
# FIREFLY ALPHA PAYLOAD USER GUIDE

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# CONTACT INFORMATION

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# REVISION HISTORY

| Revision | Date | By | Notes |
|---|---|---|---|
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# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

# OVERVIEW AND PURPOSE OF DOCUMENT

Welcome to the Payload User Guide for the Firefly Alpha Launch Vehicle. The purpose of this document is to provide summary information for preliminary mission planning purposes between the payload customer and Firefly. This document provides the vehicle information to validate payload compatibility.

The Payload User Guide is structured into two main portions:

- Sections 1 through 3 describe the Firefly organization and the characteristics and performances of the Firefly Alpha Vehicle.
- Sections 4 through 10 define interfaces, describe environmental conditions, and state the requirements to be met by payloads.

# DEFINITIONS AND ACRONYMS

## Common Definitions

The following definitions apply when referred to in this document:

| Term | Definition |
|---|---|
| Ambient | The surrounding environmental conditions such as pressure or temperature |

## Acronyms

| | |
|---|---|
| ASD | Acceleration Spectral Density |
| CAD | Computer Aided Design |
| CCAFS | Cape Canaveral Air Force Station |
| CFM | Cubic Feet per Minute |
| CoG | Centre of Gravity |
| EC | Engine Controller |
| EGSE | Electrical Ground Support Equipment |
| EMC | Electro Magnetic Compatibility |
| EPS | Electronic Power Sub-System |
| FE | Finite Element |
| FPS | Frames Per Second |

| | |
|---|---|
| GSE | Ground Support Equipment |
| HD | High Definition |
| HIF | Horizontal Integration Facility (Hangar) |
| I-bay | Information Bay |
| ICD | Interface Control Document |
| IMU | Inertial Measurement Unit |
| LEO | Low Earth Orbit |
| LV | Launch Vehicle |
| MGSE | Mechanical Ground Support Equipment |
| OASPL | Overall Sound Pressure Level |
| PAF | Payload Attach Fitting |
| PCS | Probability of Command Shutdown |
| PPF | Payload Processing Facility |
| RF | Radio Frequency |
| RIU | Remote Interface Unit |
| RMS | Root Mean Square |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| TBR | To Be Reviewed |
| TLE | Two Line Element |

# 1 INTRODUCTION

## 1.1 COMPANY DESCRIPTION

Firefly Space Systems is developing the Alpha launch vehicle to provide low-cost, high-frequency launch capability for the rapidly growing and critically underserved small satellite industry.

Firefly's simplest-soonest approach to technology selection will deliver game changing launch costs, accessibility, and reliability for customers.

Firefly's seasoned engineering team is comprised of industry-proven leaders with experience in both building commercial launch vehicles as well as successful technology firms. Augmenting and rounding out this team are passionate young minds from the country's top engineering schools. Each vehicle is engineered with cross-industry design insights and leverages high Technology Readiness Level (TRL) design elements to reduce risk and guarantee reliability. The technologies employed in our Alpha flagship vehicle provide a clear pathway for future incremental improvements in vehicle capability.

This unique development approach aims for monthly rocket launches within 3 years and a reusable launch vehicle within 5 years.

## 1.2 ALPHA VEHICLE OVERVIEW

Alpha is a two-stage launch vehicle capable of delivering 400 kg of payload to LEO. The first variant, Alpha 1.0, utilizes efficient technologies such as composite tanks, a plug cluster aerospike, and traditional bell nozzle engines with hydrocarbon fuel. Alpha operations are highly streamlined, with all facets of design, testing, and production located in central Texas.

Alpha will bring the following advantages to customers:

***Availability***

Firefly launch vehicles will be mass produced to the highest quality standards. Mass production enables the ability to change the industry through regularly scheduled launches. Although every launch vehicle is built to plan, payload attachment fittings can be adapted to specific customer needs.

***Reliability***

Firefly launch vehicles are built with reliability in mind. Separation events are kept to a minimum. There are just 3: stage, fairing, and payload separation. Each launch vehicle will run through a regime of tests, starting at the component level, up to a full stage test prior to transportation to the launch site.

***Cost***

Firefly launch vehicles give small satellite customers a tailored and dedicated launch service for a lower all-in cost than a secondary/auxiliary launch. A complete vehicle may be purchased for $8M, which includes a re-fly guarantee in the unlikely event of a launch failure. The standard offered payload interface is also included in the price.

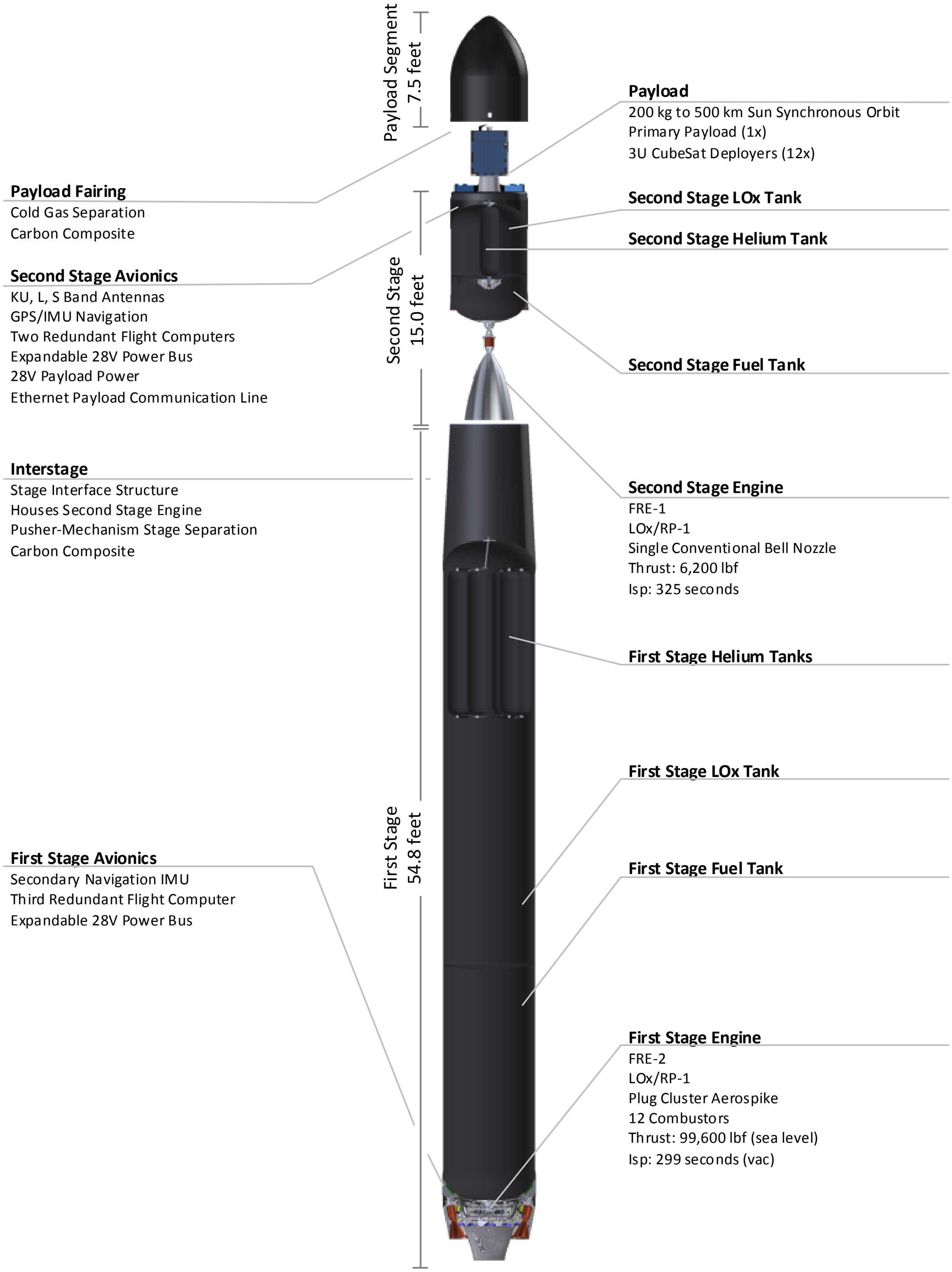



FIGURE 1: FIREFLY ALPHA VEHICLE AND KEY CHARACTERISTICS

### 1.2.1 Vehicle Axes Definitions

Figure 2 shows the definition of the Axes for the Firefly Alpha Vehicle. As is the case with most launch vehicles, the X axis is the roll axis for the vehicle, and therefore the vertical axis for any vertically mounted passenger satellite. The axes definitions in Figure 2 are used throughout this user guide to specify payload environments, loads and test requirements.

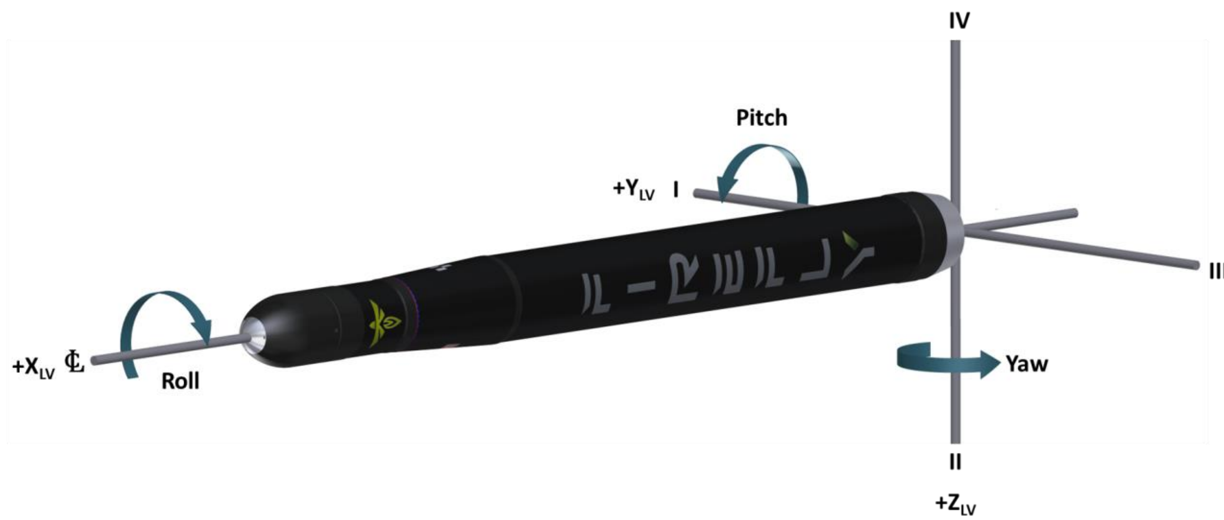



FIGURE 2: FIREFLY ALPHA VEHICLE AXES DEFINITIONS

# 2 ALPHA PERFORMANCE CAPABILITIES

## 2.1 ORBIT DELIVERY CAPABILITY

The performance capabilities of the Firefly Alpha vehicle are detailed in the figures and tables below. Alpha can accommodate a wide range of Payload requirements and our team can provide innovative performance trades to meet our customer’s needs.

Figure 3 shows orbit delivery performance for inclinations ranging from Due East to Polar and Sun Synchronous Orbits. All orbits were calculated using the Equator as the launch location. A small (10%) variation in payload delivery can be expected depending on which launch site is utilized.

## 2.2 FLIGHT SEQUENCE & PROFILE

The Firefly Alpha flight profile is depicted in 4. Most missions will follow a profile similar to that shown in 4, though the times at which key events occur may vary slightly. For direct insertion missions, payload separation will occur approximately 500 seconds after liftoff. For multi-manifested missions and/or those requiring higher orbits, the Alpha second stage will first insert into a low elliptical transfer orbit, coast to apogee, and then initiate a second burn to circularize into the final orbit. In this case, primary payload separation will occur approximately 3000 seconds after liftoff.

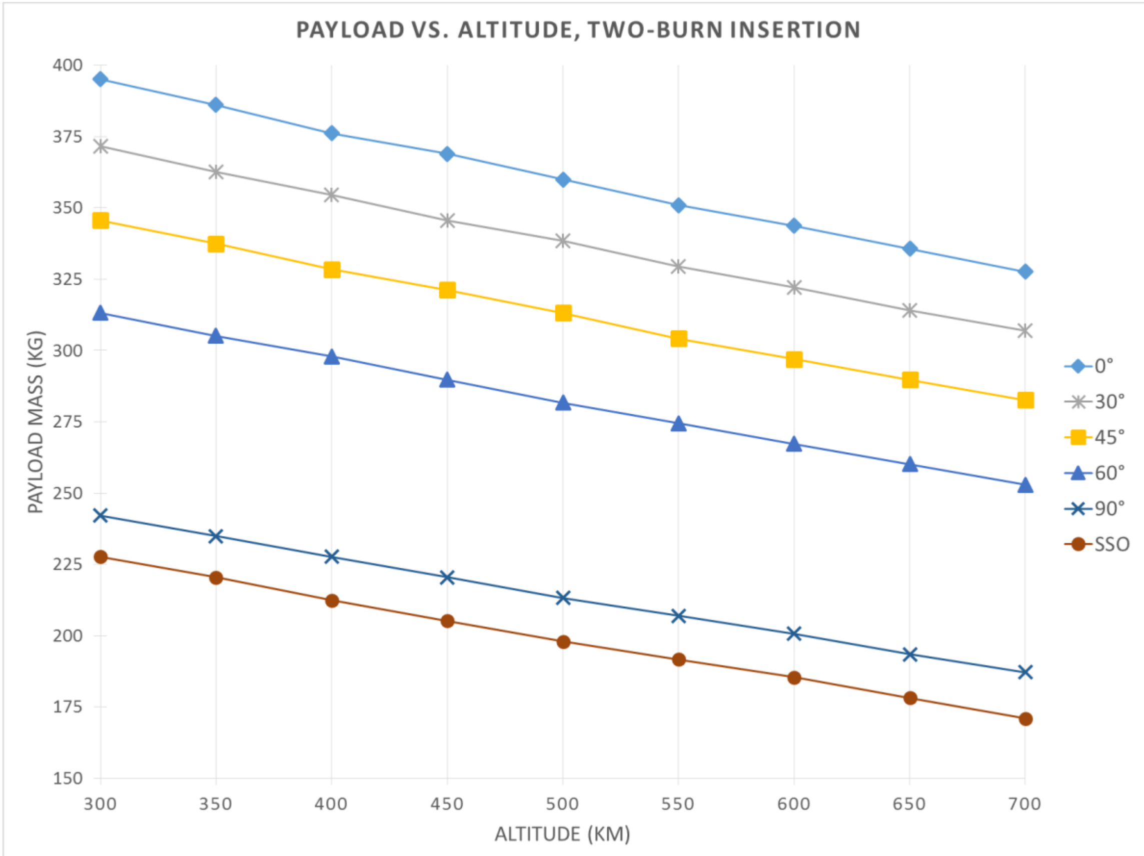
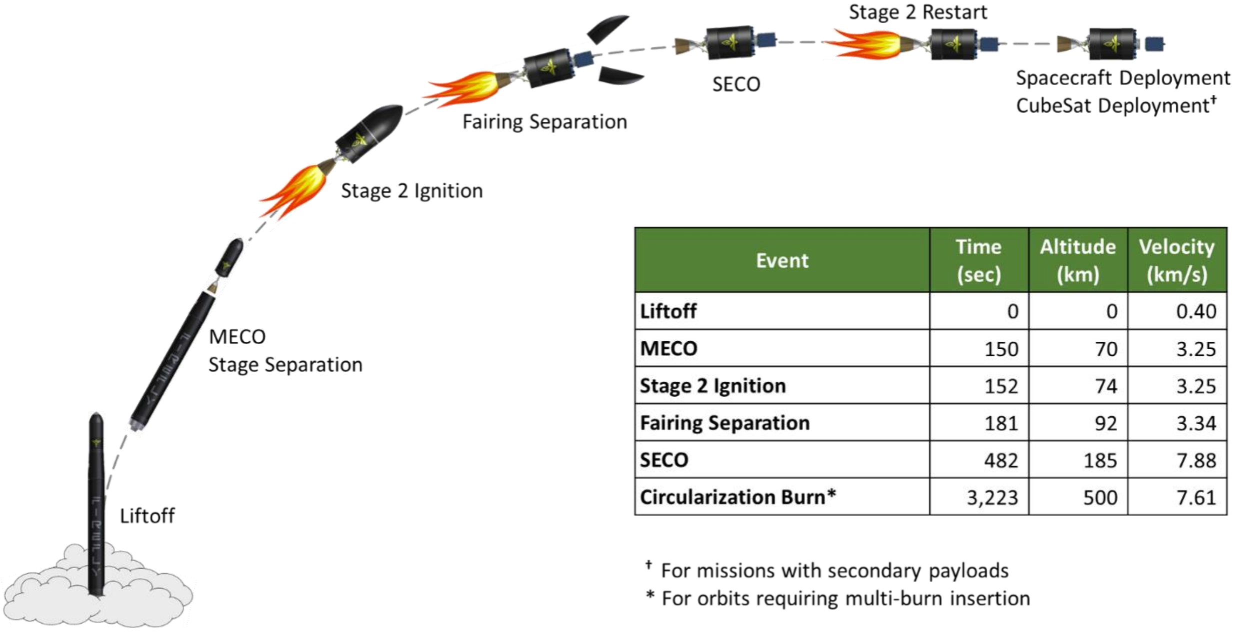



FIGURE 3: FIREFLY ALPHA PERFORMANCE TO VARIOUS INCLINATIONS AND ALTITUDES




| Event | Time (sec) | Altitude (km) | Velocity (km/s) |
|---|---|---|---|
| **Liftoff** | 0 | 0 | 0.40 |
| **MECO** | 150 | 70 | 3.25 |
| **Stage 2 Ignition** | 152 | 74 | 3.25 |
| **Fairing Separation** | 181 | 92 | 3.34 |
| **SECO** | 482 | 185 | 7.88 |
| **Circularization Burn*** | 3,223 | 500 | 7.61 |

† For missions with secondary payloads
* For orbits requiring multi-burn insertion

FIGURE 4: TYPICAL ALPHA FLIGHT PROFILE

## 2.3 Payload Insertion Accuracy

The second stage of the Firefly Alpha vehicle incorporates a redundant inertial navigation control module to provide precise pointing and orbit insertion.

For a second-stage probability of command shutdown (PCS) of 99.7%, the typical three-sigma (3σ) dispersions for a two-stage mission to low-earth orbit are:

- Perigee altitude: ± 5 km (TBC)
- Apogee altitude: ± 5 km (TBC)
- Orbit inclination: ± 0.05 deg (TBC)

# 3 Mission and Typical Program Overview

## 3.1 Planning & Preparation

### 3.1.1 Initial Contact

Initial contact should be made via the contact details included at the front of this document. Each customer will be assigned a primary point of contact (Mission Manager) who will remain as the primary interface between Firefly and the customer throughout the entire mission planning and execution process.

### 3.1.2 Meetings & Communications

Customers can expect transparency and open communication throughout the entire process, with regular status reports from their Mission Manager.

### 3.1.3 Fit Checks

One fit check meeting is foreseen during the mission preparation phase, typically to take place at Firefly's integration facilities. This will be combined with a meeting to finalize the payload to launch vehicle ICD.

Activities and objectives of the Fit Check are as follows:

- To assemble a full up, mass and volume representative model of the entire payload composite, including all payloads (in the event of multi-manifested launch configurations) and separation systems and adapters
- To validate the mechanical and electrical interfaces
- Where possible, to validate the operation of all separation systems.

The customer will be expected to provide a representative volume and mass dummy of their payload including the expected mechanical and electrical interfaces.

## 3.2 Launch Campaign Timeline

Figure 5 gives an overview of the activities in a typical launch campaign, including the launch specific activities, payload specific activities and the integrated activities. A typical expected overall launch campaign duration is 3 weeks. 7-10 days are typically assigned to payload checkout and miscellaneous autonomous payload operations, and an additional 7-10 days are typically required for payload to launcher integration activities and final launcher preparation activities (including fairing closure, transport to launch pad, and launcher erection).

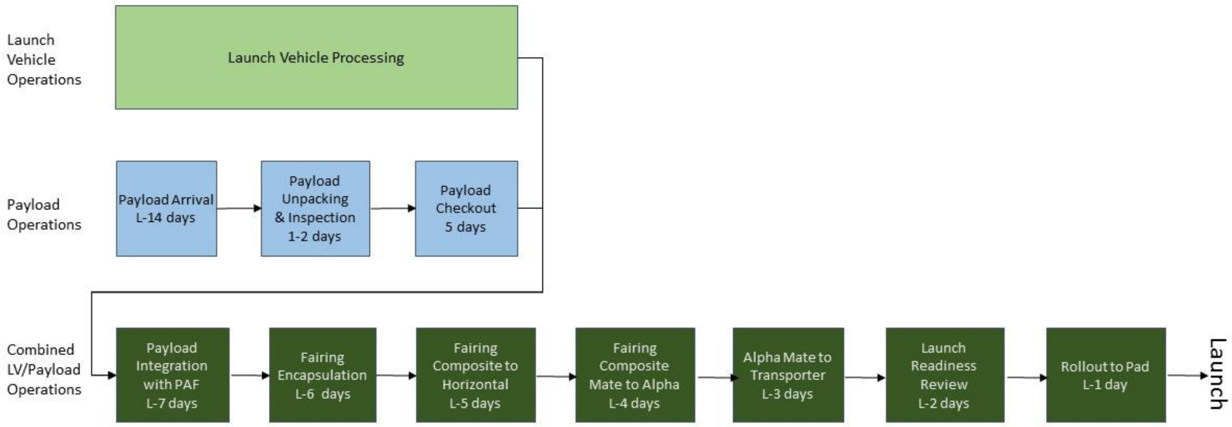



FIGURE 5: TYPICAL LAUNCH CAMPAIGN TIMELINE

## 3.3 PAYLOAD INTEGRATION OPERATIONS

Payloads will be processed in an ISO 8 (Class 100K FED-STD-209E) clean room environment. They will be mated to the Payload Attachment Fitting (PAF) and encapsulated by the payload fairing in the vertical position. The encapsulated payload will then be rotated to a horizontal orientation by means of a break-over fixture. The payload fairing 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 out to the pad and raised to the vertical position. Additional details about this process can be found in Section 7.3.

### 3.3.1 CubeSats

For customers with 3U CubeSats, a CubeSat Deployment Canister will be sent to the customer for 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. In these situations, integration must occur at the Firefly facility.

Customers with 6U, 12U, or clusters of CubeSats should contact Firefly to discuss other possible integration options.

# 4 PAYLOAD ACCOMMODATION

## 4.1 PAYLOAD FAIRING AVAILABLE VOLUME

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 a nominal outer diameter of 5ft. The maximum useable internal diameter is shown in Figure 6. Acoustic foam will be used to reduce the acoustic environment within the payload fairing.

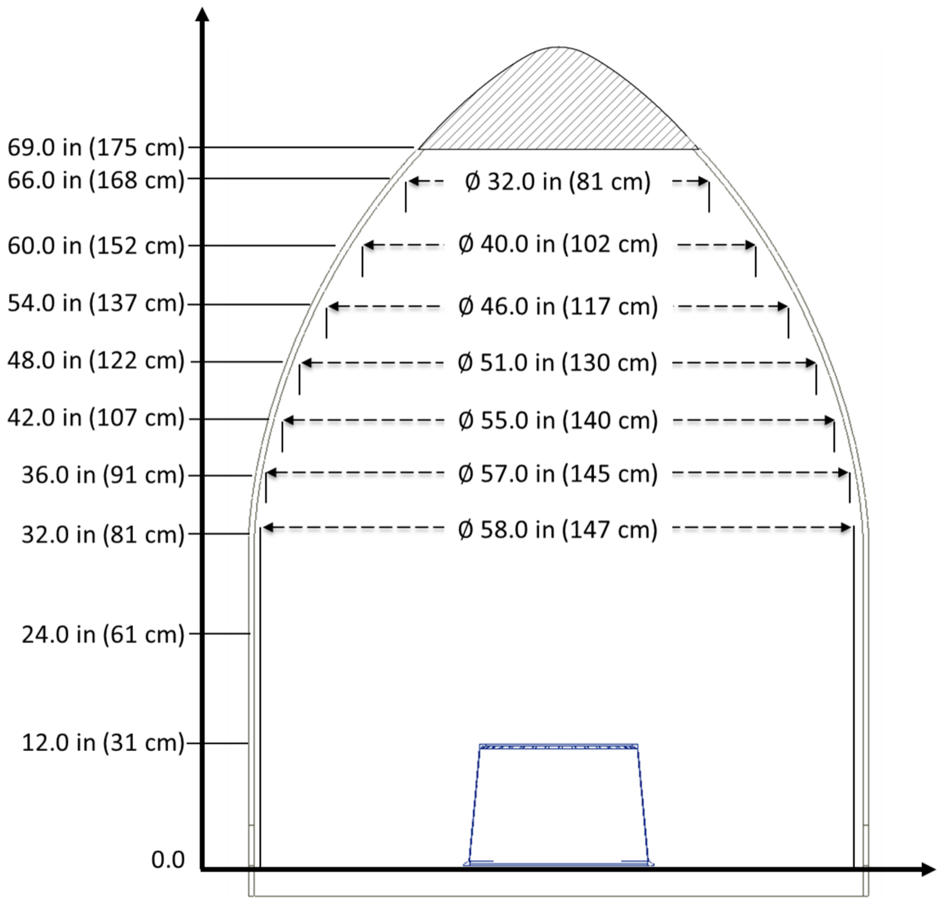



**Figure 6: Firefly Alpha Fairing Volume**

## 4.2 Payload Accommodation Scenarios

Two Initial Payload accommodation scenarios are defined for Payload Accommodation:

- Single (Primary Only) payload, and
- Primary payload plus secondary/auxiliary payloads (including CubeSats)

Requirements and constraints for Primary and Secondary payloads may be slightly different.

### 4.2.1 Payload Integration Access and Stay-out Zones

Within the payload fairing and in the vicinity of the payload adapters and interfaces, there are likely to be some stay out zones (associated with Firefly equipment and fixtures) where payloads cannot infringe. Details of stay-out zones will be included in later versions of this guide and in any case will be negotiable and flexible where possible.

## 4.3 Payload Interfaces

The Firefly Alpha vehicle features a number of standard mechanical and electrical interfaces in order to accommodate typical small satellite interfacing requirements and characteristics. The emphasis is on interface simplicity and robustness, in line with the overall Firefly Approach.

### 4.3.1 Mechanical Interfaces & Separation Systems

Firefly Alpha offers a number of common industry mechanical interface arrangements for payloads, with most common attachment patterns and bolt circles accommodated.

The standard Payload Attachment Fitting (PAF) is designed to interface with a 15-inch ("ESPA" interface) Lightband or clamp band separation system. The interface is (24x) 1/4"-28 bolts evenly spaced around a 15 inch bolt circle diameter.

The most commonly used small satellite separation systems are all accommodated, including:

- Dassault ASAP 5 (see Reference 1)
- Planetary Systems Lightband (see Reference 2)
- Ruag Clamp Band Separation Systems (see Reference 3)
- ISIPOD CubeSat Deployer (see Reference 4)

Per customer request, the PAF design can be modified to accommodate satellite separation systems of diameters ranging from 8 inches up to 24 inches ("ESPA Grande" interface). Requests for accommodation of any non-standard payload interface should be made early in the mission planning process.

### 4.3.2 Electrical Interface

The Alpha Launch Vehicle provides a set of standard payload electrical interfaces in addition to a rich set of optional but prequalified interfaces. Other custom configurations can be accommodated but may require development NRE and qualification cost and schedule. Connector type and pinouts for the payload will be specified during the spacecraft integration process. This connection will provide power, necessary communication lines, and separation detection systems as illustrated in Figure 7.

All payload interfaces to the Alpha PAF must be electrically conductive with sheet resistance less than 0.1 Ohms 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.

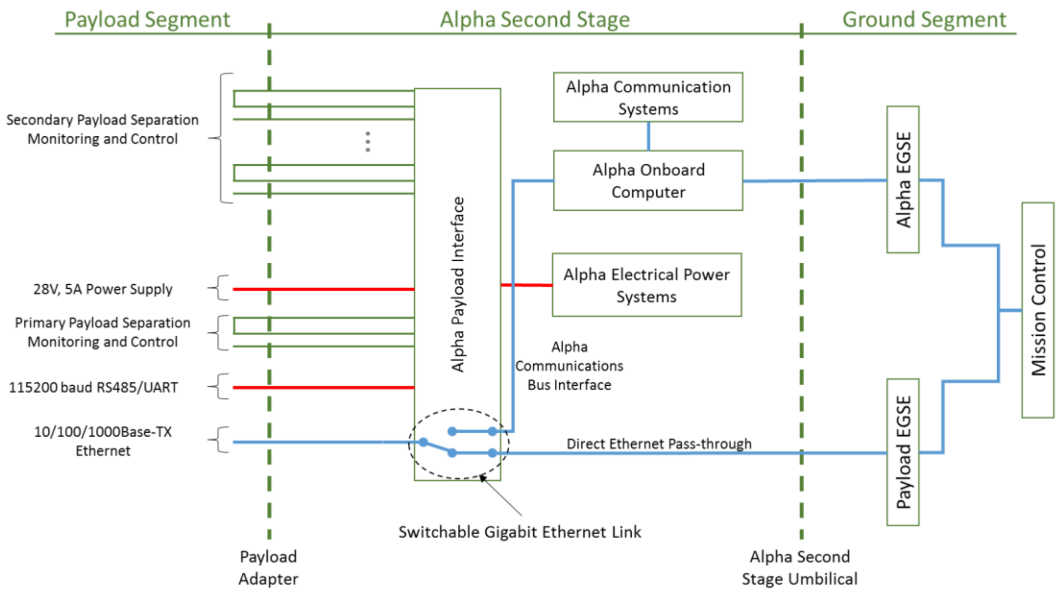



FIGURE 7: PAYLOAD TO ALPHA AND GSE WIRING DIAGRAM

#### 4.3.3 Spacecraft Power

The spacecraft is provided access to a 28V regulated voltage source that is current limited to 5 amps. This power is sourced from the Alpha EGSE through Alpha's Electrical Power System (EPS), and can be used to charge spacecraft batteries or perform other system functions prior to launch. Please note that spacecraft must contain their own voltage monitoring and charging circuitry if this power source is to be used for battery charging. The Alpha EPS does not perform those functions. This bus will be disconnected prior to launch and the spacecraft should power down at that time. Higher currents are available as an option but all sources are limited maximum-current voltage sources.

Customers with CubeSat payloads will have the opportunity to manually check battery voltage and charge if needed prior to integration with the CubeSat Deployer. By default, charging or other diagnostic checks will not be available once the deployer is mated to the vehicle.

Customers who opt to integrate their CubeSat with the deployer at their own facility and ship the integrated assembly to Firefly will not have the opportunity to check battery state before the deployer is mated to the vehicle.

Contact Firefly early in the mission planning process if your mission requires special accommodations not listed above.

#### 4.3.4 Spacecraft to Ground Data transfer

In the majority of cases it is not expected that data connections will be required between the spacecraft and ground following payload integration. The baseline offering requires all payloads to be in a powered off (inactive) state during launch; Therefore, no data transfer between spacecraft and GSE will be possible.

In cases where data transfer is required by the customer, Firefly can provide optional limited-priority/bandwidth channels through Alpha's auxiliary command and telemetry system. Firefly can provide a standard set of serial commands (115200 baud RS-485 or UART) to the payload indicating affirmative Stage 2 separation, fairing separation, and Stage 2 engine burnout prior to the payload separation command. Alpha can also provide pass through cables for payload communication to payload electrical ground support equipment. Pass-through systems are compatible with 10/100/1000Base-TX communication.

Please contact Firefly early in the mission planning process if you intend to be powered on during launch, as additional time and cost implications are likely.

# 5 PAYLOAD ENVIRONMENTS

The environment and loads that payloads will be subjected to during launch on the Firefly Alpha vehicle are described in this section.

## 5.1 MECHANICAL

#### 5.1.1 Transportation and Handling Loads

Table 1 shows the maximum transportation and handling loads anticipated in payload design. For additional information, see Reference 5.

| Transportation/Handling Loads | | | |
|---|---|---|---|
| Event | Axial Load (x), g | Lateral Load (y), g | Vertical Load (z), g |
| Ground Shipment | ± 3.5 (TBC) | ± 2.0 (TBC) | ± 6.0 (TBC) |
| Ground Handling | ± 2.0 (TBC) | ± 1.0 (TBC) | ± 1.0 (TBC) |
| Break-over and Transport Erector Roll-out | ± 1.0 (TBC) | ± 1.0 (TBC) | ± 2.0 (TBC) |

TABLE 1: TRANSPORTATION & HANDLING LOADS

### 5.1.2 Flight Loads – Quasi-Static

Table 2 shows the maximum quasi-static loads to be expected at the payload/launch vehicle interface during flight.

| Quasi-Static Loads During Flight | | |
|---|---|---|
| Event | Axial Load (x), g | Lateral Load (y,z), g |
| Liftoff | 1.3 | ±0.3 |
| Max qα | 1.8 | ±0.3 |
| Stage 1 Engine Cutoff | 6.0 | ± 0.3 |
| Stage 2 Ignition | 0.8 | ± 0.3 |
| Stage 2 Engine Cutoff | 3.7 | ± 0.3 |

TABLE 2: QUASI-STATIC FLIGHT LOADS AT SPACECRAFT/LAUNCH VEHICLE INTERFACE

### 5.1.3 Flight Loads - Random Vibration

During launch, payloads will be subjected to a random vibration environment due 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.

Spacecraft with masses above 200 lbs (91 kg) – i.e. primary payloads – shall design to the blue curve presented in Figure 8, with detailed values provided in Table 3. These levels were generated based on random vibration acceptance test levels provided in GSFC-STD-7000A (see Reference 6). ASD levels will be updated as data from further analysis and testing of the Alpha vehicle becomes available.

Spacecraft with masses below 50 lbs (23 kg) – i.e. secondary payloads, including CubeSats – shall design to the red curve presented in Figure 8, with detailed values provided in Table 4. These levels were generated based on random vibration acceptance test levels provided in GSFC-STD-7000A (see Reference 6). ASD levels will be updated as data from further analysis and testing of the Alpha vehicle becomes available.

Please contact Firefly for payload-specific ASD values if your spacecraft has sensitive equipment (e.g. optics) or has a mass in the range of 50-200 lbs (23-91 kg).

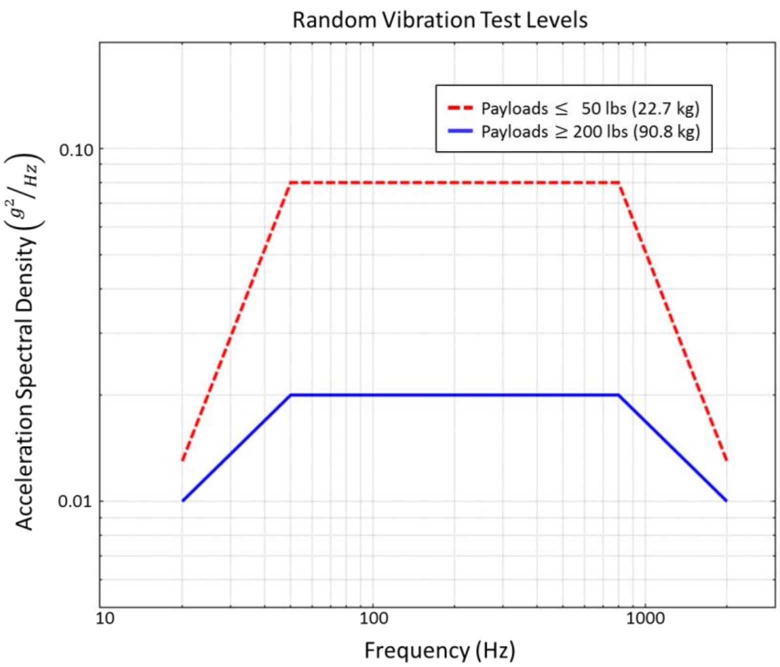



FIGURE 8: RANDOM VIBRATION TEST LEVELS – VALUES TBC

| Random Vibration Loads During Flight<br>For Payloads 200 lbs (91 kg) and Larger | |
|---|---|
| **Frequency** | **ASD Level ($g^2$/Hz)** |
| 20 Hz | 0.01 |
| 20-50 Hz | +2.28 dB/oct |
| 50-800 Hz | 0.02 |
| 800-2000 Hz | -2.28 dB/oct |
| 2000 Hz | 0.01 |
| **Overall** | **4.86 $G_{RMS}$** |

TABLE 3: RANDOM VIBRATION LOADS FOR PAYLOADS 200 LBS (91 KG) AND LARGER – VALUES TBC

| Random Vibration Loads During Flight<br>For Payloads 50 lbs (23 kg) and Smaller | |
|---|---|
| **Frequency** | **ASD Level ($g^2$/Hz)** |
| 20 Hz | 0.013 |
| 20-50 Hz | +6 dB/oct |
| 50-800 Hz | 0.08 |
| 800-2000 Hz | -6 dB/oct |
| 2000 Hz | 0.013 |
| **Overall** | **10.0 $G_{RMS}$** |

TABLE 4: RANDOM VIBRATION LOADS FOR PAYLOADS 50 LBS (23 KG) AND SMALLER – VALUES TBC

### 5.1.4 Flight Loads – Acoustic

The maximum acoustic environment the Payload sees is at liftoff and through transonic flight. The acoustic environment for the Payload in a blanketed fairing is still TBD. It is expected to meet an Overall Sound Pressure Level (OASPL) of <135 dB.

### 5.1.5 Shock Loads

The maximum shock environment at the Payload interface occurs during Payload separation from the second stage and is dependent of the PAF/Payload separation system configuration. Shock levels at the Payload separation interface due to other flight events – such as stage separation, fairing separation, and engine ignition/shutdown – are not significant compared to the shock caused by payload separation. Figure 9 illustrates the maximum expected shock environment. Detailed values are presented in Table 5.

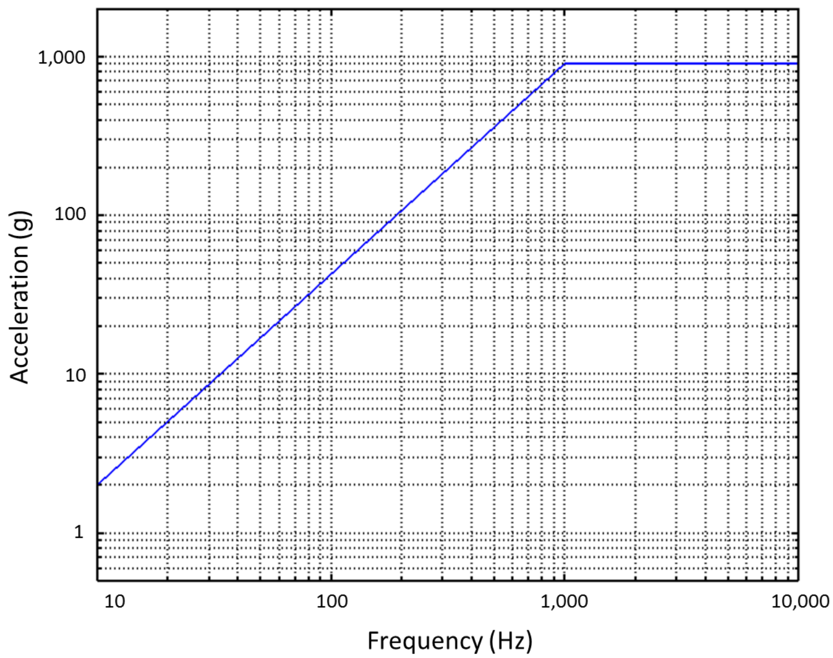



**FIGURE 9: EXPECTED SHOCK LEVELS DURING PAYLOAD SEPARATION – VALUES TBC**

| Maximum Shock Loads During Flight | |
|---|---|
| **Frequency** | **SRS (g-peak)** |
| 10 Hz | 2 |
| 10-1,000 Hz | +3.99 dB/oct |
| 1,000-10,000 Hz | 900 |

**TABLE 5: EXPECTED SHOCK VALUES – VALUES TBC**

## 5.2 THERMAL & ATMOSPHERIC

### 5.2.1 Payload Conditioning

Upon Payload encapsulation, a continuous supply of clean air is provided at a typical environment range as stated in Table 6. 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. A trickle nitrogen (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 of these trickle purges will be 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 would be removed from the sensor and the flight access panel 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.

| Payload Environmental Conditioning | | | | | | |
|---|---|---|---|---|---|---|
| Location | | Temperature | Relative Humidity | Flow Rate | Filtration | Hydrocarbons |
| Firefly HIF | Payload Integration Facility | 75F ± 5F<br>23.89C ± 2.8C | 35% - 50% ± 5% | 900-1500 CFM<br>25.5-42.5 $m^3$/min | Class 100,000 | 15ppm max |
| Firefly HIF | Fairing Encapsulated | 75F ± 5F<br>23.89C ± 2.8C | 35% - 50% ± 5% | 180-240 CFM<br>5.1-6.8 $m^3$/min | Class 100,000 | 15ppm max |
| Firefly Pad | Payload Fairing Roll Out | Not Controlled | Not Controlled | Not Controlled | Not Controlled | Not Controlled |
| Firefly Pad | Payload Fairing at Launch Pad | 75F ± 5F<br>23.89C ± 2.8C | 35% - 50% ± 5% | 180-240 CFM<br>5.1-6.8 $m^3$/min | Class 100,000 | 15ppm max |

TABLE 6: PAYLOAD ENVIRONMENTAL CONDITIONING

### 5.2.2 Fairing Thermal Environment

Upon Payload encapsulation, air-conditioning is provided at a typical temperature range as stated in Section 5.2.1, depending on mission requirements.

The Alpha fairing is made up of carbon composite with an emissivity of (TBD). The acoustic foam can provide a relatively cool radiation environment by effectively shielding the payload from ascent heating in blanketed areas.

### 5.2.3 On Orbit Thermal Environment

As most Firefly missions are expected to be of short durations (for delivery in to Low Earth orbits), active thermal control or heating of payloads is not foreseen. During coast periods, the launch vehicle can be oriented to meet specific sun angle requirements if required. Active thermal control and payload heating may be able to be accommodated as an optional extra (see Section 8 for more details).

### 5.2.4 Fairing Internal Pressure

As the Alpha 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 10.

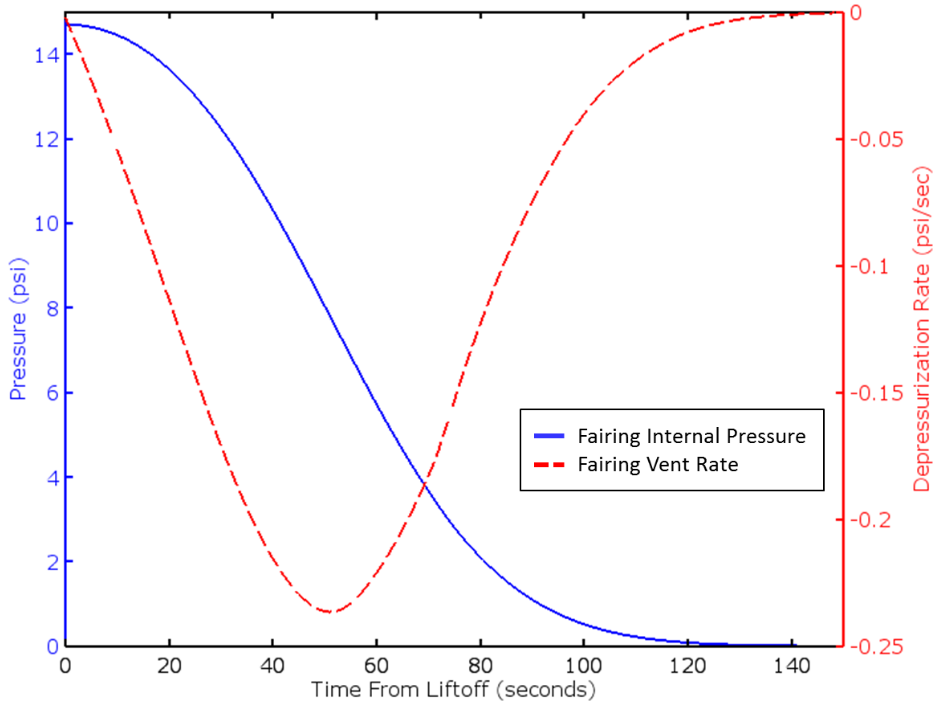



FIGURE 10: FARING INTERNAL PRESSURE PROFILE

## 5.3 PAYLOAD ENVIRONMENT – RF & EMC

### 5.3.1.1 Radio Frequency Environment

The Alpha vehicle's payload fairing attenuates RF transmissions during launch pad operations, flight ascent, and up to the point of fairing separation. After fairing separation, S-band transmission will not exceed (TBD) dBm at the Center of Gravity of the fairing. Ku-Band transmissions will not exceed (TBD) dBm. It is recommended that payloads are powered off during launch to reduce the risk of damage caused by RF interference. Payload RF characteristics shall be designed such that there is no interference with the Alpha vehicle RF systems detailed in Table 7. Alpha customers must ensure that any payload component or material constituents that are sensitive to RF transmissions are compatible with the electromagnetic environment of the Alpha vehicle.

| Payload Environmental Conditioning | | | | |
|---|---|---|---|---|
| **Function** | Stage 1 TLM | Stage 2 TLM | Alpha TLM | GPS |
| **Role** | Transmit | Transmit | Transmit | Receive |
| **Band** | S-Band | S-Band | Ku-Band | L-Band |
| **Frequency (MHz)** | TBD | TBD | TBD | TBD |
| **Bandwidth** | TBD | TBD | TBD | TBD |
| **Power Output** | TBD | TBD | TBD | TBD |
| **Sensitivity** | TBD | TBD | TBD | TBD |
| **Modulation** | TBD | TBD | TBD | TBD |

TABLE 7: ALPHA RF SYSTEM CHARACTERISTICS – VALUES TBD

# 6 PAYLOAD REQUIREMENTS

This section details the requirements to be satisfied for any payload on the Firefly Alpha Vehicle. The requirements can be classified as follows:

- Demonstrated (test) evidence of compatibility with the loads and environments generated by the Firefly Alpha Vehicle.
- Demonstrated (test) evidence of compatibility with the Firefly Alpha vehicles' electrical and communications systems
- Documentary evidence of compatibility of mechanical and electrical interfaces

In keeping with the overall goals of the Firefly service, it is intended that evidence be as succinct as possible. Guidelines on what is considered acceptable evidence is included in Appendix 2.

Requirements for Primary and Secondary/Auxiliary payloads are different for some parameters.

## 6.1 PRIMARY PASSENGER REQUIREMENTS

### 6.1.1 Resonances & First Natural Frequency

The Primary Passenger must provide evidence of the **1st lateral resonant frequency** being above **20 Hz (TBC).**

The Primary Passenger must provide evidence of the **1st axial resonant frequency** being above **25 Hz (TBC).**

Both of these requirements refer to the Firefly Alpha vehicle definitions as show in Section 1.2.1.

### 6.1.2 Quasi-static and/or Sine Vibration Loading

The Primary Passenger must provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 2, with positive margin.

### 6.1.3 Random Vibration

The Primary Passenger must provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 3, with +3 dB margin. Test duration shall be 2 minutes, per Reference 6.

### 6.1.4 Acoustic Vibration

Should the primary passenger choose to design and qualify/accept their design against the acoustic load environment (as may be expected for larger satellites), the passenger must provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Section 5.1.4, with positive margin.

### 6.1.5 Notching

Reduction of the vibration input amplitude at certain resonance frequencies (i.e. notching) may be possible for the primary passenger, but cannot be guaranteed. Any notching requirements or preferences should be communicated to Firefly as early as possible in the mission planning process.

### 6.1.6 Mass Properties

The required position of the Primary Passengers Center of Gravity (CoG), relative to the plane of separation, is as follows: (this assumes that the primary passenger is mounted centrally, i.e. with its vertical axis aligned with the launch vehicles roll (x) axis:

Offset of CoG from Y & Z axis: < 2 in (50 mm) (TBR)
Offset of CoG from separation system interface plane: < 18 in (457mm) (TBR)

### 6.1.7 Grounding, EMC & 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 spacecraft 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 Ohms 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.

### 6.1.8 Numerical & Computer Models

In order for Firefly to carry out its mission analysis and design for the primary passenger, the following numerical and/or computer models of the primary passenger spacecraft will be required:

- A computer aided design (CAD) model, in STEP (*.stp or *.step) or Parasolid (*.x_t) format. The CAD model supplied should include accurate representations of the external characteristics and features of the spacecraft, including all appendages, and the separation system.
- A Finite Element (FE) model of the spacecraft, 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 spacecraft's stiffness and mass properties, contain all relevant material/connection property definitions, and should ideally be simplified.

For the timing of model delivery requirements within the mission schedule, please refer to Section 9.

### 6.1.9 Mass Dummy

A mass representative dummy of the primary passenger spacecraft will be required for the fit check. This mass dummy should ideally be mass and volume representative and should have a representative launch vehicle interfaces fitted. For the timing of model delivery requirements within the mission schedule, please refer to Section 9.

## 6.2 Secondary/Auxiliary Passenger Requirements (including CubeSats)

Requirements for Secondary/Auxiliary passengers are different from those for primary passengers for some parameters.

### 6.2.1 Resonances & First Natural Frequency

Secondary and Auxiliary Passengers must provide evidence of the **1st lateral resonant frequency** being above **50Hz (TBD)**

Secondary and Auxiliary Passengers must provide evidence of the **1st axial resonant frequency** being above **100 Hz (TBD)**

Both of these requirements refer to the Firefly Alpha vehicle definitions as show in Section 1.2.1.

### 6.2.2 Quasi-static and/or Sine Vibration Loading

The Primary Passenger must provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 8, with positive margin.

| Quasi-Static Loads for Auxiliary Passengers | | |
|---|---|---|
| **Parameter** | **Axial Load (x), g** | **Lateral Load (y,z), g** |
| Quasi-Static Loads | 10 TBC | ±2 TBC |

**TABLE 8: QUASI-STATIC LOADING FOR AUXILIARY AND SECONDARY PAYLOADS**

### 6.2.3 Random Vibration

Secondary payloads must also provide evidence that the payload is robust and will not suffer mechanical failure under the loadings specified in Table 4, with +3 dB margin. Test duration shall be 2 minutes, per Reference 6.

### 6.2.4 Notching

Reduction of the vibration input amplitude at certain resonance frequencies (i.e. notching) will not be possible for Secondary and Auxiliary Passengers.

### 6.2.5 Mass Properties

Secondary payloads must adhere to the following requirements.

- CubeSats shall comply with the requirements stated in the CubeSat Design Specification, Rev 13 [6].
- 1U CubeSats shall not exceed a mass of 1.33 kg.
- 3U CubeSats shall not exceed a mass of 4.0 kg. (TBR)
- 6U CubeSats shall not exceed a mass of 10.0 kg. (TBR)
- Actuation of all deployment mechanisms such as booms, antennas, and solar panels shall wait a minimum of 30 minutes after the CubeSat is deployed from the vehicle.

For individual CubeSats, Firefly will provide the dispenser. Larger CubeSat masses may be evaluated on a mission by mission basis. Customers planning to supply their own deployment canisters should contact Firefly as early as possible in the mission planning process.

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 in accordance with the mission timelines identified in Section 9.

### 6.2.6 Grounding, EMC & 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. **Auxiliary and Secondary Payloads cannot be powered on during launch.**

Secondary payloads are required to follow the same grounding and EMC compliance as primary payloads, as detailed in Section 6.1.7.

### 6.2.7 Numerical & Computer Models

In order for Firefly to carry out its mission analysis and design for the primary passenger, the following numerical and/or computer models of the auxiliary and secondary passenger spacecraft will be required:

- A computer aided design (CAD) model, in STEP (*.stp or *.step) or Parasolid (*.x_t) format. The CAD model supplied should include accurate representations of the external characteristics and features of the spacecraft, including all appendages, and the separation system.

For the timing of model delivery requirements within the mission schedule, please refer to Section 9 of this user guide.

### 6.2.8 Mass Dummies

A mass representative dummy of each payload shall be provided by each customer. For secondary payload providers, this model will be retained until after launch, and will be returned by Firefly within 3 months of launch. Firefly reserve the right to launch mass dummies of secondary payloads if delivery of Flight Model Payloads is delayed for periods in excess of those comparable with primary payload requirements.

## 6.3 Documentation Requirements

Firefly's philosophy is to keep documentation to a minimum and limited to that which is absolutely required in order to execute a mission successfully and safely.

It is expected that most information will be captured in a single document, the master Launch Vehicle to Spacecraft Interface Control Document (ICD). This should include details of all interfaces (mechanical, electrical and other) and capture all information needed to describe the mission, interfaces and interactions between launch vehicle and satellite.

Additional documentation may be required within the Safety Package and Qualification/Acceptance evidence packages. These are described in Appendix 2.

## 6.4 Evidence of Qualification & Acceptance

Prior to the acceptance of all passengers, evidence must be provided to show that the requirements identified in Sections 6.1 and 6.2. Data to be provided is expected to include:

- Plots & Data from Spacecraft Flight Model or Qualification Model Mechanical Tests
- RF/ EMC Tests Results

Configuration/version controlled source files for test results, etc., are preferred as evidence for the above. In some cases, Firefly personnel may ask to be present for certain spacecraft qualification or acceptance tests.

## 6.5 Safety Requirements

At this time, prior to a final decision on a launch site location, Firefly suggests that customers meet the requirements in AFSPCMAN 91-710, Range Safety User Requirements (see Reference 7) when designing flight and ground systems. 91-710 contains requirements for mechanical, electrical, fluid system, ordnance and RF design. It also contains requirements for ground handling and lifting hardware. Firefly can assist customers in determining if their current designs meet the requirements in 91-710.

### 6.5.1 Spacecraft Batteries

Spacecraft batteries must not be allowed to overcharge excessively to the point where an explosion risk arises.

### 6.5.2 Pressure Vessels

Spacecraft containing pressure vessels shall comply with the safety standards specified in ATR-2005(5128)-1, Operational Guidelines for Spaceflight Pressure Vessels (see Reference 8).

### 6.5.3 Pyrotechnic and Explosive Devices

The standard baseline launch and launch services offering assumes 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.

### 6.5.4 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 spacecraft power to be cut in case of emergency, and to prevent overcharging of spacecraft 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.

# 7 Launch Operations

## 7.1 Launch Control Organization

Figure 11 shows the expected launch control organization and associated roles. The primary interface for the customer remains a dedicated mission/project manager who will interface directly to the customer's project manager and the Firefly Mission Director.

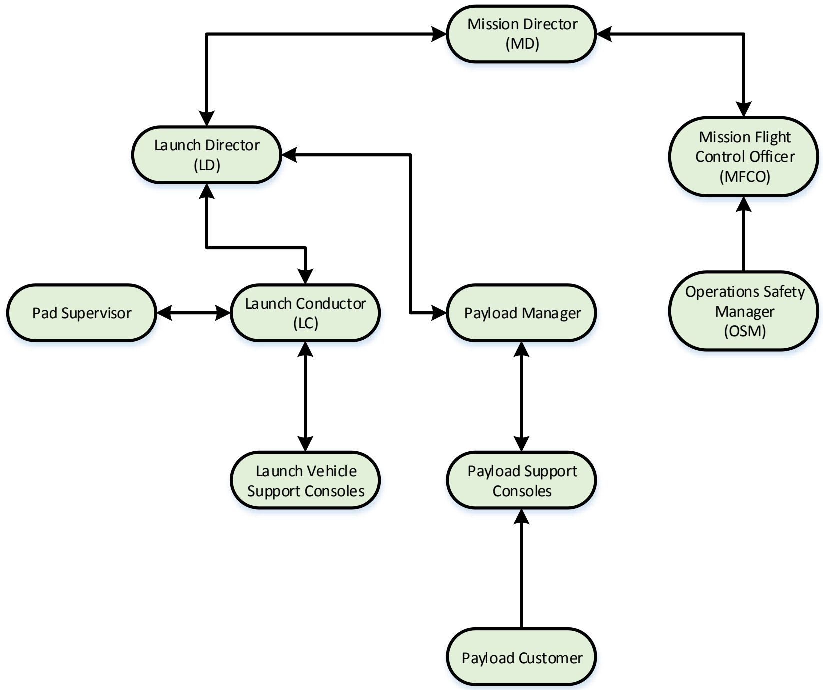



FIGURE 11: LAUNCH CONTROL ORGANIZATION

## 7.2 PAYLOAD TRANSPORT TO LAUNCH SITE

Firefly Mission Managers will work with customers to coordinate transportation of payloads from the pickup location (customer facility, airport, railway station, etc.) to the Firefly integration facility.

## 7.3 LAUNCH SITE FACILITIES, SERVICES AND PROVISIONS

### 7.3.1 Payload Processing & Checkout

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 will provide a minimum processing area of $324 ft^2$. The satellite will be removed from the shipping container with an overhead crane and mated to the PAF/separation device. Once the payload is fully assembled, checked out, and (if required) fueled, it will be encapsulated by the fairing.

### 7.3.2 Encapsulation

After the payload/s are mated to the PAF and checkouts are complete, all contamination critical hardware will be inspected and if necessary cleaned prior to encapsulation. The payload will be encapsulated by the payload fairing in the vertical position. Upon payload encapsulation, a continuous supply of clean air is provided at a typical environment range as stated in Table 8. 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 encapsulated payload will be rotated to a horizontal orientation by means of a break-over fixture. The payload fairing 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.

### 7.3.3 Fuelling

Hypergolic fueling of satellites is not a standard option. Fueling can be completed as a non-standard option and should be discussed at initial mission planning meetings.

Other types of fueling (e.g. cold gas) is considered a standard service.

Gaseous helium and nitrogen fluid panels will be 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.

### 7.3.4 Cleanliness of Facilities

The Horizontal Integration Facility is a 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 an additional charge the clean room area can be certified and operated at ISO 7 (Class 10K FED-STD-209E.)

### 7.3.5 Customer Team Accommodation & Offices

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

- Office Desks and chairs (4 desks for primary payload team, 1 each for secondary/auxiliary passengers)
- A meeting area with a small meeting table and 4 chairs

IT equipment is not provided although adequate power and network/internet connections will be provided.

Additional customer office accommodation can be provided as an extra to the standard baseline offering.

### 7.3.6 Infrastructure

#### 7.3.6.1 Power

Firefly accommodations for payload EGSE at the PPF and launch pad information bay (I-bay) provide the following power sources: 120V/240V single phase, and 208V three phase, 60 Hz. 50Hz accommodations could be made via frequency converters and should be included within the ICD requirements and discussed during initial meetings.

#### 7.3.6.2 Internet

High Speed, Broadband internet access (both Ethernet and WiFi) will be 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 as general use – if local networks are required it is expected that the customers bring their own equipment to set up local networks.

### 7.3.7 Launch Vehicle Customer Access

Access to the Firefly Launch Vehicle for customers will be restricted to the combined payload/launch vehicle processing operations and activities. Customers will be allowed to view the launch vehicle when convenient, subject to advance arrangement. Non-US customers or personnel may not be able to view the launcher whilst in its processing and assembly facility due to ITAR restrictions.

### 7.3.8 Launch Pad Access

Customers may be granted escorted access to the launch pad, subject to advance arrangement with Firefly representatives. Access to the pad when the vehicle is present is not possible.

### 7.3.9 Launch Viewing

Customers will be invited to view the launch from an official viewing point which will be a safe distance from the launch pad. A limited number of customer representatives may be allowed to be present in the launch control room, TBC.

### 7.3.10 Visitors & VIPs

It is understood and expected the customer may want to invite VIPs and other visitors to view the launch. Firefly will endeavor to accommodate these individuals at the launch viewing sites. Hospitality services can, of course, be arranged but these are not included in the baseline launch services offering.

### 7.3.11 Fluid Checkout Panels

Gaseous helium and nitrogen fluid panels will be 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.

### 7.3.12 Payload Monitoring

Payloads will be monitored for particles, relative humidity and temperature within the processing facility by means of instrumentation linked to a user interface.

### 7.3.13 Post Launch

Firefly will provide all customers with the final orbit details in the form of Two Line Elements (TLEs) for each payload. 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, will also be provided as soon as available. During launch, a live video stream from the vehicle will be provided at 620x480 resolution at 24 frames per second (FPS), TBC. High Definition (HD) video (resolution TBD) of the payload deployment process will be captured and made available to the customer post-deployment for analysis and marketing purposes.

# 8 Baseline Launch Offering

Firefly aims to offer the lowest price, best value launch service to its customers. A list of standard services and provisions are included in the basic Firefly offering and price. Additional services and provisions can be provided subject to discussion and negotiation.

The following list outlines non-standard launch services available to customers. Please advise Firefly early in mission planning meetings should any of these services be desired for mission.

- Payload access after fairing closure
- Payload power during launch

- 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 (local)
- Additional fuelling services and provisions
- Additional launch documentation
- Additional customer representatives, VIPs etc.

# 9 Mission Programmatics & Timelines

Each Firefly Mission will follow a typical timeline, starting with the initial customer contact and finishing with the successful completion of the mission.

A typical timeline with key milestones is included in Table 9. All timings and milestones are counted before, (-), or after, (+), the Launch Date. Please note that all dates in the table should be seen as guidelines, and not as firm constraints; faster timelines may be possible depending on individual circumstances.

| Firefly Alpha Mission Program Timeline | | |
|---|---|---|
| **Event** | **Typical Timing** | **Comments** |
| Initial Customer Contact | L-18 months* | TBC |
| Signing of Launch Agreement | L-12 months | TBC |
| Delivery of Initial CAD model(s) & satellite information | L-9 months | TBC |
| Planning Meeting 1 | L-8 months | TBC |
| Fit Check (with mass simulator) | L-6 months | TBC |
| Planning Meeting 2 | L- 3 months | TBC |
| Delivery of final/confirmed passenger numerical models | L-3 months | TBC |
| Commencement of Launch Campaign | L- 6 weeks | TBC |
| Delivery of all Payloads to Launch Site | < L-4 weeks | TBC |
| Launch Readiness Review | L- 3 Days | TBC |
| Launch | L0 | TBC |
| Confirmation of Launch Performance & Parameters | L +3 hours | TBC |

| | | |
|---|---|---|
| Completion of Mission & Delivery of All Data | L + 1 week | TBC |
| Return of all Customer Launch Site Equipment | L + 2 months | TBC |

**TABLE 9: TYPICAL FIREFLY ALPHA MISSION TIMELINE**

** Auxiliary passengers may be able to be accommodated at later notice than outlined, depending on the spare capacity available on any particular launch.*

# 10 REFERENCE DOCUMENTS

[1] Dassault Aviation. *Micro-satellite Support.* http://www.dassault-aviation.com/en/space/pyrotechnics-catalogue/micro-satellite-support/

[2] Planetary Systems Corporation. *MkII Motorized Lightband.* http://www.planetarysystemscorp.com/?post_type=product&p=449

[3] RUAG Space. *Payload Adapters and Separation Systems.* http://www.ruag.com/fileadmin/ruag/Divisions/Space/Products/Launcher_Structures___Separation_Systems/Adapters___Separation_Systems/PDF/PLE-Brochure-Payload-Adapter-and-Separation-Systems.pdf

[4] Innovative Solutions in Space. *ISIPOD CubeSat Deployer Brochure*. http://www.isispace.nl/brochures/ISIS_ISIPOD_Brochure_v.7.11.pdf

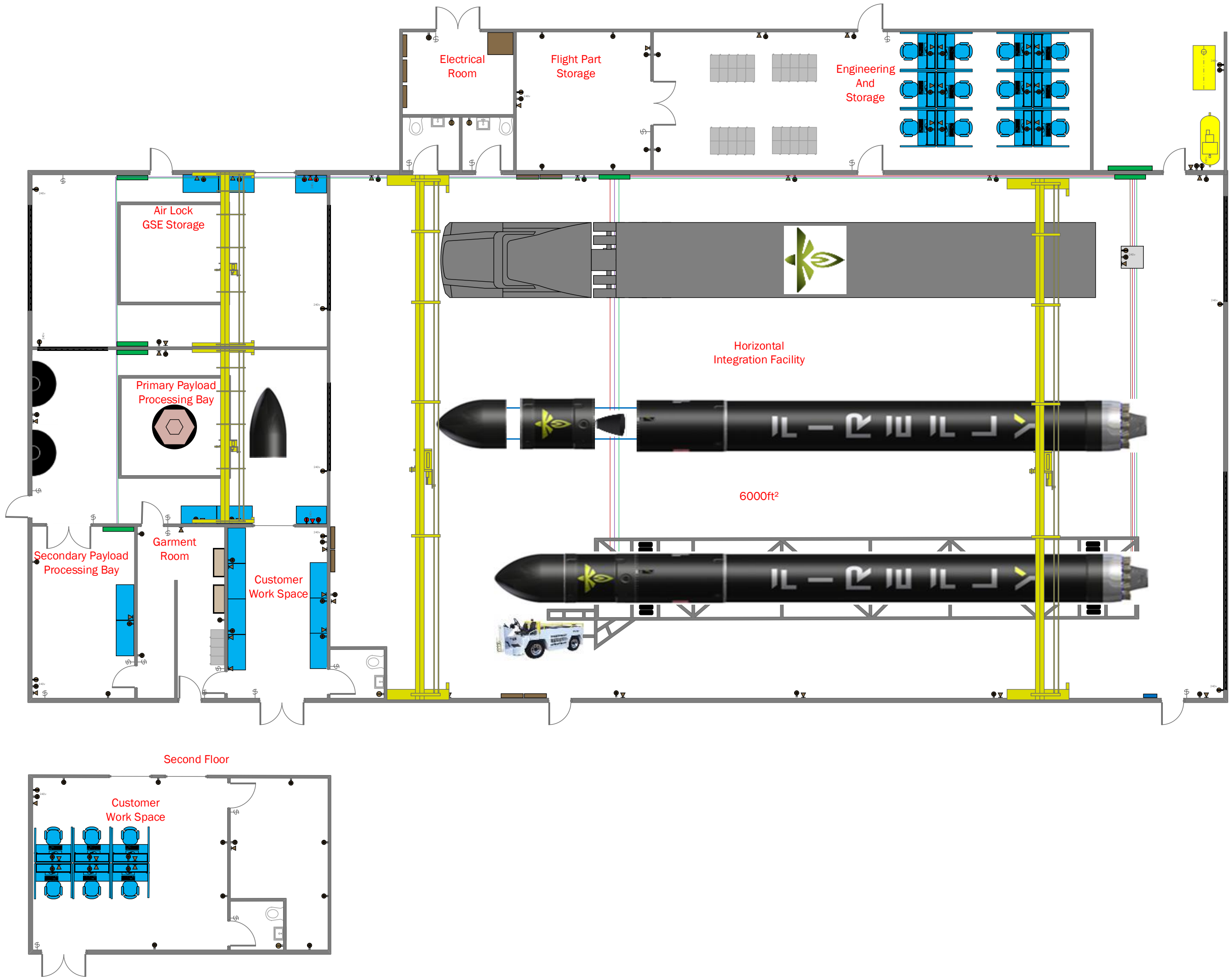
[5] NASA Langley Research Center. *NASA-SP-8077, Transportation and Handling Loads.* http://ntrs.nasa.gov/search.jsp?R=19720005242

[6] NASA Goddard Space Flight Center. *GSFC-STD-7000A, General Environmental Verification Standard (GEVS).* https://standards.nasa.gov/documents/detail/3315858

[7] 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/afspcman91-710v3.pdf

[8] The Aerospace Corporation. *ATR-2005(5128)-1, Operation Guidelines for Spaceflight Pressure Vessels*. https://www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/library/media/Operational_Guidelines_for_Spaceflight_Pressure_Vessels.pdf

# Appendix 1. Launch Site Facility Layout (Notional)



# Appendix 2. Document Content Guidelines

This appendix provides top-level guidance on documentary evidence Firefly will require customers to submit in order for payload to be accepted for flight on a Firefly launch. In line with overall Firefly values of lowest cost and best value, only required documentation is requested; superfluous information will not be requested.

**Evidence of Mechanical Robustness/Suitability**

***Vibration Testing***

The following must be provided (either as part of a report or as standalone/raw data):

- Instrumentation traces from Vibration Tests or Sine Survey (tap) tests showing that the first natural frequencies of the payload(s) are above the required values as described in section 6.1.1 (for primary payloads) and/or in section 6.2.1 (for secondary payloads).
- Instrumentation traces from Vibration Tests showing that the payload has been exposed to a random vibration spectrum specified in section 6.2.3 with margins applied for primary and secondary payloads, as defined in 6.1.3 and 6.2.3 respectively.
- Equivalent traces should an acoustic vibration test have been performed in place of a random conducted vibration test.

***Mass Properties***

The following must be provided (either as part of a report or as standalone/raw data):

- Measurement/test data from Mass Properties Measurements of the Flight Model Spacecraft/Payload, **or**
- Output data from a sufficiently representative simulation or CAD/FE model of the payload.

**Evidence of EMC Qualification/Suitability**

The following must be provided (either as part of a report or as standalone/raw data):

- Measure response traces and results from an EMC test, showing that spacecraft/payload emissions are within (less than) those specified in Table 7.

**Safety Package**

The following must be provided (either as part of a report or as standalone/raw data):

- Relevant certificates and certifications relating to the safety requirements identified in Section 6.5.
- Any exemptions or associated justifications.