DECEMBER 2016 | VERSION 4.0

PAYLOAD USER'S GUIDE

ROCKET LAB

ROCKET LAB 2016 | PAYLOAD USER'S GUIDE

PAYLOAD USER'S GUIDE OVERVIEW

This document is presented as an Introductory Payload Planners Guide and provides an initial overview of the system design of Rocket Lab's new launch vehicle – Electron. It is made available for existing and future Rocket Lab customers.

All information contained in this guide is for initial planning purposes only. It is not mission specific and is subject to change. All mission specific data will be captured in mission specific documentation (i.e. a payload ICD) after a Launch Service Agreement is signed by all parties.

REVISION HISTORY

DATE	VERSION	HISTORY
June, 2015	1.0	First Release
May, 2016	2.0	Updated Release
September, 2016	3.0	Updated Release
December, 2016	4.0	Updated Release

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TABLE OF CONTENTS


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1. INTRODUCTION

Rocket Lab's mission is to make space accessible by offering small satellite customers a rapid-response orbital service that is frequent, reliable and affordable. To enable this, Rocket Lab has entered the launch market with Electron - a launch vehicle featuring revolutionary advancements in turbo - pump technologies, additive manufacturing and carbon fiber composite construction - resulting in true reductions in cost and a high launch frequency.

1. INTRODUCTION CONTINUED

1.1 Rocket Lab History

Founded in 2006 by CEO and Technical Director, Peter Beck, Rocket Lab is a privately-owned global aerospace company headquartered in Los Angeles. In the course of its ten-year history, Rocket Lab has delivered complex systems and launch vehicles for commercial and government customers. In 2009, Rocket Lab became the first private company in the Southern Hemisphere to reach space.

KEY FEATURES OF ROCKET LAB AND ELECTRON

Rocket Lab is leading the way in delivering a one-of-a-kind service to small payload customers. Rocket Lab has sourced an extensive design and production team including Launch Vehicle, Propulsion and GNC Engineers who are leaders in their respective fields across all disciplines of aerospace manufacture. The key to liberating the emerging small satellite industry lies in the pricing, availability, innovation and reliability of Rocket Lab's Electron launch vehicle.

PRICING AND AVAILABILITY

The standard launch price of Electron starts at **US $4.9 M** (2016 price), and the vehicle is projected to provide at least **100 launches per year**. The high-frequency launch capability also provides unparalleled launch opportunities and flexibility to the payload customer. Flight system and launch vehicle components are designed and manufactured in-house at Rocket Lab's facilities. In addition, several synergies in the structural and propulsion elements within the Electron launch vehicle simplify and streamline the production processes as well as reduce cost significantly. The Electron launch vehicle employs essentially the same engine for the Stage 1 and Stage 2 propulsion totalling ten Rutherford liquid rocket engines per Electron launch vehicle. Similarly, Stage 1 and Stage 2 carbon composite construction is identical bar its dimensional differences. Rocket Lab's flat organization coupled with a talented team and significant in-house development allows for quick turnaround times, increased efficiencies and significant cost reductions thereby enabling the significant pricing and availability advantage of the Electron launch vehicle.

INNOVATION

Rocket Lab is unrestrained by traditional space hardware or software and this promotes a renewed, simple, innovative and cost-effective approach to accessing space. This has also resulted in several technological breakthroughs through rapid development cycles and rigorous design, build and test schemes, particularly with the development of the Rutherford liquid rocket engine that powers Electron, the all-carbon-composite construction and the use of pyrotechnic-free separation systems.

RELIABILITY

Rocket Lab has built its heritage through numerous previous launches including 80 successful launches of sounding rockets. This launch history has led to the successful development of all-carbon-composite launch vehicle structures as well as rocket engine technologies with proven reliability.

The high-volume production capability of Electron's structural and propulsion elements not only cuts costs but also ensures Electron's high reliability through extensive qualification testing and tight quality measures.

1.2 Payload Mission Manager

To manage communications, each customer will be assigned a Payload Mission Manager at Rocket Lab. The Payload Mission Manager will serve as the primary medium of communication between the customer and the Rocket Lab team covering all aspects of the mission from contract agreement through to launch and post-launch activities. A request to establish a Payload Mission Manager at Rocket Lab may be sent to enquiries@rocketlabusa.com.

2. LAUNCH VEHICLE OVERVIEW

The Electron launch vehicle is the first orbital launch vehicle designed and manufactured by Rocket Lab. It is a two-stage vehicle servicing the emerging small satellite market and has been designed with a high flight rate in mind. Combining the latest manufacturing technologies with standardized analysis packages and multiple domestic launch ranges, Electron is optimized for quickly launching constellations of small satellites. Capable of launching 150 kg (330lbs) to a nominal 500 km sun-synchronous orbit from our Rocket Lab Launch Complex in New Zealand as well as from U.S. domestic ranges, Electron provides a primary payload quality launch service at a secondary payload price.

2. LAUNCH VEHICLE OVERVIEW CONTINUED

2.1 Electron Launch Vehicle Description

Electron is a two-stage vertically launched vehicle. Electron's design incorporates a fusion of both conventional and advanced liquid rocket engine technology coupled with innovative use of electrical systems and carbon fiber composites. The launch vehicle (as shown in Figure 1) stands 17 meters (55 feet and 9.3 inches) tall, with a diameter of 1.2 meters (3 feet 11.2 inches) and a lift off mass of 13,000 kg (28,600 lbs). Electron is designed to launch a 150 kg (330 lbs) payload to circular sun-synchronous orbit. Overall dimensions of Electron are summarised in Table 1.

The first two stages use liquid propellants that are powered by Rocket Lab's advanced turbo-pumping techniques. Electron is powered by ten liquid oxygen (LOx) and rocket grade kerosene engines which are re-generatively cooled and turbo pump fed. Nine Rutherford engines power Electron's Stage 1 and one Rutherford engine (which is modified for vacuum), powers Electron's Stage 2. The Rutherford engine is gimballed for attitude control of the rocket on both the 1st and 2nd liquid stages. The propellant tanks are constructed from a carbon fiber composite designed and manufactured in-house by Rocket Lab.

Figure 1 Electron Launch Vehicle Configuration

SPECIFICATION	VALUE
Length	17 m
Diameter	1.2 m
Stages	2
Vehicle Mass (Lift-off)	13,000 kg
Payload Mass	150 kg (Sun-Synchronous Orbit)
Payload Diameter	1.08 m
Standard Orbit	500 km (Sun-Synchronous Orbit)
Propulsion – Stage 1	9 x Rutherford Engines (LOx/Kerosene)
Propulsion – Stage 2	1 x Rutherford Engine (LOx/Kerosene)
Material/Structure	Carbon Fiber Composite
Standard Launch Site	Mahia, New Zealand

Table 1 Electron Launch Vehicle Overall Dimensions and Specifications

2.2 Stage 1

Stage 1 contains liquid oxygen (LOx) and rocket grade kerosene and uses advanced turbo pumping technologies. Stage 1 is powered by nine Rutherford engines and is electromechanically thrust vector controlled. Propellant tanks are constructed entirely from carbon fiber composite.

2.3 Stage 2

Stage 2 contains LOx and rocket grade kerosene and uses advanced turbo-pumping technologies. Stage 2 is powered by one Rutherford engine and is electromechanically thrust vector controlled. A cold gas thruster (CGT) attitude control system is used for roll attitude and rate control. Propellant tanks are constructed entirely from carbon fiber composite.

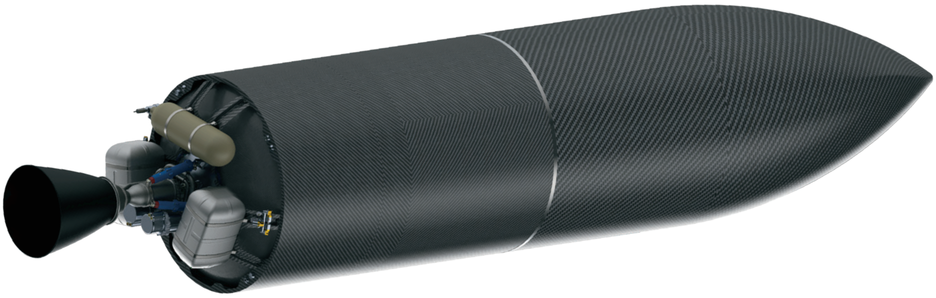

Figure 2 Electron Stage 2

2.4 Standard or Optional "Plug-In" Payload Integration

Electron's payload fairing is designed to decouple payload integration from the main assembly. Rocket Lab's standard process is to integrate payloads at the launch site in a traditional manner. However, with the Rocket Lab Plug-In Payload module, the customer can choose to manage this process using their own preferred facilities and personnel. Rocket Lab will assist on location as required with all payload and fairing separation device final closeout. Environmentally controlled or sealed payload modules will then be transported back to Rocket Lab where integration with Electron can occur in a matter of hours. Rocket Lab's novel approach eliminates the risk of cascading delays, and enables customers to have standby payloads ready to go.

Figure 3 Electron Fairing

2. LAUNCH VEHICLE OVERVIEW CONTINUED

2.5 Payload Fairing

The Payload Fairing is a split clam shell design and includes environmental control for the payload. Characteristics of the payload fairing are summarised in **Table 2**. For more specific interface volumetric data, please see section 4.

SPECIFICATION	VALUE
Length	2.5 m
Diameter (maximum)	1.2 m
Mass	44 kg
Acoustic Protection	Foam Sheets
Separation System	Pneumatic Unlocking, Springs

Table 2 Payload Fairing Characteristics

2.6 Rutherford Engine Description

Electron's Rutherford engines are named after notable New Zealand-born Physicist Ernest Rutherford (1871 – 1937), who split the atom in 1917 and challenged scientific thinking of the day. Rocket Lab's flagship engine, the 4,600 lbf (21 kN) Rutherford, is an electric turbo-pumped LOx/RP-1 engine specifically designed for the Electron launch vehicle.

Rutherford adopts an entirely new electric propulsion cycle, making use of brushless DC electric motors and high-performance lithium polymer batteries to drive its turbo-pumps.

Rutherford is also the first oxygen/hydrocarbon engine to use additive manufacturing for all primary components, including the regeneratively cooled thrust chamber, injector pumps, and main propellant valves. Stage 2 features a larger expansion ratio for improved performance in near-vacuum-conditions. All aspects of the engine are designed, developed and manufactured at Rocket Lab.

Figure 4 Rutherford Electro Turbo-Pumped Engine

Figure 5 Rutherford Stage 1 Configuration

Figure 4 shows the Rutherford electro turbo-pumped engine and **Figure 5** shows nine Rutherford engines placed in web configuration on Stage 1 of the Electron launch vehicle.

SPECIFICATION	RUTHERFOD (STAGE 1)	RUTHERFORD (VACUUM)
Lift Off Thrust	16.8 kN	n/a
Vacuum Thrust	n/a	22.2 kN

Table 3 Rutherford Engine Specifications

2.7 Carbon Composite Structures

Electron utilizes advanced carbon composite technologies in the structural elements of the vehicle including propellant tanks. Rocket Lab has heritage in the use of carbon composite structures from many in-house designed and built sounding rockets that have successfully incorporated the technology to date. The all-carbon-composite construction of Electron decreases mass by 40 percent resulting in enhanced vehicle performance. Rocket Lab fabricates tanks and other carbon composite structures at the Auckland production facility to provide a more affordable and time-efficient customer solution.

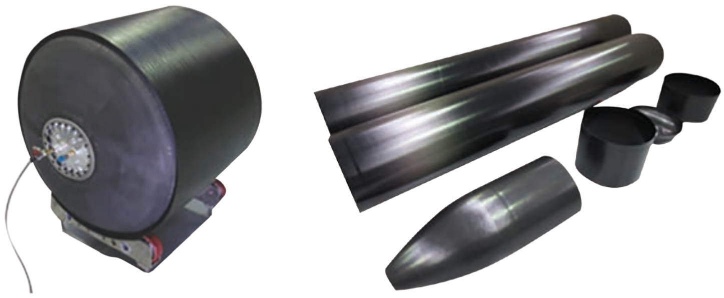

Figure 6 Carbon Composite Structures on the Electron - Propellant Tank, LV Structures.

2. LAUNCH VEHICLE OVERVIEW CONTINUED

2.8 GNC and Electronic Systems Overview

Guidance, Navigation and Control (GNC) systems are designed with emphasis on rapid configurability resulting in faster customer turnaround times. This enables Rocket Lab to achieve its goal of providing rapid and cost-effective launch capabilities of multi-satellite constellations. Avionics flight hardware is custom designed by Rocket Lab and includes flight computers and a navigation suite incorporating an initial measurement unit (IMU), GPS receiver and S band transmitter which transmits telemetry and video to ground operations. Guidance and control algorithms are developed with flexibility of customer payload and orbit in mind and the combination of flight hardware, software and guidance and control algorithms is fully tested and validated using hardware-in-the-loop testing frameworks.

Figure 7 GNC System

2.9 Stage Separation System

Rocket Lab has developed a separation system consisting of pneumatically controlled mechanisms and guided springs to separate each stage on Electron. This allows for a low-shock environment with a relatively low nominal acceleration (≈1g) during stage separation. Additionally, the performance of the separation system has been fully characterised through rigorous in-house testing, ensuring high reliability. A similar separation system with pneumatic locks and guided springs is used to separate the Payload Fairing.

2.10 Electron Coordinate System

ELECTRON BODY AXIS

- +X : Pitch Axis, fairing split line
- +Y : Roll Axis, through nose
- +Z : Yaw Axis
- Origin at nose, right handed

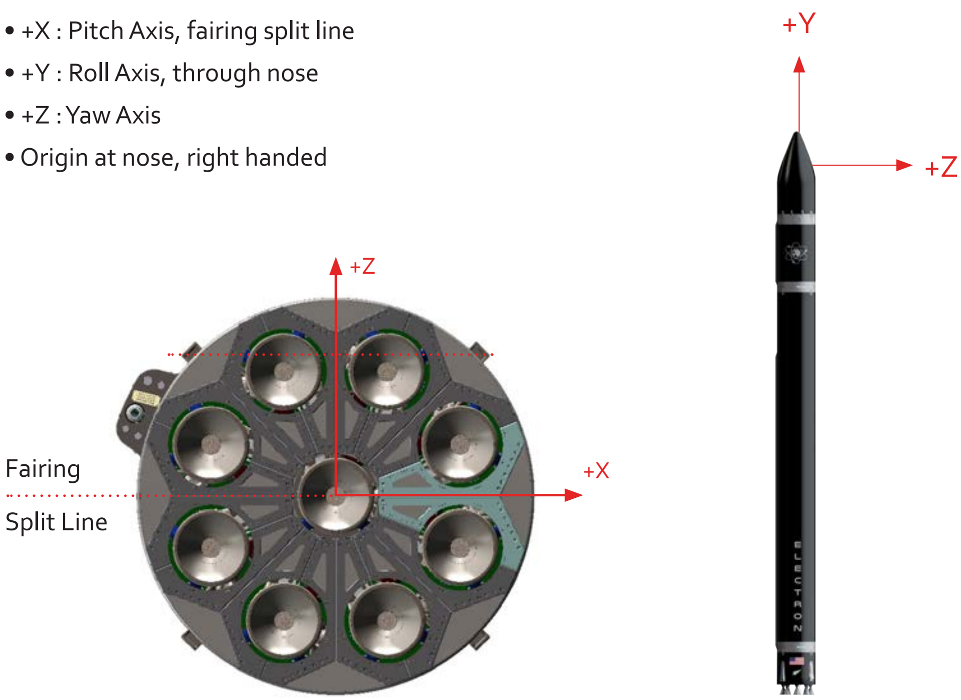

Figure 8 Electron Coordinate System (XZ and YZ Plane)

3. GENERAL PERFORMANCE CAPABILITY

3.1 Performance

Please contact Rocket Lab directly with your specific performance requests. Some general bounding performance examples are given below. However, Rocket Lab has the ability to service most orbital requirements.

3.1.1 Performance to a Sun-Synchronous Orbit

Electron's performance to a sun-synchronous orbit is shown in **Figure 9** and **Table 4**. The launch vehicle performance capability shown is the maximum capability of a typical mission profile to a sun-synchronous orbit. Please contact Rocket Lab directly with your specific performance requests.

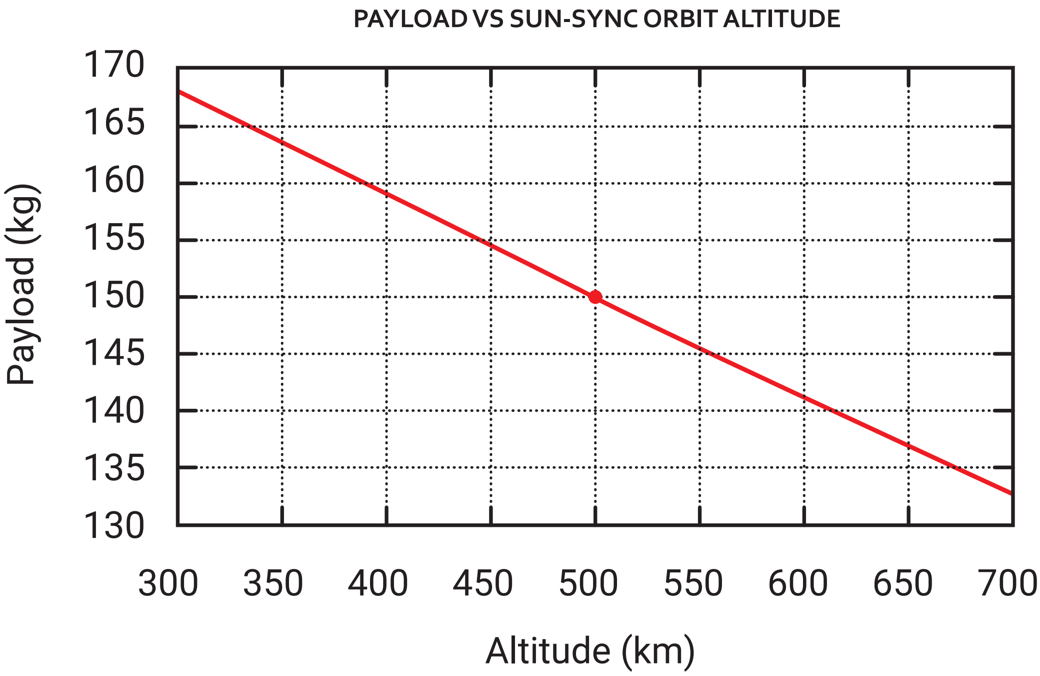

Figure 9 Performance to Circular Sun-Synchronous Orbit

ORBIT ALTITUDE (KM)	PAYLOAD MASS (KG)
300	168
400	159
500	150
600	142
700	133

Table 4 Performance to Circular Sun-Synchronous Orbit

3. GENERAL PERFORMANCE CAPABILITY CONTINUED

3.1.2 Performance to Elliptical Orbit at 45° Inclination

Electron's maximum performance to a 180 km (111 mile) Perigee at 45° inclination elliptical orbit is shown in **Figure 10** and **Table 5**.

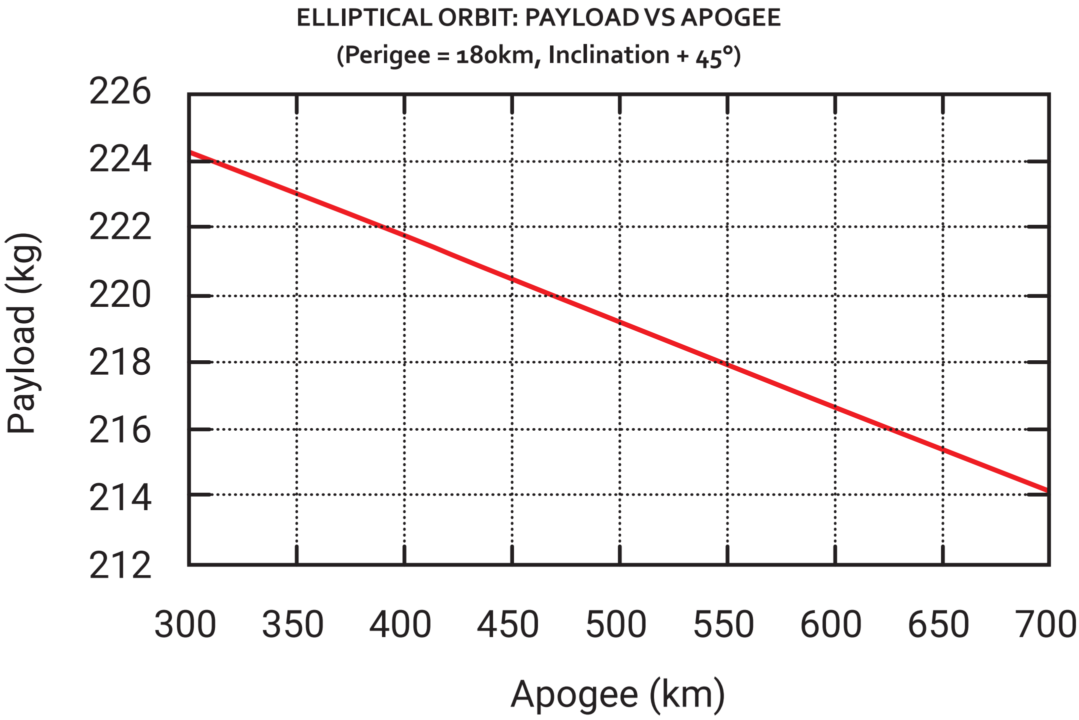

Figure 10 Performance to a 180 km Perigee at 45° Inclination Elliptical Orbit

APOGEE (KM)	PAYLOAD MASS (KG)
300	224
400	222
500	219
600	217
700	214

Table 5 Performance to a 180 km Perigee at 45° Inclination Elliptical Orbit

3.2 Sample Flight Profile – Circular Sun Synchronous Orbit

Although the exact flight profile is dependent on customer requirements, the main events during a typical mission of 150 kg (330 lb) to a 500 km (310 mile) circular sun-synchronous orbit are shown in **Table 6**. These include stage burn times, stage separation events, fairing separation and payload separation. Payload fairing separation occurs when the free molecular heat flux is below 1135 W/m^2.

EVENT	TIME (S)	ALTITUDE (KM)
Lift-off	0	0
Max Q	79	11
MECO/S1 Separation	152	69
Stage 2 Ignition	159	69
Fairing Separation	183	110
SECO	457	284
Stage 2 Apogee Kick	3157	499
Payload Separation	3200	500

Table 6 Sample Flight Profile – Sun-Synchronous Orbit

3.3 Deployment Mechanism Mass Allocation

In general, the mass of the payload separation system is considered a portion of the "launch mass" as it is discussed in this document. Thus, any items placed on top of the "Payload Adaptor" count towards the total mission "launch mass." For example, a small satellite to be deployed that weighs 100 kg and requires a 3 kg Lightband has a total contractual launch mass of 103 kg.

There are a variety of payload CubeSat deployers that can be used; please contact your Rocket Lab Mission Manager to discuss your requirements.

3.4 Mission Injection Accuracy

Injection accuracy will be mission dependent and reliant on the payload. Typical altitude accuracy is ±15 km. Mission-specific payload injection accuracies will be calculated as part of mission analysis at Rocket Lab. As a liquid propellant vehicle, the Electron launch vehicle provides flexibility required for payload insertion into orbit with higher eccentricity and for deploying multiple payloads into slightly different orbits. For example, Rocket Lab expects to achieve the following minimum target orbital insertion accuracy[1] for a typical sun-synchronous mission to 500 km:

Inclinations:	±0.1°
Perigee:	±5 km
Apogee:	±15 km

The current margins for the deployment attitudes are ±0.75° for roll accuracy, ±0.5° for yaw accuracy and ±0.5° for pitch accuracy. The current margins for deployment rates are ±0.8°/s for roll rate accuracy, ±0.3°/s for yaw rate accuracy and ±0.3°/s for pitch rate accuracy[2].

3.5 Payload/Launch Vehicle Separation

The on-board CGT (cold gas thruster) attitude control system will provide the capability to hold a nominal attitude prior to separation of the payload. The on-board CGT controller is disabled prior to each deployment and re-enabled after each deployment through integration with mission data per customer requirements. Payload deployment will be controlled by the Electron Stage 2 Avionics. The electrical connection to the payload separation system consists of:

- Up to 20 programmable General Purpose Outputs (28V, 5A) that can be modified to accommodate a variety of payload separation systems.
- Two or more programmable General Purpose Digital Inputs per payload for connecting to payload separation sensors.

[1] Mission dependent
[2] Mission dependent

4. GENERAL PAYLOAD INFORMATION

4.1 Payload Fairing Description

The Electron launch vehicle Payload Fairing is 2.5 m (8 feet and 2.4 inches) in length with a 1.2 m (3 feet and 11.2 inches) diameter and a total mass of 44 kg (97 lbm). The internal dimensions of the payload fairing are shown in **Figure 11**. The fairing consists of two composite shell halves and associated separation systems. It is constructed out of thin carbon composite sandwich panels on either side. Each half of the fairing is designed to rotate on hinges mounted on Stage 2. All fairing deployment systems are environmentally controlled or sealed payload modules.

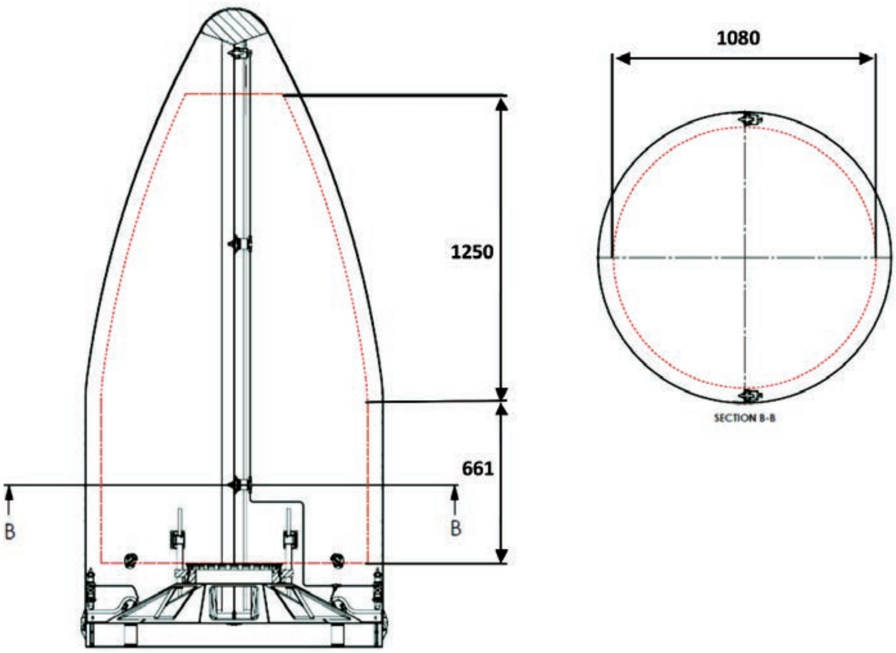

Figure 11 Electron Payload Fairing Internal Dimensions

4.2 Payload Interfaces

Payload launch-vehicle interfaces are heavily dependent on the characteristics of the payload. Both mechanical and electrical interfaces on Electron are modifiable to accommodate a variety of payloads. Please contact your Rocket Lab Mission Manager for additional information.

4.2.1 Mechanical Interface, Example for Satellites

A standard satellite payload will mechanically interface with Electron's payload adapter via a 15 inch class "Clampband" based Launch Vehicle Adapter (LVA). Typically, the customer is responsible for procurement of an appropriate LVA with assistance from Rocket Lab. Electron is compatible with various adapters available from the following companies:

- The Mark II Lightband separation system – Payload customers are advised to review the Mark II Lightband User's Manual to obtain more information - http://www.planetarysystemscorp.com/
- The 15" class RUAG Launch Vehicle Adapter - https://www.ruag.com/space/products/launcher-structures-separation-systems/adapters-separation-systems/
- The 15" class CASA Launch Vehcile Adapter - http://www.casaespacio.com/products/payload-adapter

4.2.1.1 CubeSat Deployer

Customers are responsible for procurement of their CubeSat Deployer(s) (box) as required. Electron is compatible with deployers from Tyvak, ISIS, Planetary Systems Corp. (PSC) and others. Rocket Lab will produce an in-house CubeSat deployer specifically for its CubeSat customers to ensure controlled deployment and make it available for purchase in mid 2017. The basic configuration of the deployer will follow that of the Poly-Picosatellite Orbital Deployer (P-POD) from the Cal-Poly CubeSat standard - http://www.cubesat.org/

Please contact Rocket Lab Mission Management for additional information on Deployer options.

4.2.2 Electrical Interface (Small Sat Example)

The electrical interface to the payload and payload deployment system is illustrated in **Figure 12**. Electrical connection to the payload is through the payload separation system, typically the 15-pin Mark II Lightband connector for satellites.

A feedthrough connection is provided from the payload to the Ground Support Building for pre-flight checkout. Twelve pins on the Electron Stage 2 Umbilical Connection are reserved for customer use. The wiring between the GSE building and Electron's fairing interface consists of:

- Harness #6 – 6 shielded twisted pairs, 22 AWG
- Connection D.1/D.2 (Electron Second Stage Umbilical Connection)
- Harness #5 – 6 shielded twisted pairs, 22 AWG
- Connection C.1 –(Electron Fairing Connection – MIL-DTL-38999)

The harnesses and connections inside the fairing are typically provided by the customer, or by Rocket Lab as a non-standard service.

Rocket Lab can also connect the payload to Electron's avionics system as a non-standard service for pre-flight and in-flight operations. This connection consists of:

- One General Purpose Output circuit (28V, 5A)
- One RS-422 circuit

Payload deployment is controlled by the Electron Stage 2 Avionics. The electrical connection to the payload separation system consists of:

- Twenty (one per payload with more on request) programmable General Purpose Outputs (28V, 5A) which are modifiable to accommodate a variety of payload separation systems.
- Forty (two per payload, more on request) programmable General Purpose or Analog Inputs for connecting to payload separation sensors.

Harness #5 is typically supplied by the customer according to the appropriate separation system, or supplied by Rocket Lab as a non-standard service. Harness #5 terminates in Connection B.1 (MIL-DTL-38999).

Further details of connector types and pin designation will be provided by Rocket Lab as part of the payload integration procedure.

4. GENERAL PAYLOAD INFORMATION CONTINUED

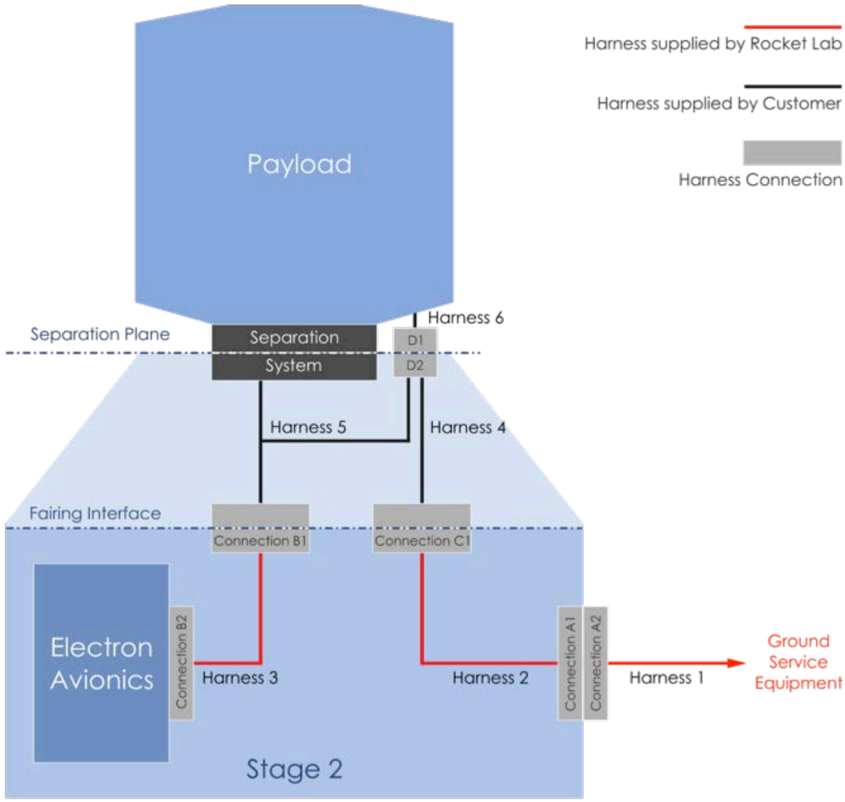

Figure 12 Payload Electrical Interfaces

4.2.3 Interface Check

An Interface Control Document describing the separation system and electrical connections can be provided to the payload customer to conduct interface checks. This will be done well before launch to ensure payload compatibility with the Electron launch vehicle. The interface check will be coordinated through the customer's Payload Mission Manager.

4.3 Payload Separation

Rocket Lab requires payloads to be a minimum of single fault tolerant to an inadvertent activation during launch. For example, a CubeSat would require two inhibits to inadvertent activation when loaded into a deployer.

The separation system is integrated into the payload adaptor between Stage 2 and the payload itself. The payload adaptor is mated to Stage 2 by pneumatic locking mechanisms. Rocket Lab can also accommodate other payload separation systems and enhancements upon request. Rocket Lab uses a payload separation system designed according to the P-POD CubeSat standard for any combination of U-Class satellites (i.e. 1U, 3U, 6U, 12U, 24U). For microsatellites, a Mark II Lightband or similar – a pyrotechnic-free separation system – is used.

4.4 Payload Environments

This section highlights the environmental conditions experienced by a typical payload through the various mission phases. Rocket Lab performs mission-specific analyses as part of a standard orbital launch service. **All data provided below in sections 4.4.1 – 4.4.5 is for reference only. All payloads shall be designed and tested to the NASA General Environmental Verification Standard (GEVS) document number GSFC-STD-7000 unless otherwise directed by your Rocket Lab Mission Manager.**

4.4.1 Contamination and Environmental Control

Rocket Lab will provide a customized mission-specific plan to maintain proper thermal and contamination control for customer payload requirements and is targeting the specifications described in **Table 7** during each phase. Please contact your Rocket Lab Mission Manager if you have non-standard or more stringent cleanliness needs.

PHASE	TEMPERATURE HEATING LEVEL	HUMIDITY LEVEL	CLEANLINESS LEVEL
Payload ops. facility and encapsulated	Conditioned Air Purge 25°C ± 3°C	50% ± 15%	Class 100,000 (ISO 8)
Transport from processing facility to launch site and launch pad[3]	Conditioned Air Purge 25°C ± 3°C	50% ± 15%	Class 100,000 (ISO 8)
Control System on Pad	Conditioned Air Purge 20°C to 25°C ± 3°C	20% to 50% ± 15%	Class 100,000 (ISO 8)

Table 7 Contamination and Environmental Control

4.4.1.1 Temperature exposure during flight

During flight, the environment within the fairing is kept clean through positive pressure. The fairing itself has an emissivity of approximately 0.2. Payload fairing jettison will also occur based on the customer's requirements and therefore, temperature exposure can vary based on these requirements. Please contact your Rocket Lab Mission Manager for additional information.

4.4.2 Free Molecular Heating

The payload fairing is nominally deployed when free molecular aero-thermal heating is less than 1,135 W/m².

4.4.3 Flight Acceleration Loads

The payload will be subjected to a range of axial and lateral accelerations during flight resulting from thrust, drag, thrust vectoring and wind gusts. Conservative flight acceleration axial load factors are summarised in **Table 8**.

EVENT	AXIAL (G)	LATERAL (G)
Lift-off	±0.2	±0.9
Max q	±2.0	±0.9
MECO/S1 Separation	±5.3	±0.7
Stage 2 Ignition	±1.0	±0.7
Fairing Separation	±1.2	±0.5
Stage 2 Burn Out	±6.6	±0.2
Stage 2 Apogee Kick	< 5	±0.2

Table 8 Electron Flight Acceleration Loads

3 Conditioned air will be disconnected briefly upon arrival at the erector as the fairing umbilical is changed over to the launch pad air conditioning supply.

4. GENERAL PAYLOAD INFORMATION CONTINUED

4.4.4 Shock Environment

The shock environment the payload is subjected to is highly dependent on the mission and the payload. Rocket Lab will characterise the payload shock environment once the characteristic mass properties of the payload are known. Typically, the payload's worst case shock environments are experienced in vehicle hold-down release at launch, Stage 2 separation, fairing separation and payload separation.

The pyrotechnic-free separation systems of each stage and the payload fairing result in minimal shock environments for the payload at each of these events. The shock environment at hold-down release during launch is also not expected to affect the payload as it is separated by a distance and several joints over which shocks and stress waves will dissipate. Therefore, the major shock environment to be considered is during payload separation.

The shock generated by the Lightband during separation on the upper ring and lower ring is depicted in **Figure 13**. Note that the shock response spectrum is dependent on the payload mass properties. The shock spectrum in **Figure 13** is only a sample shock spectrum.

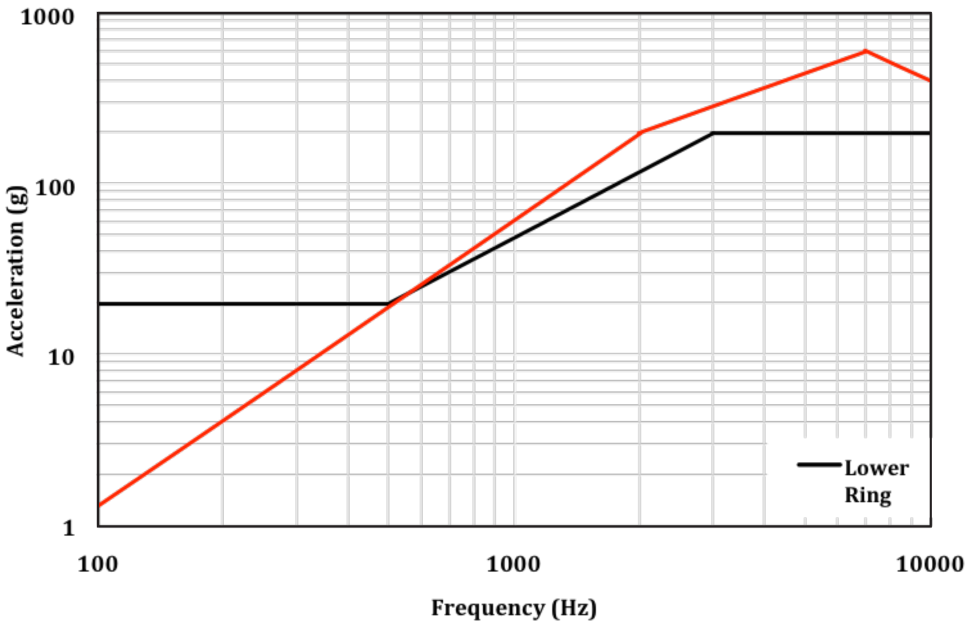

Figure 13 Nominal Shock Response Spectrum from Lightband Separation* Sample

*Adapted from shock test data in the Mark II Lightband User's Manual (Reference PSC Doc 2002076). The shock response spectrum corresponds to a Lightband with the following characteristics:

- *Diameter = 280 mm (11 in)*
- *Mass adjoining upper ring = 50.4 kg (111 lb)*
- *Mass adjoining lower ring = 5x 105 kg (1 x 106 lb)*

4.4.5 Acoustic Environment and Sine-Vibration

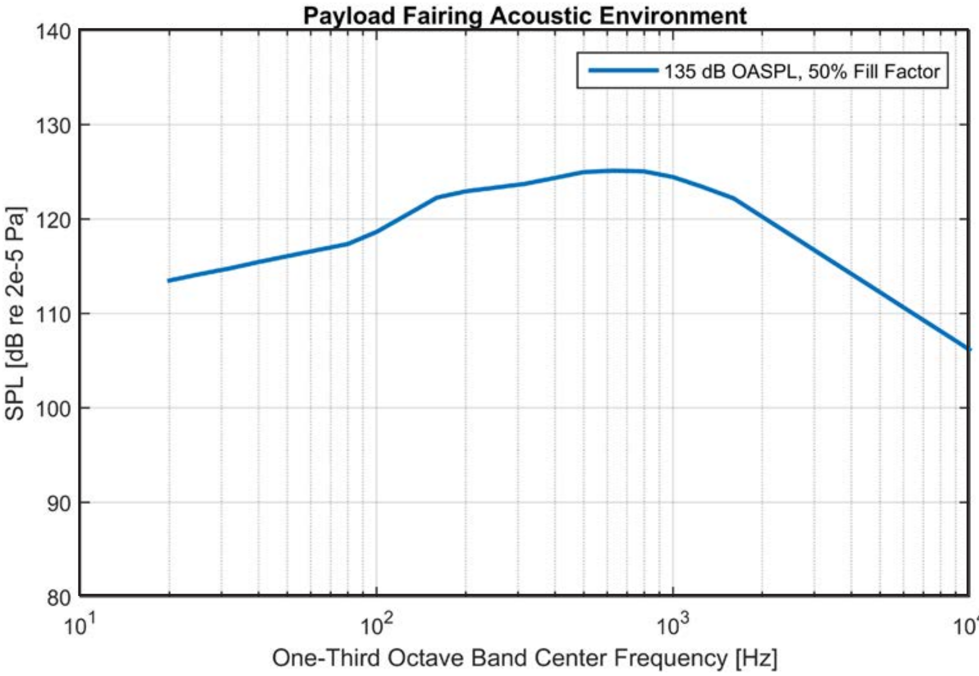

Figure 14 Payload Fairing Acoustic Environment

Acoustic levels in the payload fairing vary throughout the flight, with peak levels occurring during liftoff and transonic flight. The maximum predicted environment for a typical payload is presented in **Figure 14** in one-third octave bands.

The payload is subjected to a wide range of dynamic excitation during launch. For this reason, maximum expected flight dynamic environments are defined by the following categories: low-frequency, mid-frequency, and high-frequency. The low-frequency environment covers the 0-50 Hz range. The high-frequency range is characterized by two environments: acoustics and shock. The transition zone between the low and high-frequency is the mid-frequency range (50-100 Hz). The low-frequency transient response environment during flight is characterized by a combination of the equivalent sinusoidal vibration specified at the payload interface and coupled loads analysis CLA.

If measured and historical data is not available, Rocket Lab aims to accurately determine a payload-specific sine vibration environment via a curve based upon a CLA. Rocket Lab develops a mission-specific sine spectrum for each launch service using the results from the CLA.

4.4.6 RF Environment

Electron provides telemetry to Rocket Lab ground stations via three S band transmitters housed in the Stage 2 avionics bay alongside two FTS receivers and two GPS modules. The launch vehicle is equipped with the transmission and reception systems summarized in **Table 9**. The position of the vehicle is determined by two independent sources and transmitted to ground systems through telemetry links. Electron's Stage 2 attenuates the launch vehicle transmissions during launch pad operations, flight and up to fairing separation. The S band transmissions at this time will not radiate into the fairing environment and affect the payload, but Rocket Lab recommends the payload is switched off during the launch to minimize the risk of interference and damage to the payload. The spacecraft RF characteristics should be such that there is no interference with the launch vehicle RF systems listed in **Table 9**.

4. GENERAL PAYLOAD INFORMATION CONTINUED

	SOURCE		
Function	**Command Terminate**	**Source Stage 2 Telemetry**	**GPS L1**
Band	UHF	S-Band	L-Band
Direction	Receive	Transmit	Receive
Frequencies	400-450 MHz	2.3-2.4 GHz	1.57 GHz
Quantity	2	3	2

Table 9 Sample RF Environment Characteristics

4.4.7 Fairing Pressure Evolution

The fairing internal pressure evolution during a nominal mission to sun-synchronous orbit is depicted in **Figure 15**. The maximum de-pressurisation rate is 1.6 kPa/s or 0.23 Psi/s.

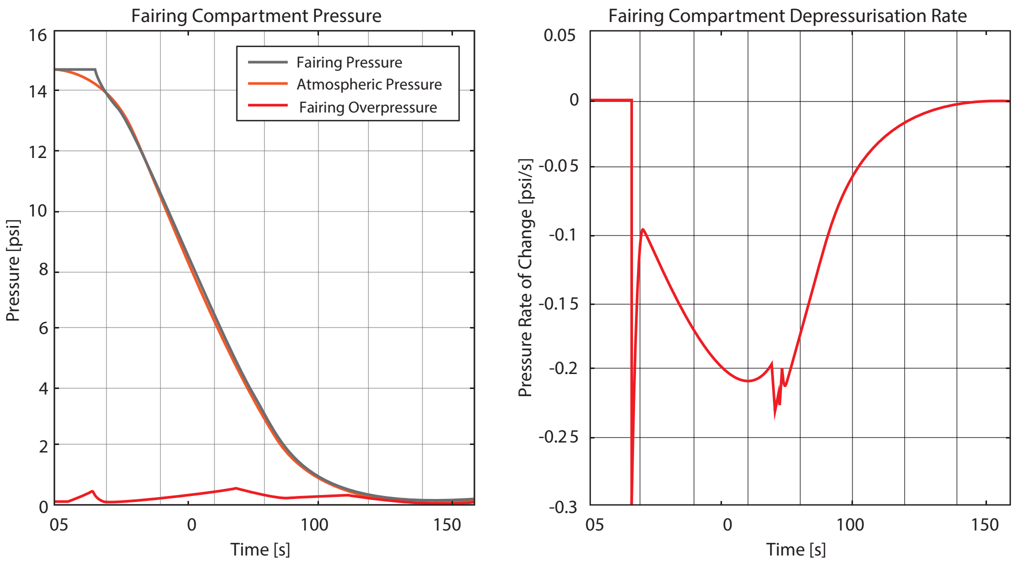

Figure 15 Fairing Internal Pressure Evolution

4.5 Collision Avoidance

As a standard service, a collision avoidance maneuver (CAM) can be completed if required, performance permitting. A CAM will be performed following the conclusion of the payload separation using the on-board RCS thrusters.

4.6 Lightning

Due to relatively benign lightning conditions in New Zealand and at the launch site, the requirement for a lightning tower was waived. Rocket Lab gets prior warnings from the New Zealand Meteorological Service, related to cloud cover and cloud categories, to scrub launches that would involve lightning being generated by the launch vehicle. Protection for lightning will be inherent to the vehicle through launch as grounding is set for all frequency ranges.

4.7 Documentation Obligations

The customer is responsible for generating and providing their own documents formally detailing the intended payload content, mission purpose and planning, payload safety hazards, special requirements and all required documentation from the Civil Aviation Authority of New Zealand (CAA). Customers are also responsible for creating of their own export paperwork to export from their country of origin to the launch site (DSP-5, for example, if coming from the USA).

Minimum documentation requirements as set by the FAA:

- Payload design overview
- FAA launch and range safety approval paperwork
- Safety documentation including hazard analyses and reports, detailed design and test information for all hazardous systems (batteries/pressurised systems/hazard or safety critical materials)
- Interface specification requirements and verification documentation
- Appropriate licensing with the appropriate regulatory commission (FCC, NOAA, ITU, etc.)
- Information, documentation, and general support for the creation of a Launch and or Mission Integration TAA (Technical Assistance Agreement) with the U.S. Government as required.

Services Offered

As part of any standard launch service Rocket Lab aims to provide the following:

- Payload processing and fairing encapsulation
- Interfacing to the appropriate Deployer or LVA as required.
- Provide a fairing encapsulation kit for the customer if the customer chooses to carry out payload processing and encapsulation
- Mechanical, Electrical Ground Support Equipment, software, personnel services
- Interface Requirements, Control and Verification Documentation
- Facilities to support mission planning and launch operations
- Electromagnetic Compatibility (EMC) constraints assessment
- Coupled Loads Analysis (CLA)
- One flight set of electrical connectors for launch vehicle interface if applicable
- Conditioned air into the payload fairing
- Launch vehicle processing, payload encapsulation unit integration to launch vehicle at launch site, testing of electrical and signal interfaces at the launch site
- Provide a range and safety compliance documentation support for the customer
- Facilitate the launch range and safety integration process
- Launch the payload into the targeted orbit (within specified environmental constraints)
- Post-flight analysis and assessment data reports of mission success

4.8 Services On-Request

Additional services may be provided on request. Following are some of the non-standard services Rocket Lab offers.

- Payload (non-hazardous fuels) fuelling at payload processing facility
- Use of non-standard separation systems
- Use of non-standard CubeSat Deployers
- Additional Gaseous Nitrogen (GN_2) purge

4. GENERAL PAYLOAD INFORMATION CONTINUED

- Supply of a Class 100,000 (ISO 8) clean room environment and air in the fairing
- Visibly clean – Level 1 of launch vehicle surfaces within the fairing
- Electromagnetic Compatibility (EMC) integrated power-on testing
- Mission dependent acoustic analysis with the payload support team
- Non-standard CLA analysis

4.9 Safety Requirements

Details of all safety requirements will be discerned once all the safety documentation has been received. Hazardous operations include but are not limited to the use of high-pressure systems, heavy hydraulic lifting, toxic materials and ordnance operations. Rocket Lab will work closely with the payload customer to ensure all safety procedures are understood and implemented.

4.9.1 Range Safety

Rocket Lab customers are expected to meet the safety requirements defined by the Range Safety authority. Rocket Lab will provide the appropriate User's Safety Manual based on the mission and the designated launch range. Until advised otherwise, the AFSPCMAN 91-710 Range User's Manual is to be used to determine requirements of various aspects of the payload design and operation. Additionally, Electron is a FAA licensed launch vehicle as per FAA Launch Licensing Regulations for ELVs (also RCC319-10 complaint). If your payload is not built to meet the 91-710 requirements, please reach out to Rocket Lab as flight may still be possible.

4.9.2 Payload Propellant

Rocket Lab only supports the use of Green Propellants (or ECAPS) on payloads. Hydrazine will not be accommodated from Rocket Lab's New Zealand launch site. However, other U.S. domestic sites can support hydrazine and similar propellants. Please contact Rocket Lab with any mission-specific propellant needs.

4.9.3 Exemptions

Rocket Lab understands that the payload may not meet all range safety or payload propellant requirements. For payload systems that do not meet Rocket Lab's safety requirements but may be considered allowable, Rocket Lab will consider accommodating exemptions from certain safety requirements upon the approval of relevant authorities.

Rocket Lab is committed to supporting the customer in meeting safety requirements and completing the associated documentation.

5. ROCKET LAB FACILITIES

5.1 Administration and Facilities

Rocket Lab operates from a large combined office and factory production facility located close to Auckland Airport. The facility employs a team of engineers and technicians with production resources covering a wide scope of equipment and machinery, enabling rapid cost-effective fabrication of flight system and vehicle components.

5.2 Test Facility

Rocket Lab operates a test facility situated within close proximity to the administration and factory facility in Auckland. Propulsion system tests primarily take place in this test facility. Rapid design, build and test schedules are made possible with such a conveniently located test cell.

5.3 Launch Sites

Rocket Lab currently operates a private launch range at Mahia Peninsula located in Hawkes Bay, New Zealand. Future U.S. domestic launches will be occurring from both U.S. coasts via existing ranges. New Zealand's Southern Hemisphere location offers Rocket Lab clients a unique launch environment as an island nation surrounded by open water and clear air.

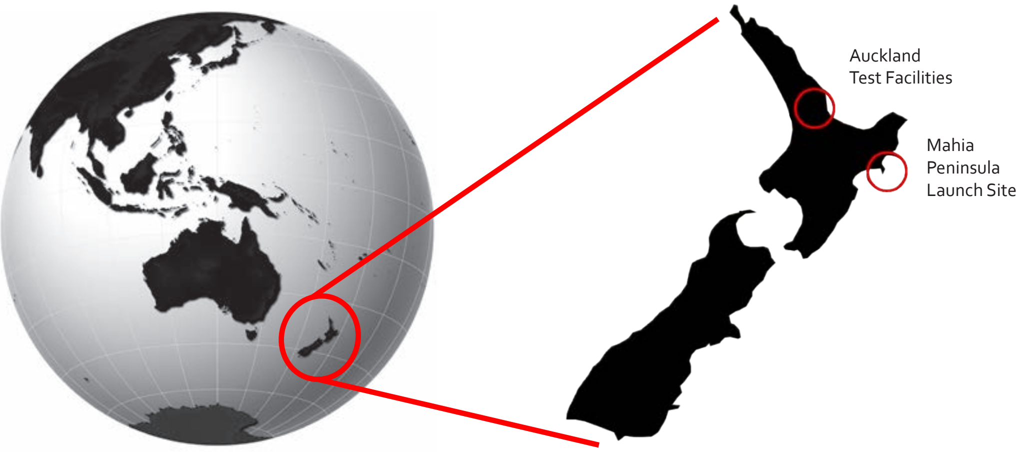

Figure 16 New Zealand and its Global Location

5.4 Launch Control Center and Complex

The main launch control center consists of workstations for each team, including the flight safety team, the payload team, the launch vehicle team and the launch director.

Figure 17 Rocket Lab Launch Complex at Mahia

5. ROCKET LAB FACILITIES CONTINUED

5.4.2 Launch Complex

Rocket Lab's Launch Complex consists of a Command and Control Facility and the Launch Site Facility located on the Mahia Peninsula. The Launch Complex has been designed to be modular and easily reconfigured for any changes to its operational schedule.

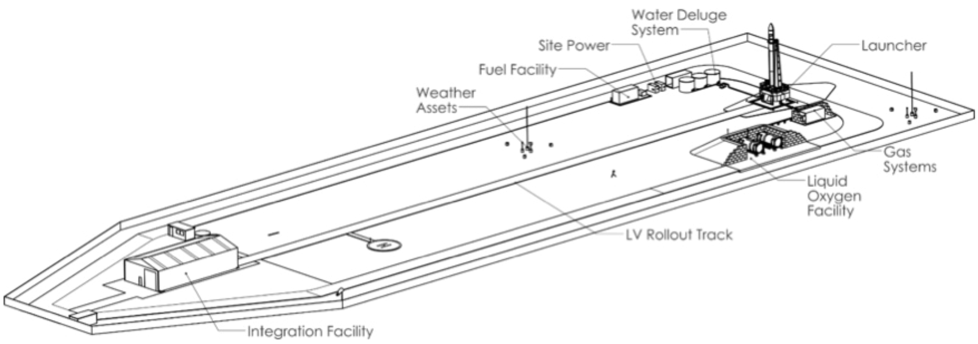

Figure 18 Launch Site Layout

5.4.2.1 Command and Control Facility

The command and control facility is located outside of the safety zone: 3.5 km from the launch pad.

5.4.2.2 Launch Site Facility

The launch site facility is fully equipped to handle launch operations and abort scenarios. Key infrastructure at the launch site facility includes a launch pad, a Vehicle Processing Hangar for Electron and the payload module, sealed accessways to the pad and storage and security facilities.

5.4.2.2.1 Launch Processing Hangar

The launch processing hangar is designed to execute the full cycle of operations required to prepare Electron and the payload for transportation to the launch pad. The hangar is designed to conduct assembly, integration of payload module to Electron, execution of launch vehicle integrated checkouts prior to moving the vehicle onto the launch pad, and to perform operations in case of a scrubbed launch.

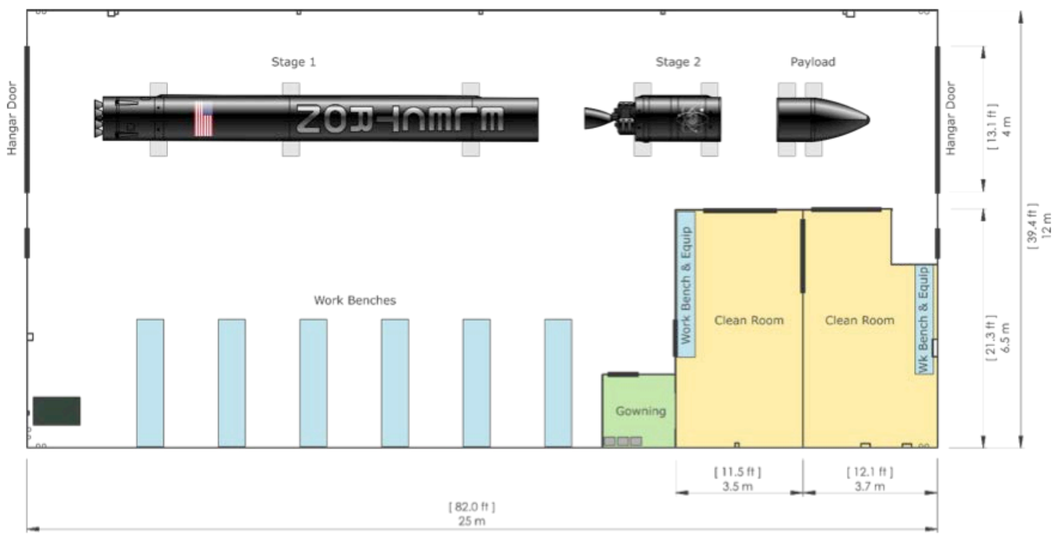

Figure 19 Hangar Floor Plan

5.4.2.2.2 Storage and Security Facilities

The launch facility has storage for fuel, payload and other auxiliary ground support equipment. The facility is secure 24 hours per day, seven days a week. Fuel and LOx storage tanks are located well within FAA Safety guidelines.

6. PAYLOAD & LAUNCH OPERATIONS

6.1 Payload Integration and Support

Rocket Lab will keep payload and launch operations as smooth and seamless as possible. Payload and launch operations take place at the Rocket Lab Launch Complex. Payload processing and encapsulation will take place at the launch site.

6.1.1 Payload Module Integration

Rocket Lab offers two options for payload integration. The first is an in-house encapsulation service and the second is a Plug-In Payload solution.

6.1.1.1 Standard Encapsulation Service

The standard payload integration solution involves Rocket Lab providing the encapsulation service. The customer's payload is shipped to Rocket Lab's Payload Processing Facility at the launch site and is encapsulated with Rocket Lab's engineers as support with the direction of the payload support engineers. On arrival, the payload is processed; it is integrated by mounting it to an adapter. This is then attached to the base plate of the Payload Module. The fairings enclose the payload at the base plate.

6.1.1.2 Optional Plug-In Payload Kit Solution

It will include all parts needed to complete encapsulation (fairing, payload adapter, separation system(s),etc.). The kit will be shipped to the payload customer at an agreed date. On arrival, the payload customer will be responsible for integrating the payload into the Payload Module. Rocket Lab will provide on-site support for all agreed separation system device final closeout. Specific build instructions will also be provided including handling and other constraints to sign-off all work done. All mission specific details relative to payload integration will be captured in the appropriate payload interface control documentation (ICD or similar). Upon encapsulation, the completed assembly will need to be shipped to an appropriate Rocket Lab facility via approved shipping methods for preparation for launch. Once on-site, the encapsulated payload can be put in an "as required" state for emergency call up and prompt launch. For example, an emergency replacement spacecraft could be encapsulated and ready for launch upon call up.

6.1.2 Payload Processing Facility

The Payload Processing Facility consists of clean rooms and adjacent machine rooms that provide a dual function of regulating the conditions in the clean room as well as providing an area to use machinery that may support the payload processing procedures.

Services and infrastructure that will be provided at Rocket Lab's Payload Processing Facility include:

- Cleanroom classification 100,000 (ISO 8) for payload processing, integration and encapsulation
- Electrical ground support equipment such as 110V AC at 60HZ and 230V AC at 50HZ as per MIL-STD1542 grounding standards
- Office and desk spaces equipped with Internet/Ethernet ports for customers' mobile devices
- Mobile fuelling for payload fuelling since this is a non-standard service
- Storage area before launch in an environmentally controlled area
- Security procedures such as locked labs, lab IDs, an area warning system

6. PAYLOAD & LAUNCH OPERATIONS CONTINUED

6.1.2.1 Payload Processing Schedule

The current payload processing schedule is consistent with other legacy systems with an example shown below. Note that payload processing, integration and launch timelines can be greatly reduced upon request. Please contact Rocket Lab for more information.

LAUNCH RANGE OPERATIONS FLOW/SCHEDULE

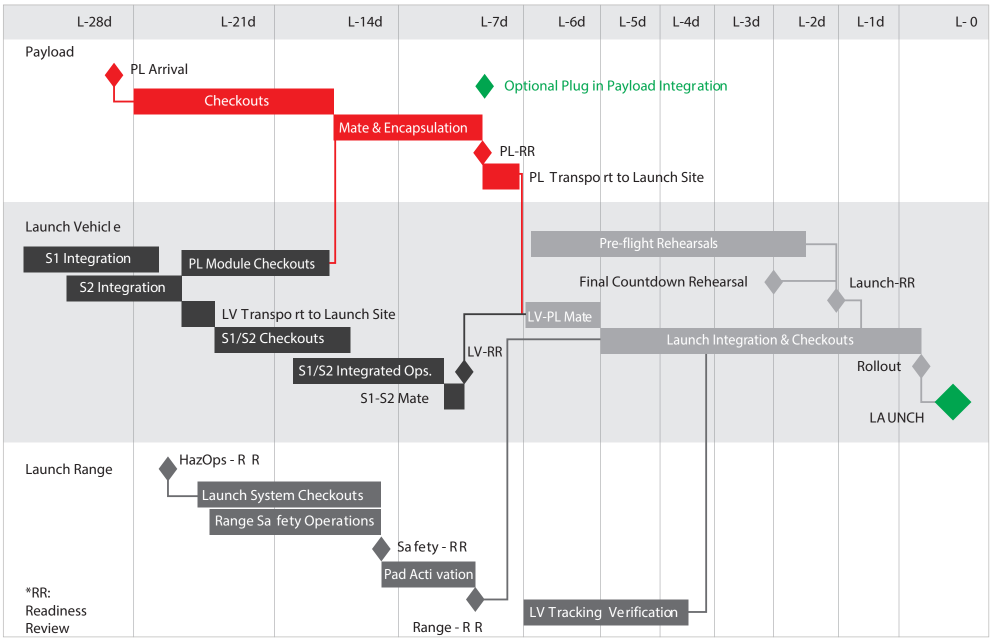

Figure 20 Launch Range Operations Flow / Schedule

6.1.3 Payload Transport to Launch Site

Payload support staff and Rocket Lab will work together to make sure the payload or encapsulated payload arrives at the launch site secure for either payload processing and/or mating with the launch vehicle on site.

6.2 Launch Campaign Organizational Structure

Rocket Lab has established a launch control center at its Auckland facility. The launch control center will house all the necessary equipment to communicate with the launch range and launch vehicle in real-time.

Key personnel and their authority during the launch procedures are described in the figure below. The Launch Director (Rocket Lab) holds the final "go" or "no go" decision. Subordinate to the Launch Director are the Payload Director (customer) and the Launch Conductor (LC) (Rocket Lab). The Launch Safety Officer (LSO) has equal authority as the LC to ensure range safety is upheld. A Rocket Lab Management Representative will be present during launch in an oversee capacity.

6.2 Launch Campaign Organizational Structure Continued

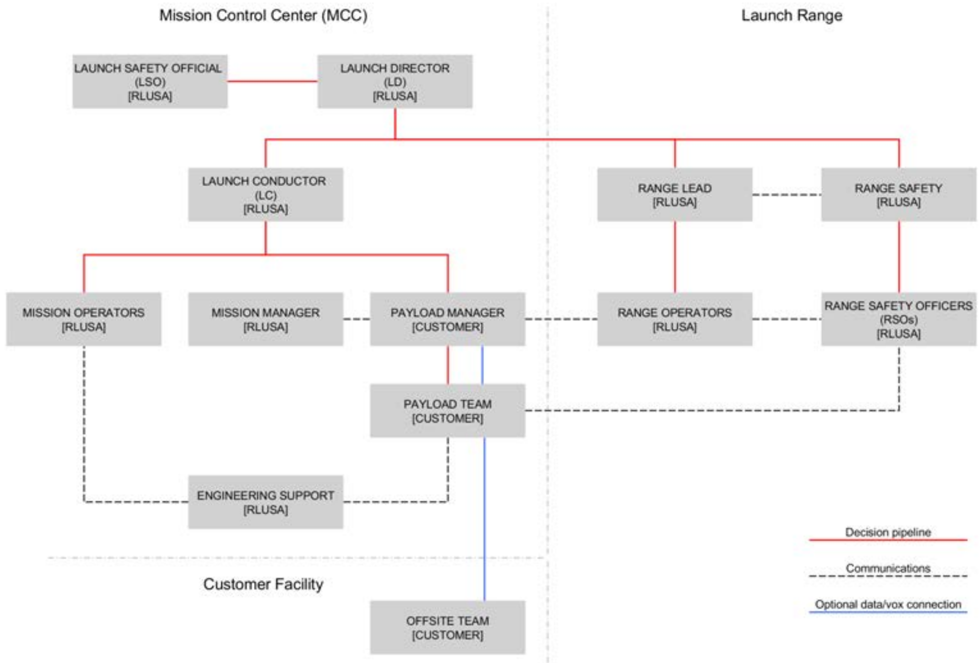

Figure 21 Mission Control Center (MCC)

6.3 Launch Schedule

Electron's operating schedule aims to be operationally efficient in terms of time, cost and simplicity. An example of the launch day or countdown schedule for our standard launch timeline is shown below.

COUNTDOWN OPERATIONS FLOW

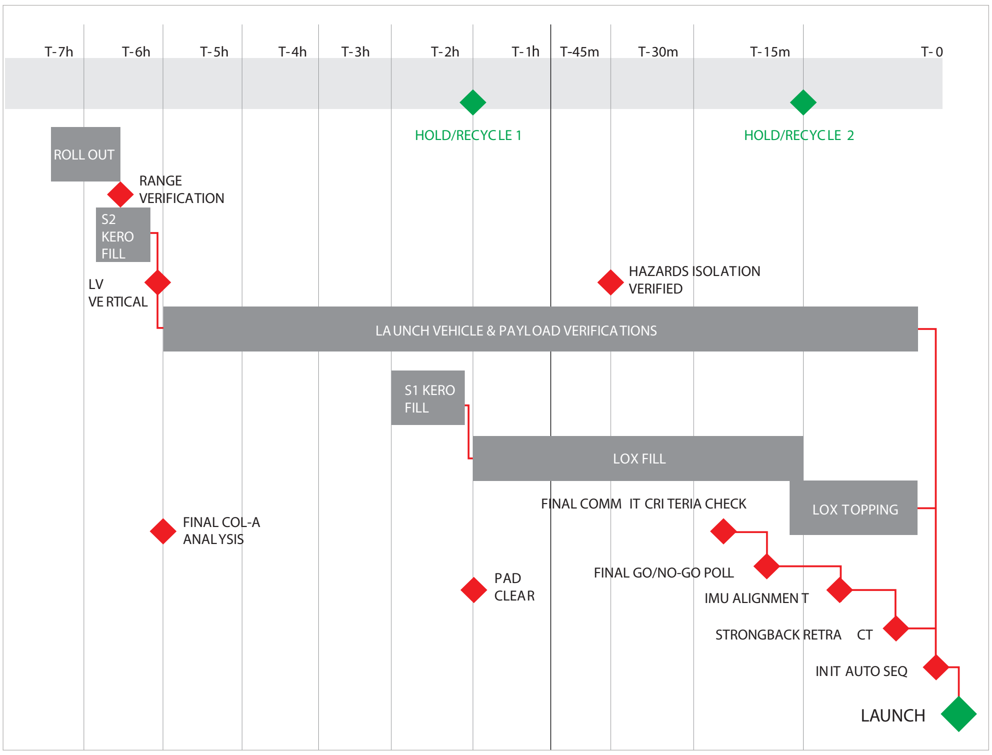

Figure 22 Countdown Operations Flow

7. QUICK REFERENCE GUIDE

7.1 List of Figures

7.2 List of Tables

7.3 List of Acronyms

CAA	Civil Aviation Authority of New Zealand
CLA	Coupled Loads Analysis
DARPA	Defence Advanced Research Projects Agency
EMC	Electromagnetic Capability
FTS	Flight Termination System
GN2	Gaseous Nitrogen
GNC	Guidance, Navigation and Control
GPS	Global Positioning System
GSE	Ground Support Equipment
HIL	Hardware In the Loop
IMU	Inertial Measurement Unit
LOx	Liquid Oxygen
LV	Launch Vehicle
MDR	Mission Dress Rehearsal
ONRG	US Office of Naval Research Global
ORS	Operationally Responsive Space
TVC	Thrust Vector Control
UHF	Ultra-High Frequency

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