7.2 Internet

High-speed, broadband internet access (both Ethernet and Wi-Fi) is available to Customers both in the offices provided and the payload processing cleanroom facilities. A single connection in each office/ area will be provided. This is not part of the mission network and can only be used generally – if local networks are required it is expected that the Customers bring their own equipment to set up local networks.

4.2.8 Launch Vehicle Customer Access

Customer access to the launch vehicle is restricted to the combined payload/launch vehicle processing operations and activities. Customers can view the launch vehicle during agreed upon times, arranged in advance. Due to export compliance regulations, non-US Customers or personnel may view the launcher while it is in its processing and assembly facility only if the proper government approvals are in place.

4.2.9 Launch Pad Access and Viewing

Pre-arranged, escorted viewing of and access to the launch pad is granted to Customers as agreed-upon by all parties. Customers will be invited to view the launch from an official viewing point which will be a safe distance from the launch pad. Non-US Customers will be allowed to view the launch vehicle only during agreed-upon times, arranged in advance, and only with U.S. Government authorization in compliance with the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR).

4.2.10 Visitors & VIPs

It is understood, and expected, that Customers may invite VIPs and other visitors to view the launch. Firefly endeavors to accommodate these individuals at the launch viewing sites. Hospitality services may gladly be arranged as a non-standard service offering.

4.2.11 Post Launch

Firefly provides all Customers with preliminary and final vehicle orbit details at the time of payload deployment. This will occur as soon as is feasible, following the final separation of all payloads. Information on the overall achieved payload delivery, including separation times and any anomalies seen, is be provided as soon as available. During launch, a video of the payload deployment process is captured and made available to the Customer post-deployment for analysis and marketing purposes.

5 Payload Accommodations & Requirements

5.1 Payload Envelope

The payload is protected by a fairing that shields it from aerodynamic buffeting and heating while in the lower atmosphere. The fairing is a carbon fiber composite structure with nominal dimensions shown in Figure 16 for the Alpha Vehicle, and Figure 17 for the Beta Vehicle. Two payload accommodation scenarios are available:

- Single (Primary Only) payload, and
- Primary Payload with Secondary Payloads (including CubeSats)

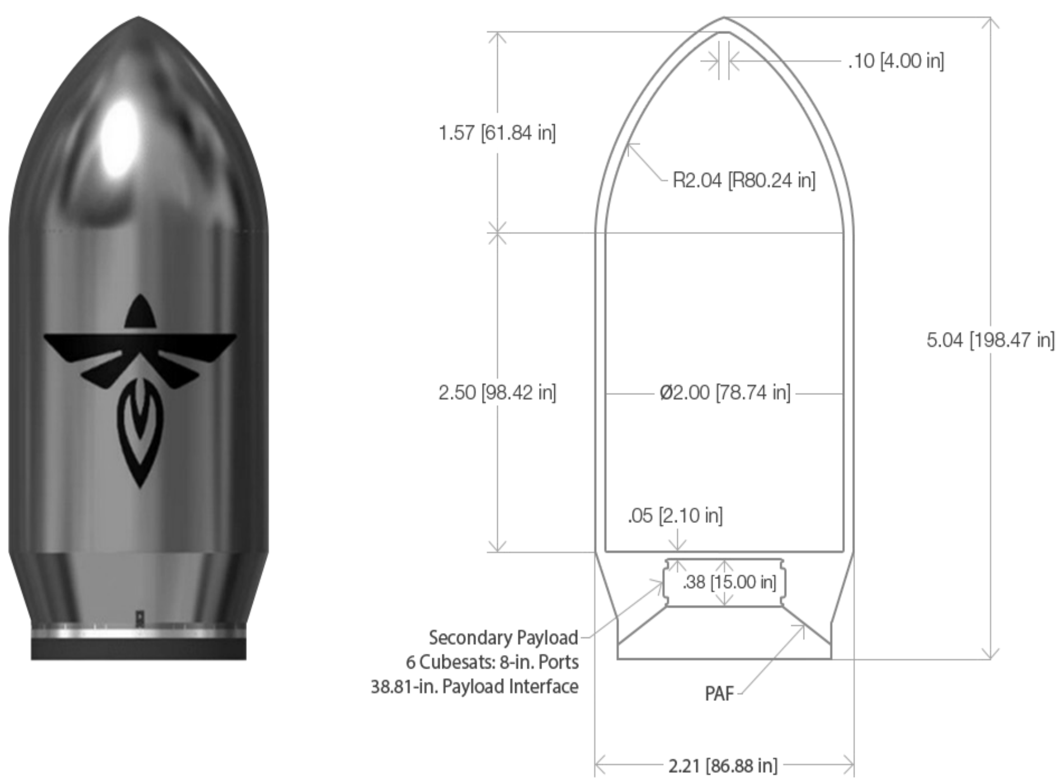

Figure 16: Firefly Alpha Standard Fairing

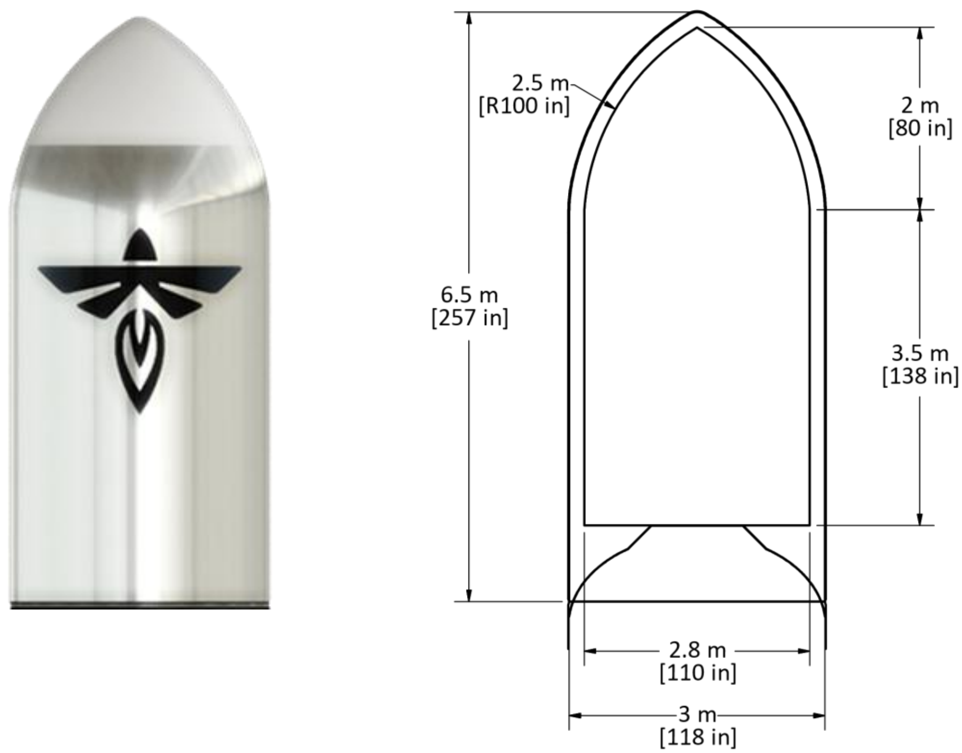

Figure 17: Firefly Beta Standard Fairing

Baseline accommodations for Secondary Payloads are presented in Section 5.5. Figure 18 depicts a representative secondary payload configuration.

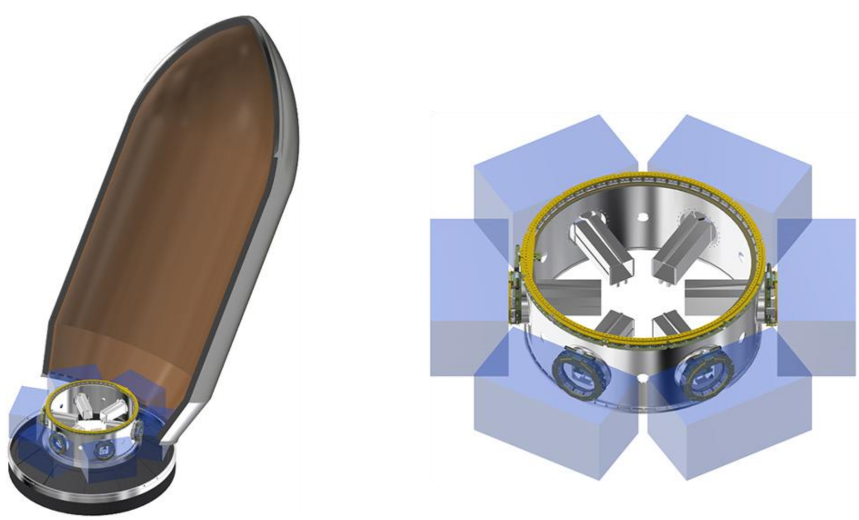

Figure 18: Secondary Payload Configuration

5.2 Payload Interfaces

Firefly vehicles feature an adaptable, standardized attachment pattern, with multiple options for electrical interfaces to accommodate typical small satellite interfacing requirements and characteristics. in line with the overall Firefly approach, the emphasis is on interface simplicity and robustness.

5.2.1 Mechanical Interfaces & Separation Systems

Standard Firefly services assume a customer-provided payload separation system that interfaces directly to the Firefly-provided PAF. The PAF is designed to interface with a 38.81-inch standard or clamp band separation system, using 60 evenly spaced fasteners. The most commonly-used small satellite separation systems are all accommodated, including:

- Dassault ASAP 5
- Planetary Systems Lightband
- Ruag Clamp Band Separation Systems
- ISIPOD CubeSat Deployer

On Customer request, Firefly may provide a separation system as a non-standard service. the PAF design can be modified to accommodate satellite separation systems of diameters ranging from 8 inches up to 38.81 inches. Requests for accommodation of any non-standard payload interface should be discussed early in the mission planning process.

5.2.2 Electrical Interface

Firefly launch vehicles provide a set of standard payload electrical interfaces in addition to a set of optional but prequalified interfaces. Other custom configurations can be accommodated yet may require development NRE and qualification cost and schedule. Connector type and pinouts for the payload are specified during the payload integration process.

All payload interfaces to the Alpha PAF must be electrically conductive with sheet resistance less than 0.1 Ω per unit area. This interface will be auto verified during payload integration. It is the Customer's responsibility to ensure this requirement is met prior to shipment of the payload to the launch site.

5.2.2.1 Standard Payload Configuration

On the ground, in the standard payload configuration, the second stage umbilical connection provides the payload access to a current-limited 28V DC supply. This power supply is monitored and controlled by Firefly as depicted in Figure 19. Upon launch, payloads are powered by their own batteries.

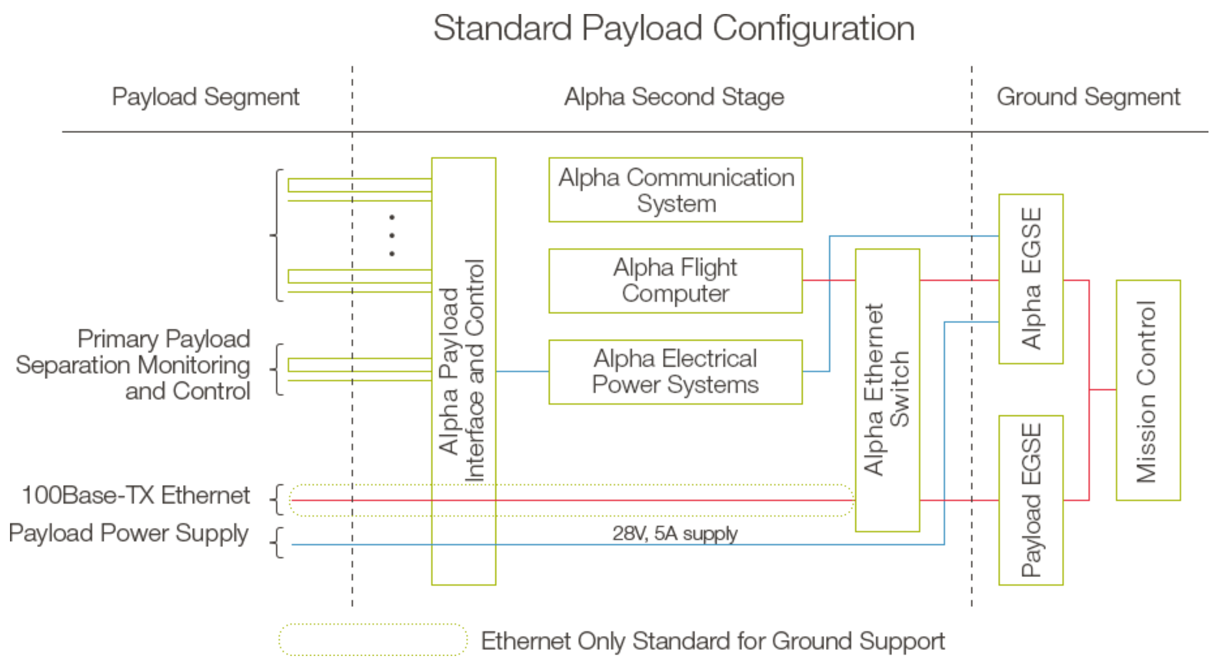

Figure 19: Payload Wiring Diagram –Standard Configuration

Payload data is provided via a second-stage Category -5E umbilical pass-through to the Alpha Ethernet Switch, providing the operator access to telemetry during pre-flight operations. This configuration isolates the payload data from other vehicle systems. It should remain powered off until payload deployment. Customers that require a powered payload during launch should coordinate with Firefly early in the mission planning.

5.2.2.2 Optional Configurations

Given sufficient notice, two additional communications methods may be configured as additional non-standard options which do not affect standard configuration features.

- 100Base-TX link – This data will be sent directly through Firefly's communication system and will not be processed by any vehicle computers except for bandwidth monitoring. Customers should contact Firefly early to determine network compatibility and bandwidth limitations to ensure that Alpha is well-equipped to handle the format and size of the desired data. Additional integration time might be required to ensure compatibility. This switchover will be performed prior to launch for verification.

- RS-422 – This connection can be provided to the payload for simple signaling of events including stage separation, fairing deployment and payload separation at no greater than 115200bps.

The Customer may request one or both of two forms of digital communication. A representative optional payload configuration from the Alpha vehicle is depicted in Figure 20.

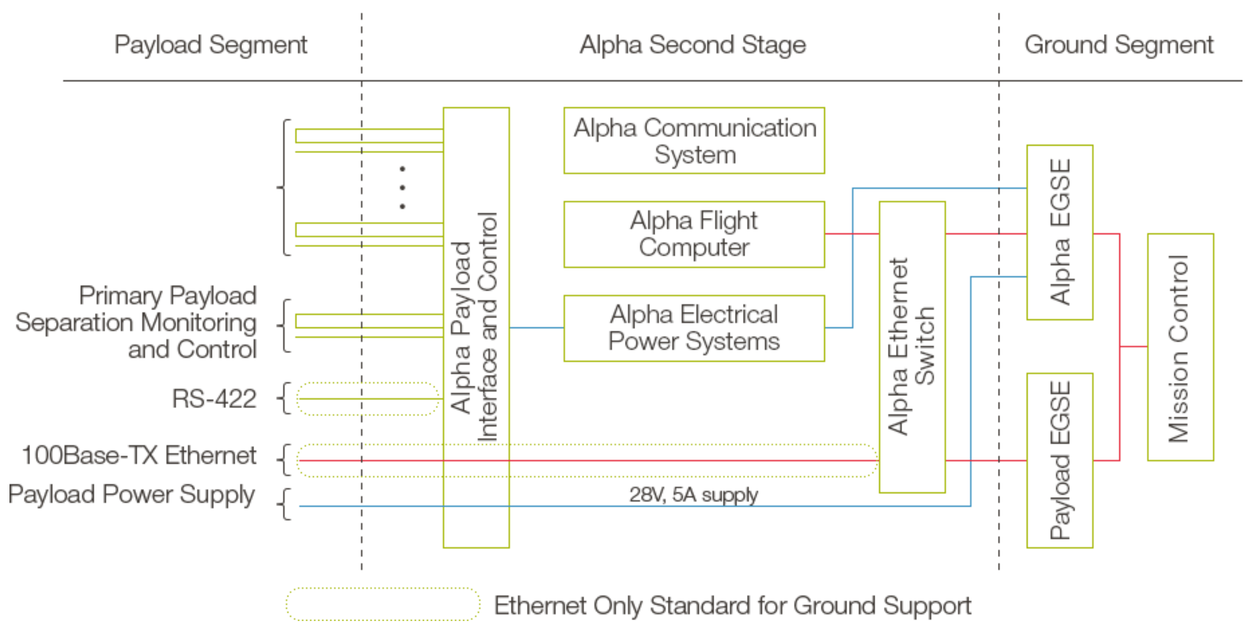

Figure 20: Payload Wiring Diagram –Optional Payload Configuration

5.3 Payload Environments

This section describes the mechanical, and both natural and induced environmental conditions during a Firefly launch campaign. Loads include estimates for transportation, as well as processing, and flight. This information is provided as a guideline and a specific analysis will be conducted for each mission.

5.3.1 Mechanical

5.3.1.1 Transportation and Handling Loads

Table 5 shows the maximum transportation and ground handling loads anticipated during payload accommodations. Launch Site Ground Handling refers to truck or rail transport per NASA SP-8077, which is currently not provided as a service to the Customer. A slow-moving dolly will be used for any service to be provided to the Customer, which will have the same loading capacity as the Transport Erector Rollout (TEL). The following values reflect the concept of operations that assume an integrated launch vehicle is rolled to the pad horizontally.

Table 5: Typical Transportation & Handling Loads

EVENT	AXIAL LOAD (X), G	LATERAL LOAD (Y), G	VERTICAL LOAD (Z), G
Slow-Moving Dolly, TEL Rollout	± 1.0	± 0.75	± 2.0
Launch Site Ground Handling	± 1.0	± 0.75	± 2.0

5.3.1.2 Flight Loads – Quasi-Static

Payloads experience a range of axial and lateral loads during flight, and a detailed analysis can be provided for each mission profile. An example of axial acceleration for a direct-insertion mission is depicted in Figure 21. The Alpha vehicle assumes a 1,000kg to 200km orbit; The Beta vehicle assumes 4,000kg to 200km orbit. Note that accelerations are trajectory dependent and will vary.

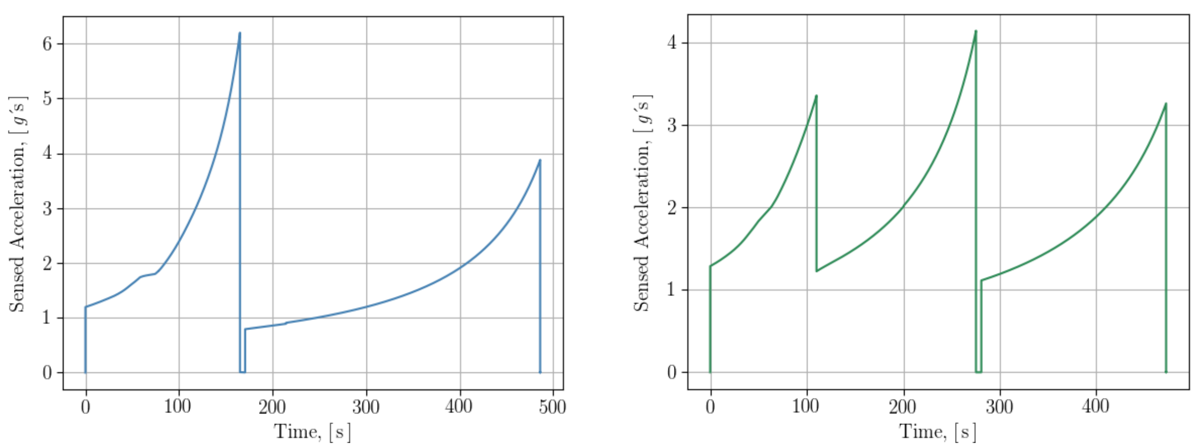

Figure 21: Example Steady State Axial Acceleration Alpha (left) and Beta (right)

Firefly recommends using the quasi-static limit load factors provided by NASA-HDBK-7005. Coupled Loads Analysis (CLA) is the process implemented to determine the loads for any specific payload coupled to the launch vehicle. Some examples of the axial and lateral acceleration mean values and fluctuating limits for different load events are shown in Table 6, which will be updated based on new analyses and customer-specific flight data.

Table 6: Axial and Lateral Accelerations

EVENTS	AXIAL MEAN, G	AXIAL FLUCTUATING LIMITS, G	LATERAL MEAN, G	LATERAL FLUCTUATING LIMITS, G
Liftoff	1.0	± 0.7	0.0	± 0.8
Max Q	2.0	± 0.6	± 0.2	± 0.6
Stage 1 engine shut down	5.5 to 0.2	± 3.1	much smaller than axial	much smaller than axial
Stage 2 engine start up	0.0 to 0.8	± 1.2	much smaller than axial	much smaller than axial
Stage 2 engine shut down	4.5 to 0.2	± 2.5	much smaller than axial	much smaller than axial

5.3.1.3 Flight Loads - Random Vibration

During launch, payloads are subjected to a combination of engine vibrations, vehicle structural modes, and aerodynamic buffeting. The intensity of these vibrations is highly dependent on payload mass and the interface between the payload and the launch vehicle.

The estimated random vibration PSD for a payload mass of 90 kg or larger, based on preliminary analysis for Alpha, is shown below in Figure 22. These values include appropriate margins due to uncertainty. PSD levels will be updated based on new analyses and flight data. The intensity of the vibration is highly dependent on the payload and the interface between the payload and the launch vehicle.

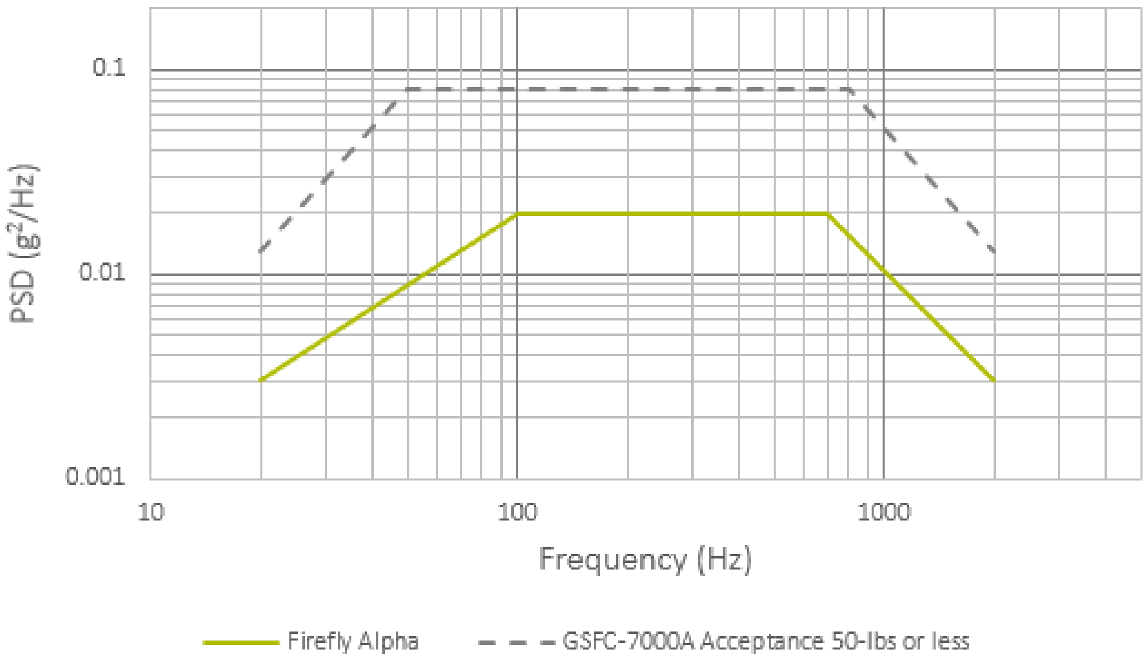

Figure 22: Payload Interface Random Vibration Test Levels

The PSD values in Figure 22 are summarized in Table 7. The NASA General Environmental Verification Standard (GEVS) GSFC-7000A (See Reference 2) levels are designed to encompass most of the common launch vehicles used and are shown for reference.

Table 7: Firefly Vehicle Random Vibration Maximum Predicted Values

FREQUENCY	ALPHA PSD LEVEL	BETA PSD LEVEL
20 Hz	0.003	Beta Vehicle Random Vibration Analysis in Work
20 – 100 Hz	See Figure 22	
100 –700 Hz	0.02	
700 –2,000 Hz	See Figure 22	
2,000 Hz	0.003	
GRMS	4.9 g	

5.3.1.4 Flight Loads – Acoustic

Analysis of the vibroacoustic environment inside the Firefly vehicle payload fairing during flight is ongoing. Acoustic protection is planned to provide Overall Sound Pressure Level (OASPL) at or below 135*dB*.

The acoustic environment for the payload includes acoustic levels during liftoff and ascent. The estimated sound pressure level (SPL) within the fairing is shown in Figure 23 and is an envelope of the sound pressure levels for both liftoff and ascent flight. The plot will be updated based on new analyses and flight data.

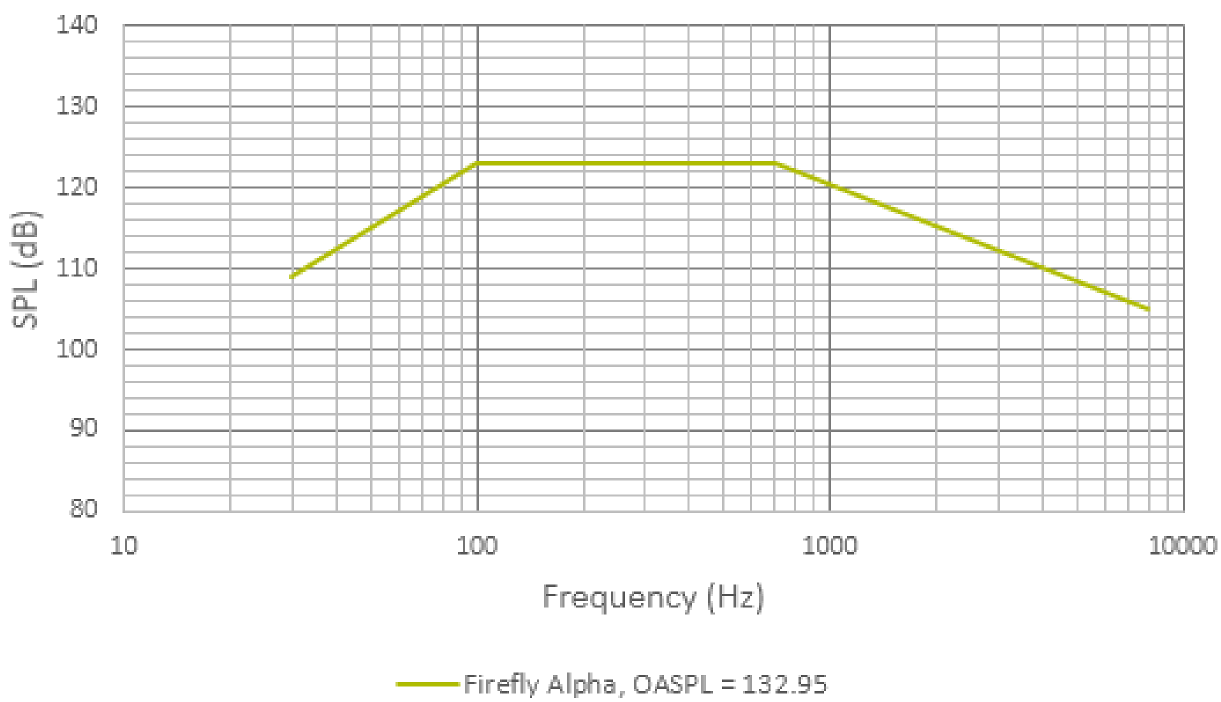

Figure 23: Alpha Payload Fairing Interior SPL (db, reference 20 mPa)

5.3.1.5 Shock Loads

The maximum shock environment at the payload interface occurs during payload separation from the second stage and is dependent on the PAF/Payload separation system configuration. Shock levels at the payload separation interface due to other flight events – such as stage separation and engine ignition/shutdown – are not significant compared to the shock caused by fairing separation and payload separation. Figure 24 shows estimated shock levels at the interface between payload and adapter for clamp band separation systems. The actual flight shock levels will be unique to the mission and payload separation system.

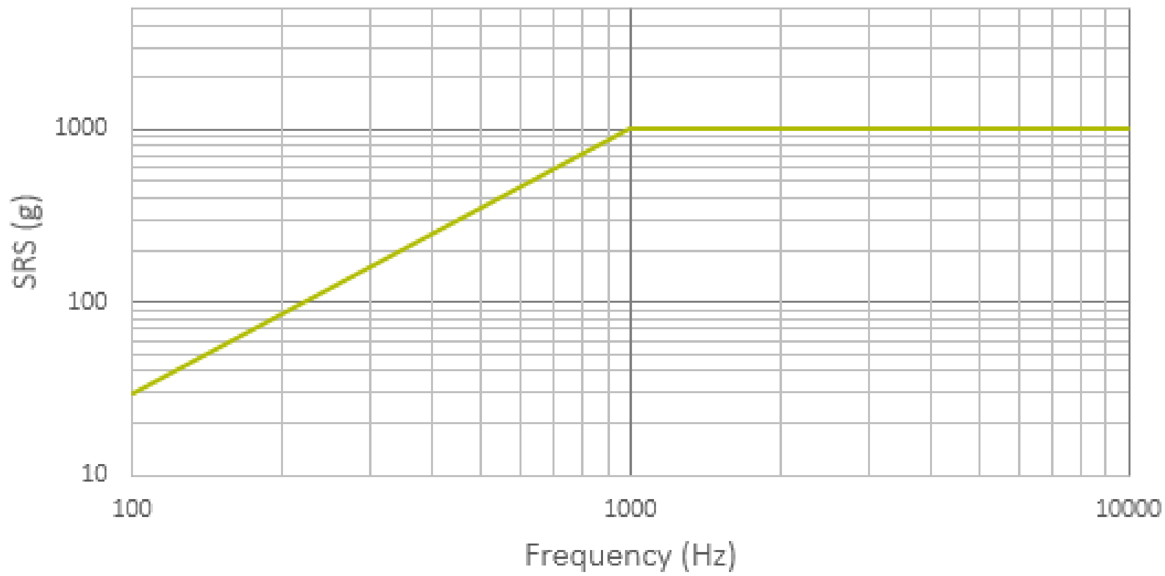

Figure 24: Estimated Shock Levels During Payload Separation

Estimated values corresponding to the Shock Response Spectrum (SRS) are presented in Table 8.

Table 8: Estimated Shock Values

FREQUENCY	SRS (G-PEAK)
100 Hz	30
100-1,000 Hz	See Figure 24
1,000-10,000 Hz	1,000

5.3.2 Thermal & Atmospheric

5.3.2.1 Payload Conditioning

A nitrogen trickle (MIL-PRF-27401F, Type 1, Grade B purge) can be provided for specific bagged sensors while inside the processing facility prior to and after encapsulation. After encapsulation, a trickle purge line to a sensor bag can be accommodated through a strategically placed fairing access panel opening. Both trickle purges are controlled by Customer supplied equipment. Source nitrogen can be provided by facility systems or K-bottles. After roll-out, a continuous supply of clean air is provided at a typical environment range as stated in the table below. After roll-out and prior to the vertical position movement, the bag is removed from the sensor and the flight access panel is installed on the fairing. A nitrogen purge can be provided through the payload air-distribution umbilical ducting while at the launch pad. The air distribution umbilical is attached to the fairing by means of locking mechanism that is pulled away by a lanyard at lift off. As the umbilical is pulled away from the fairing the spring-loaded access door automatically closes.

Table 9: Payload Environmental Conditioning

LOCATION & DURATION	PHASE	TEMP.	RH%	FLOW RATE	CLEANLINESS	HYDROCARBON
Firefly PPF	Payload Processing; Non-Encapsulated	75F ± 10F 23.89C ±5.6C	50% ± 15%	N/A	Class 100,000	15ppm max
Appx. Duration 1-2 Weeks	Payload Processing; Encapsulated	75F ± 5F 23.89C ± 2.78C	50% ± 15%	120-200 CFM	Class 10,000	15ppm max
Firefly HIF Appx. Duration 3-4 Days	Integrated Operations; Encapsulated Payload	75F ± 10F 23.89C ± 5.6C	50% ± 15%	120-200 CFM	Class 10,000	15ppm max
Rollout from HIF to Pad Appx. Duration <30 Minutes	Pre-Launch Operations; Encapsulated Payload	N/A	N/A	N/A	Class 10,000	15ppm max
LV on Pad Appx. Duration 1-2 Days	Launch Operations; Encapsulated Payload	75F ± 15F 23.89C ± 8.3C	(Customer TBD) 0% - 75%	120-200 CFM	lass 10,000	15ppm max

5.3.2.2 Fairing Thermal Environment

Upon payload encapsulation, air-conditioning is provided at a typical temperature range as stated in Section 5.3.2.1, depending on mission requirements.

The Firefly vehicle fairings are made up of carbon composite with a hemispherical total emissivity of 0.8. Acoustic foam can provide a relatively cool radiation environment by effectively shielding the payload from ascent heating in blanketed areas. Analysis on the payload and fairing will detail the radiative environment in which Firefly will shield the payload from hazardous heating.

5.3.2.3 On Orbit Thermal Environment

As most Firefly missions are expected to be of short durations (for delivery into Low-Earth orbits), active thermal control or heating of payloads is not foreseen. Active thermal control and payload heating may be able to be accommodated as an optional service.

5.3.2.4 Fairing Internal Pressure

As the Firefly vehicle ascends through the atmosphere, the fairing will be vented through one-way vents at the bottom of the fairing. The maximum expected pressure decay rate inside the fairing compartment is -0.24 psi/second. The internal pressure and depressurization rates are illustrated as functions of time in Figure 25.

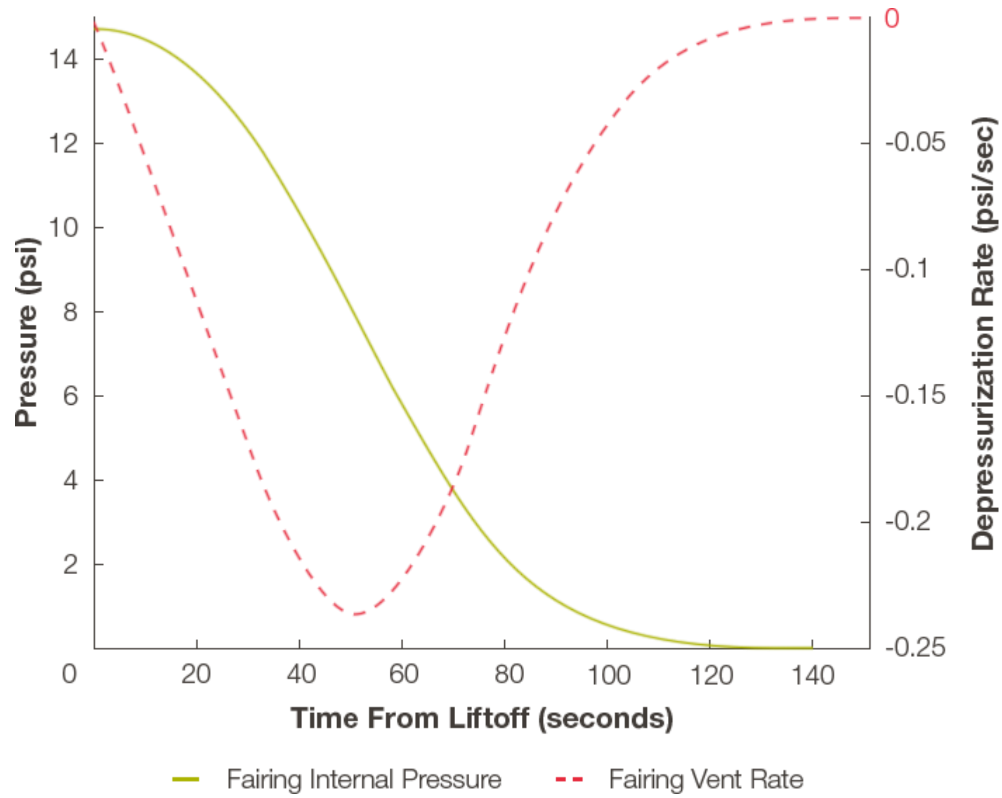

Figure 25: Example of Fairing Internal Pressure Profile [Reference 4]

5.3.3 Payload Environment – RF & EMC

5.3.3.1 Radio Frequency Environment

The Firefly vehicle RF system characteristics are detailed in Table 10. All payloads are expected to pass testing to MIL-STD-461 for radiated emissions and susceptibility. For payloads that are connected to the vehicle avionics system, all connections must pass conducted emissions and susceptibility testing per MIL-STD-461.

The Firefly vehicle RF system is particularly sensitive to payload RF emissions in the L-band GPS frequencies. It is recommended that payloads are powered off during launch to reduce the risk of damage caused by RF interference.

Additionally, Customers must ensure that any payload component or material constituents that are sensitive to RF transmissions are compatible with the electromagnetic environment provided in Table 10.

Table 10: Firefly Vehicle RF System Characteristics

FUNCTION	STAGE 2 TLM	GPS
Role	Transmit	Receive
Band	S-Band	L-Band
Frequency	2.2-2.4 GHz	L1: 1575.42 MHz L2: 1227.60 MHz

5.4 Payload Requirements

5.4.1 Primary Payload Customer Requirements

The primary payload requirements for the customer are outlined in Table 11.

Table 11: Firefly Primary Payload Customer Requirements

ID	TITLE	DESCRIPTION
1	Resonances and First Natural Frequency	The Primary Payload Customer shall provide evidence of the 1st lateral resonant frequency being above 6 Hz at Max Q [Ref 2]. Please refer to the Firefly vehicle axis definitions as shown in Section 2.1. Firefly will complete a Coupled Loads Analysis (CLA) as early as possible to identify any issues associated with dynamic coupling. The threshold given in this requirement is a representative value of a similar vehicle and will be re-evaluated upon completion of the CLA. The Primary Payload Customer shall provide evidence of the 1st axial resonant frequency being above 25 Hz at Max Q. Please refer to the Firefly vehicle axis definitions as shown in Figure 3 of Section 2.1.
2	Quasi-static and/ or Sine Vibration Loading	The Primary Payload Customer shall provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Section 5.3.1.2, with positive margin.
3	Random Vibration	The Primary Payload Customer shall provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 7, with +3 dB margin. Test duration shall be 2 minutes, per Reference 2.

ID	TITLE	DESCRIPTION
4	Acoustic Vibration	Should the Primary Payload Customer choose to design and qualify/accept their design against the acoustic load environment (as may be expected for larger satellites), the Customer shall provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Section 5.3.1.4, with positive margin.
5	Notching	Reduction of the vibration input amplitude at certain resonance frequencies (i.e. notching) may be possible for the Primary Payload Customer but cannot be guaranteed. Any notching requirements or preferences should be communicated to Firefly as early as possible in the mission planning process.
6	Mass Properties	The required position of the payload's Center of Gravity (CoG), relative to the plane of separation, is defined below. This assumes that the Primary Payload Customer is mounted centrally, i.e. with its vertical axis aligned with the launch vehicle roll (X) axis. Offset of CoG from Y & Z axis: < 2 in (50mm)
7	Grounding, EMC and RF Transmissions	It is assumed that all payloads will be powered off during launch (in line with the Firefly baseline launch offering), and therefore will not be emitting any signals or radio frequency noise during the launch phase. Payloads that request to be powered on during launch will be required to provide evidence of a payload level EMC test which shows EM compatibility with the Firefly vehicle assuring that any payload operations during launch cannot interfere with Firefly's Avionics & Flight Systems. All payloads (including those which will be powered off) are required to show compliance to the Firefly EMC specification to ensure that post-separation operations of the launch vehicle upper stage are not compromised by the payload(s). All payload interfaces to the Alpha PAF must be electrically conductive to less than 0.1 Ω per unit area. This interface will be auto verified during payload integration. It is the Customer's responsibility to ensure this requirement is met prior to shipment of the payload to the launch site.
8	Primary Payload Data Package	For Firefly to carry out its mission design, analysis, and verification for the Primary Payload Customer, the following numerical/computer models and reports for the Primary Payload will be required, in addition to the general requirements of the Payload Data Package found in Table 11:

ID	TITLE	DESCRIPTION
		A computer aided design (CAD) model, in STEP (*.stp or *.step) or Parasolid (*.x_t) or Inventor format: The CAD model supplied should include accurate representations of the external characteristics and features of the payload, including all appendages, and the separation system. A Finite Element (FE) model of the payload, in ANSYS Workbench Project Archive (*.wbpz), Femap Neutral (*.neu, version 11.1 or older) or NASTRAN input (*.nas or *.bdf) format: The FE model should accurately represent the payload's stiffness and mass properties, contain all relevant material/connection property definitions, and should ideally be simplified. Mass properties report: The report shall include total mass, center of mass location in body coordinates, and moment of inertia properties about the center of mass. Analysis and Test report: The report shall include information regarding the first six modes of the payload, and evidence that the payload has been analyzed and/or tested to withstand the quasi-static and random vibration loads stated in Section 5.3.1.2 in each of the three orthogonal body axes. The report shall also include compliance evidence for atmospheric, thermal, and EMI/EMC requirements.
9	Mass Simulators	A mass representative model of the Primary payload will be required for the fit check. This mass simulator should ideally be mass and volume representative and should have a representative launch vehicle interfaces.

5.5 Secondary Payload Accommodations

With the approval of the Primary Payload Customer, Secondary Payloads may also be accommodated on the Firefly vehicle. For Customers with 3U CubeSats, a CubeSat Deployment Canister will be sent to the Customer for convenient loading and shipment back to the Firefly facility. Customers may also complete this portion of the integration process at the Firefly facility in a shared-use Secondary Payload clean room (ISO 8 / Class 100K FED-STD-209E). To maximize Secondary Payload capacity, 1U and 2U CubeSats from multiple Customers may be integrated into a single 3U CubeSat Deployment Canister.

Customers with CubeSat payloads will have the opportunity to manually check battery voltage and charge if needed prior to integration with the CubeSat dispenser. By default, charging or other diagnostic checks will not be available once the dispenser is mated to the vehicle. Customers who opt to integrate their CubeSat with the dispenser at their own facility and ship the integrated assembly to Firefly will not have the opportunity to check battery state before the dispenser is mated to the vehicle.

Please contact Firefly early in the mission planning process if your Secondary Payload requires data or power accommodations similar to those mentioned in Section 5.2.2.1 or Section 5.2.2.2

5.5.1 Secondary Payload Customer Requirements

Requirements for Secondary Payloads may vary slightly from those for Primary Payloads. In general, all Secondary Payloads shall comply with, and provide evidence for, all requirements stated in the CubeSat Design Specification document. For individual CubeSats, Firefly will provide the dispenser, and Customers planning to supply their own deployment canisters are requested to contact Firefly as early as possible in the mission planning process.

Table 12: Alpha RF System Characteristics

ID	TITLE	DESCRIPTION
1	Resonances and First Natural Frequency	Secondary Payload Customers shall provide evidence of the 1st resonant frequency being above 100 Hz.
2	Quasi-static and/or Sine Vibration Loading	Secondary Payloads shall withstand structural integrity under the loading of ±10g with positive margin.
3	Random Vibration	Secondary Payload Customers shall provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 6, with +3 dB margin. Test duration shall be 2 minutes, per Reference 2.
4	Notching	Reduction of the vibration input amplitude at certain resonance frequencies (i.e. notching) will not be possible for Secondary Customers.
5	Mass Properties	Secondary Payloads shall adhere to the following mass limits. Larger CubeSat masses may be evaluated on a mission by mission basis.

ID	TITLE	DESCRIPTION
		1U CubeSats shall not exceed a mass of 1.33 kg 3U CubeSats shall not exceed a mass of 4.0 kg 6U CubeSats shall not exceed a mass of 12.0 kg
6	Center of Gravity (CoG)	There are no strict requirements for CoG positioning on the Secondary Payloads, as they are expected to be arranged as a whole within the payload space by Firefly to achieve optimal mass distribution. Measured mass properties of all payloads must be communicated to Firefly.
7	Grounding, EMC and RF Transmissions	It is assumed that all payloads will be powered off during launch (in line with the Firefly baseline launch offering), and therefore will not be emitting any signals or radio frequency noise during the launch phase. Secondary Payloads cannot be powered on during launch. Secondary Payloads are required to follow the same grounding and EMC compliance as Primary Payloads.
8	Secondary Payload Data Package	The Secondary Payload Data Package is the same as the requested Primary Payload Data Package, sans Finite Element Analysis.
9	Mass Simulators	A mass representative model of each payload shall be provided by each Customer. For Secondary Payload Customers, this model will be retained until after launch, and will be returned by Firefly within 3 months of launch. Firefly reserves the right to launch mass simulators of Secondary Payloads if delivery of flight model payloads is delayed for periods in excess of those compatible with Primary Payload timelines.

5.6 Evidence of Qualification & Acceptance

The following Payload Data Package is requested by Firefly to comprehensively understand the Customer payload and interface; The package includes, yet may not be limited to the following items defined in Table 13 below.

Table 13: Requested Payload Data Package

ITEM	DESCRIPTION
Payload Questionnaire	The Payload Questionnaire is soon to be provided on the Firefly website with the purpose of introducing the objectives and requirements of the Customer.
Payload Flight Mode	Data outputs from qualification model mechanical tests or payload flight models to inform Firefly of the specific path of the payload once deployed, which may affect the trajectory and launch window of the vehicle.
RF Data Sheet	Test results of RF transmissions are requested so that Firefly may prepare ground support for specific frequencies and expected durations.
EMC Data Sheet	Response traces and results from an EMC test must be provided, showing that payload emissions are within acceptable ranges. Electromagnetic compatibility test results ensure that the provided payload or its elements do not generate interference that can adversely affects its own subsystems and components, or other payloads, or the safety and operation of the launch vehicle and launch site.
Payload Model	CAD and a finite element model are required for Coupled Loads Analysis (CLA) so Firefly can assess payload dynamics. Requirements, tools, and formats can be provided by Firefly.
Mass Properties	The following must be provided as part of a report or in the form of raw data: • Measurement/test data from mass properties measurements of the flight model payload or • Output data from a sufficiently representative simulation or CAD/ FE model of the payload
Media Package	When appropriate and desired, Firefly intends to help socialize the launch of specific payloads through the use of Payload Customer logos, insignias, graphics, video files, solid models and drawings. The earlier this package, or components of this package arrive, the more comprehensive the branding effort may be. In the case of mission- specific insignias to be positioned on the launch vehicle, Firefly requests the proposed design submission no later than 4 months before the launch date.

ITEM	DESCRIPTION
Safety Package	The following shall be provided as part of a report or in the form of raw data: • Relevant certificates and certifications relating to the safety requirements • Any exemptions or associated justifications
Representative volume	Representative volume and mass dummy of payload including the expected mechanical and electrical interfaces.
Loads Compatibility	Demonstrated (test) evidence of compatibility with the loads and environments generated by the Firefly vehicle.
Comm. Compatibility	Demonstrated (test) evidence of compatibility with the Firefly vehicle’s electrical and communications systems.
Mechanical Compatibility	Documentary evidence of compatibility of mechanical and electrical interfaces.

6 Facilities

6.1 Headquarters & Mission Control Center

The Mission Control Center (MCC) is located at Firefly headquarters in Cedar Park, TX. The MCC seats up to fifteen personnel and include GUI displays and voice and data communication systems, allowing personnel to view ground systems data and monitor telemetry from the LV prior to and after launch. It is the engineering backroom on launch day.

A separate viewing area for the Customer can also be provided. The data and communication to this area is limited to a payload graphical user interface (GUI) and the countdown net.

6.2 Test Site

Both propulsion and structural tests are conducted at the 200-acre Firefly Test Facility located just north of Headquarters. With full utilities, the site includes two operational test stands for engine and component testing and integrated stage testing. Conveniently located less than an hour from downtown Austin, the site is fully staffed and incorporates several facilities including a 10,000 square foot Test Control and Fabrication building, a 2,500 square foot surface finish shop and a 30,000 square foot production shop.

Figure 26: Lightning Heatsink in Testing at Firefly's Test Facility

6.3 Launch Site

Firefly is currently securing a site at Vandenberg Air Force Base (VAFB) to support the initial test flights of Alpha and a substantial number of future Customers. Documentation submission to Air Force Space Command and VAFB 30th Space Wing is complete. Vandenberg Air Force Base (VAFB) is Firefly's primary planned domestic launch site. This operational launch site services multiple inclinations, with typical orbits being Polar (90°) and SSO up to 2,000 km (104.89°). The Alpha launch vehicle is compatible with mission infrastructure and operations at launch sites defined by the Firefly Concept of Operations (ConOps). A conceptualized layout of the infrastructure is depicted in Figure 27.

In the future, Firefly may offer additional launch sites and will soon begin the process to secure a site on the east coast with potential locations being KSC, CCAFS or the Mid-Atlantic Regional Spaceport (MARS). Once an east coast location is determined, Firefly can establish a site within 24 months or less to include approvals and necessary construction.

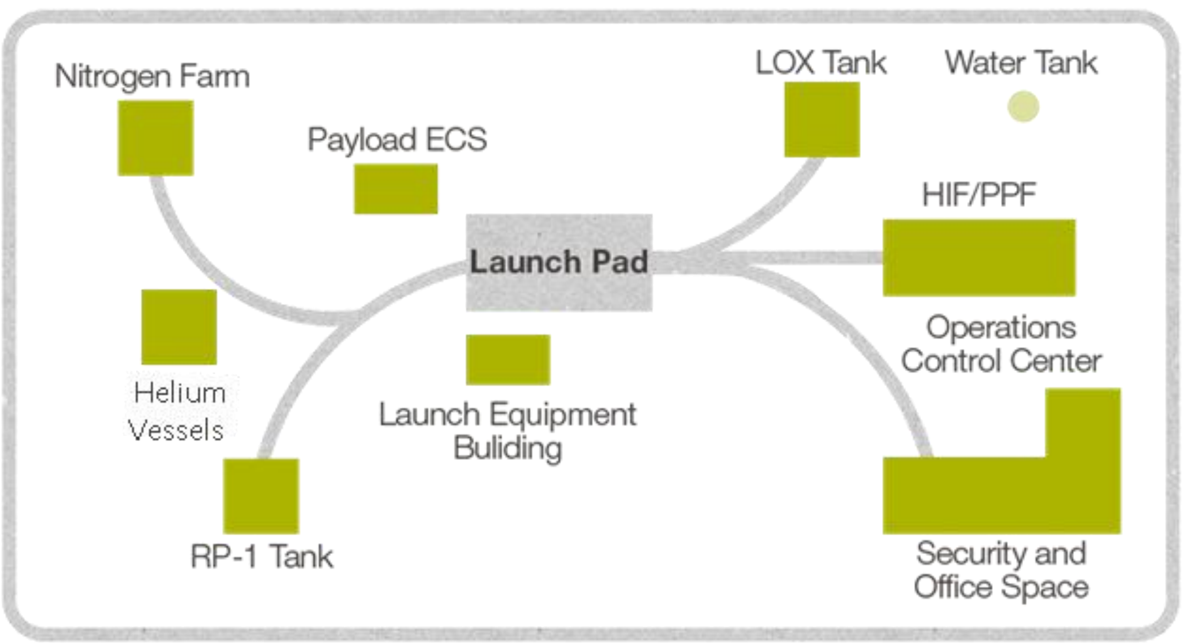

Figure 27: Firefly Launch Site Concept

6.3.1 Horizontal Integration Facility

An on-site Horizontal Integration Facility (HIF) will be utilized for processing and integration of Firefly vehicles. The HIF will be climate controlled and provide 120/240V single phase 60Hz, 208V three phrase 60Hz, and 240/480V three phase 60Hz electrical power for processing. The HIF will consist of a five thousand square foot open high bay with an eave height of twenty-five feet. This eave height allows for the removal of Alpha components from their shipping fixtures located on flatbed transportation trailers with deck heights up to 58 inches. Two bridge cranes in the high bay will support shipping and processing efforts. Within the HIF will be space for engineering work stations and consumable storage. The high bay and ancillary rooms will be operated as visibly clean, air conditioned, humidity-controlled work spaces maintained at a temperature of 75° F ± 10° F (23.89 ° C ± 5.55 ° C) and a relative humidity between 30% and 75%.

The HIF provides short-term storage of Firefly launch vehicle assemblies prior to shipping to a storage site. Several vehicles may be stored at each site, with the details of the storage yet to be defined. The ultimate intent is to maintain an inventory of Firefly vehicles to support near-term flight rates with possible market surges and commercial missions.

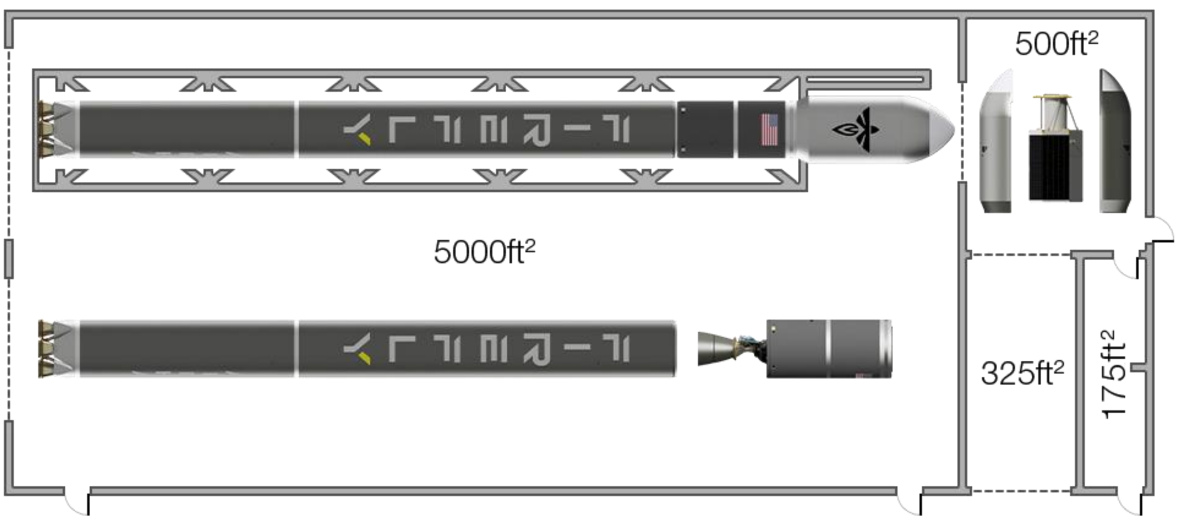

Figure 28: Typical Horizontal Integration Facility Layout with the Alpha vehicle

6.3.2 Payload Processing Facility

A Payload Processing Facility (PPF) provides the environment and tools for processing and encapsulation. The PPF will be climate controlled. Cleanliness will be maintained as required for the specific payload. 120/240V single phase 60Hz, 208V three phrase 60Hz, and 240/480V three phase 60Hz power will be available for processing. 230V 50Hz power can be made available in a few key locations within the PPF. The PPF will consist of a high bay that has 500 ft^2 of processing space, and a 325 ft^2 airlock, as well as a 175 ft^2 garment room.

The high bay will be an ISO 8 cleanroom (Class 100K). Climate will be maintained to a temperature of 75F ± 10F (23.89C ± 5.6C) and a relative humidity of 50% ± 15%. Ancillary rooms will be visibly clean, air conditioned, humidity-controlled work space. Additional payloads will be processed in modular soft- walled ISO 8 cleanrooms (Class 100K) within the Alpha processing area.

6.3.3 Launch Control Center

A Launch Control Center (LCC) will be located at the launch site. This may be a mobile solution or integrated within an existing facility. Personnel at this location will serve as Primary controllers. The LCC will setup to twelve personnel and include GUIs and voice communication. LCC will allow personnel to control ground and LV manual systems and continually monitor data from the LV prior to and after launch.

Additional facilities near the launch site may include:

- A separate viewing area for additional payload team members which will provide data and communication (limited to a payload GUI and the countdown net),
- approximately 3,000 square feet of office space for Engineering support,
- a GSE shop area, and
- storage space.

7 Safety

7.1 Safety Requirements

Customers must meet the requirements in AFSPCMAN 91-710, Range Safety User Requirements (see Reference 3) when designing flight and ground systems. AFSPCMAN 91-710 contains requirements for mechanical, electrical, fluid system, ordnance and RF design along with requirements for ground handling and lifting hardware. Firefly is happy to assist Customers in determining whether their current designs meet such requirements.

Table 14: Payload Safety Requirements

ID	ITEM	DESCRIPTION
1	Payload Batteries	Payload batteries must not be allowed to overcharge excessively to the point where an explosion risk arises.
2	Pressure Vessels	Payloads containing pressure vessels shall comply with the safety standards specified in ATR-2005(5128)-1, Operational Guidelines for Spaceflight Pressure Vessels.
3	Pyrotechnic and Explosive Devices	The standard baseline launch services assume that no pyrotechnic devices are present on the payload(s). Customers planning to include pyrotechnic devices should contact Firefly as early as possible in the mission planning process.
4	Ground Support Equipment	All ground support equipment (GSE) shall be safety tested with test reports available for review upon request. Electrical GSE should include safety measures which allow payload power to be cut in case of emergency, and to prevent overcharging of payload batteries. Lifting fixtures should be clearly marked with proof load limits. Propulsion system GSE should include vent valves that will automatically activate to prevent over pressurization.

Payload Questionnaire

A completed Payload Questionnaire informs Firefly of Customer requirements which feed into preliminary feasibility and compatibility assessments. If you are considering using Firefly for your mission needs, please complete and return the requested information to Firefly approximately 18 months prior to your desired launch date.

Alternatively, this questionnaire will soon be available on our website, www.fireflyspace.com.

With your dedicated, single point of contact, Firefly ensures a streamlined and secured process from initial contact through end of mission. We look forward to working with you

Payload Questionnaire

PAYLOAD INFORMATION	
Payload Name/Acronym	
POINTS OF CONTACT	
Name	
Email	
Phone	
Payload Contractor / Sponsor	
Payload Description	
Primary Objectives	
Maximum Expected Payload Mass [kg]	
Payload Height [cm]	
Payload Max Diameter [cm]	
Desired Launch Date [mm/dd/yy]	

PAYLOAD INTERFACE

Post-encapsulation access needed?	☐	Yes	☐	No

Describe desired door location with respect to the payload	

If additional information is available, please continue to populate the following with your mission specific data:

PAYLOAD TRAJECTORY PARAMETERS

Desired Orbit Apogee [km]	
Desired Orbit Perigee [km]	
Desired Right Ascension of Ascending Node (RAAN) [deg]	
Desired Orbit Inclination [deg]	
Payload Contractor / Sponsor	

		Packaged Configuration		Tolerance
Center of Gravity [cm]	X		±	
	Y		±	
	Z		±	

PAYLOAD ENVIRONMENT	
THERMAL AND HUMIDITY	
Pre-launch Temperature Range [C°]	
Pre-launch Vapor in Air [grains/lb of dry air]	
CONTAMINATION CONTROL	
Desired Cleanroom and Fairing Air [Class]	
Desired Fairing Air Cleanliness [Class]	
DYNAMIC ENVIRONMENT	
Max Allowable Acoustic Sound Pressure level [dB/OASPL]	
Maximum Allowable Sine Vibration [GRMS]	
Maximum Allowable Shock [g]	
Maximum Lateral Acceleration [g]	
Maximum Axial Acceleration [g]	
Fundamental Lateral Frequency [Hz]	
Fundamental Axial Frequency [Hz]	

Supporting Documents

1. NASA Langley Research Center. NASA-SP-8077, Transportation and Handling Loads.

   https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19720005242.pdf

2. NASA Goddard Space Flight Center. GSFC-STD-7000A, General Environmental Verification Standard.

   https://standards.nasa.gov/standard/gsfc/gsfc-std-7000

3. United States Air Force Space Command. AFSPCMAN 91-710, Range Safety User Requirements.

   http://static.e-publishing.af.mil/production/1/afspc/publication/afspcman91-710v3/afspcman90-710v3.pdf

4. Test Requirements for Launch, Upper-Stage, and Space Vehicles. MIL-STD-1540E/TR-2004(583)

   http://everyspec.com/USAF/TORs/download.php?spec=TR2004-8583-1A.026768.pdf

Acronyms

AFSPCMAN	Air Force Space Command Manual
AFTS	Autonomous Flight Termination System
AFTU	Autonomous Flight Termination Unit
C&DH	Command and Data Handling
CAD	Computer Aided Design
CFM	Cubic Feet per Minute
CLA	Coupled Loads Analysis
COTS	Commercial-Off-The-Shelf
EEE	Electrical, Electronic and Electromechanical
EGSE	Electrical Ground Support Equipment
EIRP	Effective Isotropic Radiated Power
EPS	Electric Power System
ESPA EELV	Secondary Payload Adapter
FAA	Federal Aviation Administration
FED-STD	Federal Standard
FF	Firefly
FRR	Flight Readiness Review
FPS	Frames Per Second GLOW Gross Lift-Off Weight
GN&C	Guidance Navigation and Control
GPS	Global Positioning System
GRMS	Root Mean Square Acceleration
GSE	Ground Support Equipment
GUI	Graphical User Interface
HIF	Horizontal Integration Facility
ICD	Interface Control Document
ISO	International Organization for Standardization
Isp	Specific Impulse
ITAR	International Traffic in Arms Regulations
LEO	Low-Earth Orbit
LRR	Launch Readiness Review

LOCC	Launch Operations Command Control
LOX	Liquid Oxygen
LV	Launch Vehicle
MCC	Mission Control
MCTU	Message Transfer and Control Unit
MECO	Main Engine Cut-off
MIL-STD	Military Standard
MRR	Mission Readiness Review
NRE	Non-Recurring Expense
OASPL	Overall Sound Pressure Level
OBC	Onboard Computer
PAF	Payload Attach Fitting
PPF	Payload Processing Facility
PSD	Power Spectral Density
QPSK	Quadrature Phase Shift Keying
RCC	Range Commander Council
RF	Radio Frequency
RP-1	Rocket Propellant
SECO	Second Engine Cut-off
SMC	Space and Missile Systems Center
SRS	Shock Response Spectrum
SSO	Sun-Synchronous Orbit
TBC	To be Confirmed
TBD	To be Determined
TLM	Transmission Line Matrix
TRL	Technology Readiness Level
VAFB	Vandenberg Air Force Base

List of Figures

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