



ORBIT



LAUNCHERONE SERVICE GUIDE

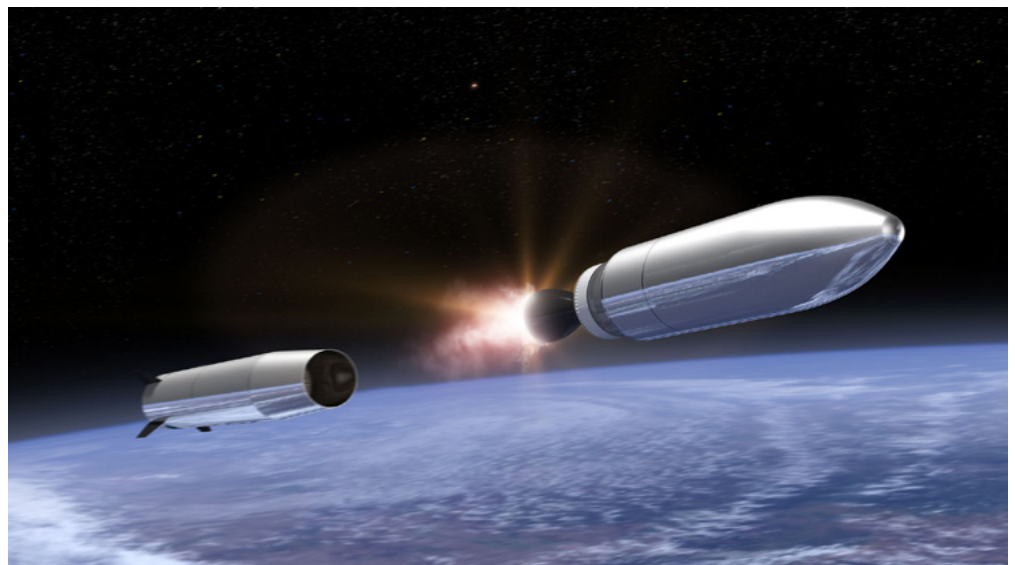


LAUNCHING THE SMALL SATELLITE REVOLUTION

Virgin Orbit is excited about the tremendous potential of small satellites to provide global connectivity, remote sensing, security, and visionary new capabilities that benefit our planet. Small satellites are doing more on shorter timelines, and at lower cost. We developed LauncherOne to complement this transformational movement; to get small satellites to orbit quickly, reliably, and affordably. Designed from scratch with these guiding principles, the LauncherOne air-launch system provides freedom from the constraints of fixed ground infrastructure and onerous pre-launch paperwork. We believe launching your small satellite should be hassle-free, and we are enabling this with streamlined processes and the superior customer service that distinguishes Virgin companies.

We invite you to contact us and share your mission needs. Together we open space to change the world for good!

Dan Hart
President and CEO of Virgin Orbit



Contact Us

launch@virginorbit.com
virginorbit.com
+1 562 384 4400

CONTENTS

1/ THE VIRGIN ORBIT EXPERIENCE 3

- 1.1 Capabilities at a Glance 6

2/ DESIGN YOUR MISSION 7

- 2.1 Payload Delivery Capability 8
- 2.2 Orbit Insertion Accuracy 9
- 2.3 Payload Accommodations 10
- 2.4 Supported Separation Systems 11

3/ THE ORBIT VIRGIN LAUNCH SERVICE PROCESS 13

- 3.1 Launch Service Elements 14
- 3.2 Launch Service Schedule 15
- 3.3 Customer Responsibilities 15
- 3.4 Safety and Mission Assurance 16

4/ PAYLOAD PROCESSING AND LAUNCH OPERATIONS 17

- 4.1 Payload Processing Facilities 18
- 4.2 Payload Processing Flow 19
- 4.3 Launch Locations 20
- 4.4 Launch Operations Flow 20

5/ PAYLOAD ENVIRONMENTS 21

- 5.1 Vehicle Coordinate System 22
- 5.2 Payload Constraints 22
- 5.3 Acceleration from Quasi-Static Loads 23
- 5.4 Shock Environment 23
- 5.5 Random Vibration 24
- 5.6 Acoustics 25
- 5.7 Payload Radio Frequency (RF) Constraints and Environment 26
- 5.8 Thermal and Humidity Environment 27
- 5.9 Fairing Pressure Environment 27
- 5.10 Separation System Signal 27
- 5.11 Spacecraft Electrical Interface 27

6/ ABOUT VIRGIN ORBIT 29

- 6.1 Corporate Overview 30
- 6.2 Launch Vehicle Production and Test Facilities 31
- 6.3 Spaceport Facilities 32

7/ DOCUMENT REFERENCE 33

- 7.1 List of Acronyms 34
- 7.2 List of Tables 34
- 7.3 List of Figures 35



THE
VIRGIN
ORBIT
EXPERIENCE

1 THE VIRGIN ORBIT EXPERIENCE

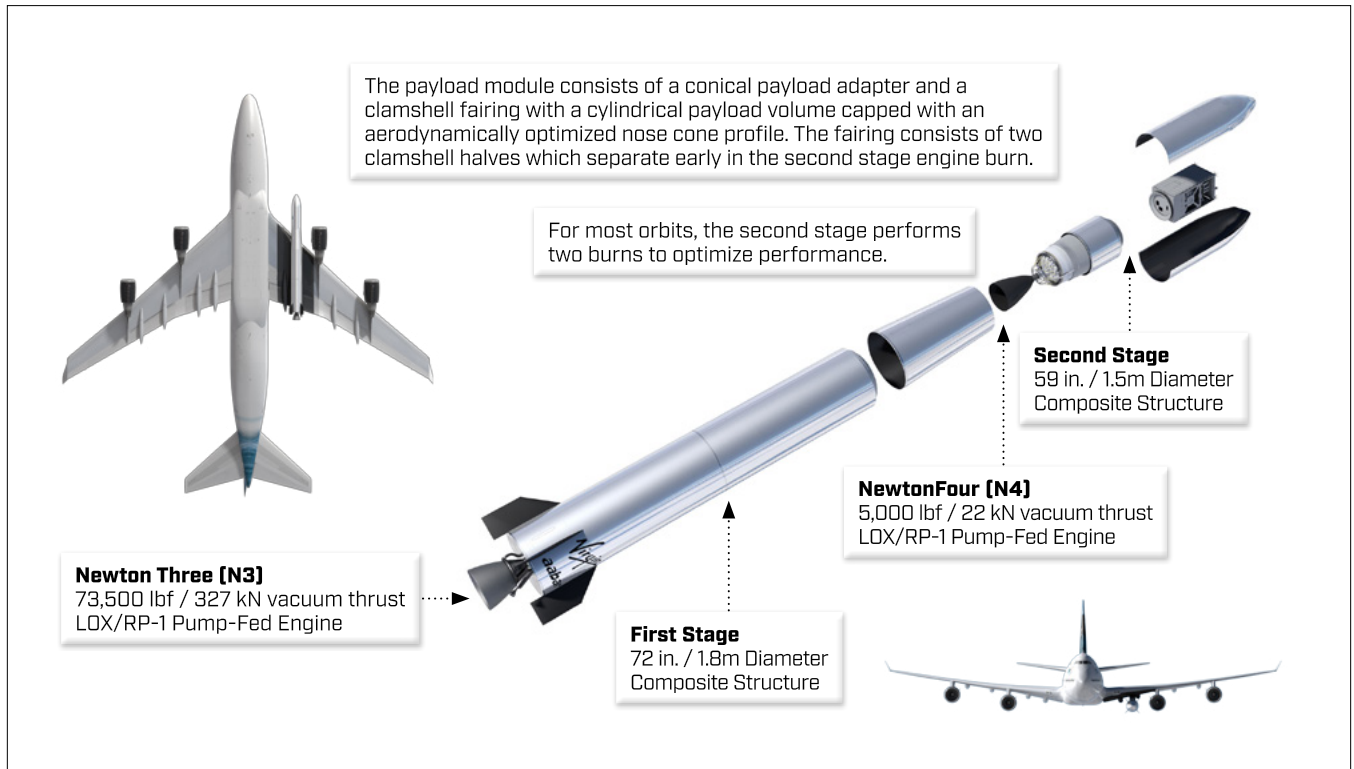
The rapidly growing small satellite industry requires a launch service that is equally agile, flexible, and affordable. Virgin Orbit's launch vehicle, LauncherOne, is the result of our investment in the team, technologies, and facilities required to build a customer-focused launch service.

LauncherOne is Your Ride to Space

LauncherOne is a simple, expendable, launch vehicle designed to place small satellites of up to 500 kg / 1100 lbm into a wide range of Low Earth Orbits (LEO) at an affordable price. Rather than launching from ground level, LauncherOne is carried to an altitude of approximately 35,000 feet by the 747-400 carrier aircraft, Cosmic Girl, as depicted in **FIGURE 1**.

The simple design of LauncherOne increases reliability while keeping costs low. In order to balance performance with commercially-competitive pricing, LauncherOne was designed through a "clean-sheet" design process, in which all potential vehicle configurations were traded against each other (different numbers of stages, various propulsion types, etc.). Throughout LauncherOne's design, the Virgin Orbit team actively rejected complexity, favoring a straightforward and reliable design. This avoids the common trap of incurring significant cost increases for only a marginal increase in performance.

FIGURE 1/
LAUNCHERONE SYSTEM
EXPANDED VIEW



Your Orbit on Your Schedule

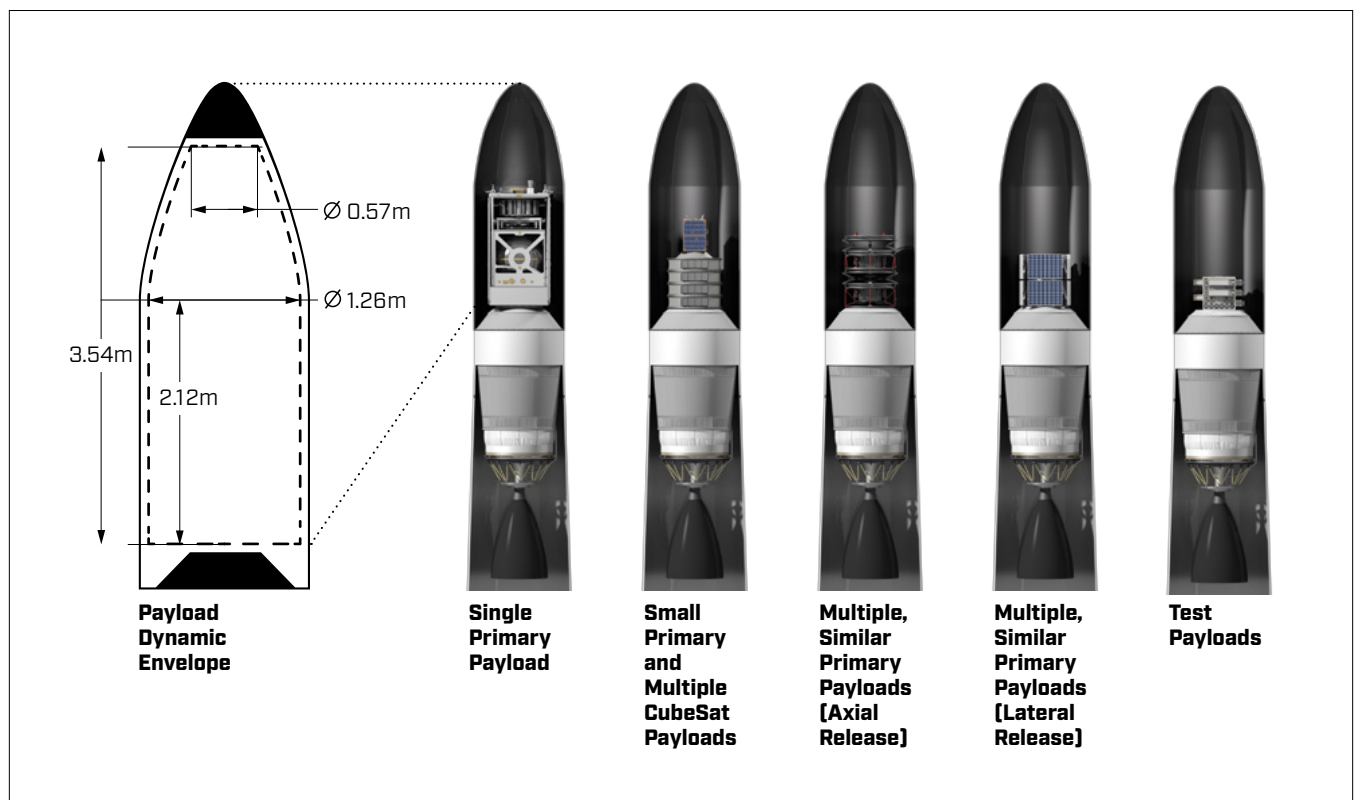
Orbit offerings to any orbit inclination on as short as 6 month lead time.

Air-launch eliminates much of the compulsory overhead of ground launched systems, and provides unprecedented flexibility in launch operations. By operating independently from national launch ranges, LauncherOne avoids common causes of launch delays such as logjams in the launch queue, weather, unavailable radar tracking assets, and boats in the launch pad stay-out zone. The carrier aircraft serves as a mobile launch platform, offering custom launch solutions not traditionally available to small satellites, including tremendous flexibility in the spaceport of origin, orbital destination, and launch date.

Class Leading Payload Flexibility

LauncherOne offers a large fairing for its class with a payload adapter capable of accommodating a variety of standards for one or multiple spacecraft.

FIGURE 2/
LAUNCHERONE SAMPLE
PAYLOAD CONFIGURATIONS



Customers are welcome to use Virgin Orbit's dedicated payload processing facility in Long Beach, California with a class 100k clean room and a full complement of ground support equipment. Small satellites have primary payload status on LauncherOne. Your mission is our priority.

Bringing the Virgin Experience to Space Launch

As a member of the Virgin family, Virgin Orbit aims to extend the world renowned Virgin customer service to the space launch industry, placing particular emphasis on the value that our dedicated and spirited team of engineers can add to your launch experience. To accomplish this we are improving the overall experience of getting to orbit, by streamlining the processes leading up to launch and emphasizing customer satisfaction.

This document is intended as a launch planning resource, and more detailed, mission specific information is available upon request. After a Launch Services Agreement is executed, a Mission Manager is assigned to each customer to assist in all aspects of the mission. Please do not hesitate to contact us with questions or special accommodation requests.

1.1

CAPABILITIES AT A GLANCE

Key components of Virgin Orbit's LauncherOne service are summarized in **TABLE 1**. The capabilities listed here are discussed in greater detail in the following sections of this Service Guide, and may be customized as needed to suit each customer's mission-specific requirements.

**TABLE 1/
LAUNCH SERVICES
QUICK REFERENCE**

Service	Capability Summary
Payload Capability	<ul style="list-style-type: none">Up to 300 kg / 661 lbm to 500 km / 270 nmi Sun-Synchronous Orbit (SSO)Up to 500 kg / 1100 lbm to 230 km / 124 nmi circular 0 degree inclination Low Earth Orbit (LEO)
Payload Dynamic Volume	<ul style="list-style-type: none">1262 mm / 49.7 inch constant cylindrical diameter2123 mm / 83.6 inch constant cylindrical length3543 mm / 139.5 inch overall payload fairing envelope length
Launch Altitudes/ Inclinations	<ul style="list-style-type: none">Up to 1200 km depending upon payload and inclinationWest Coast US (Mojave Air and Space Port): 60 to 180 degrees inclinationEast Coast US : 0 to 60 degrees inclinationFlexibility to conduct launch from any licensed spaceport facility
Launch Schedule	<ul style="list-style-type: none">Emphasis on reducing time-to-launch; 6 months for a typical primary payloadFlexible launch windows to accommodate schedule changes/variation
Payload Processing	<ul style="list-style-type: none">Independently-operated customer payload processing facility with ISO Level 8 (100k class) clean room in Long Beach, CAOptions exist for receipt of pre-encapsulated payloads
Payload Integration	<ul style="list-style-type: none">Conical payload adapter with baseline interface diameter of 609.6 mm / 24.0 inches; other various diameters and bolt patterns availableCompatible with ESPA and ESPA-Grande class configurationsSupport for commercially-available separation systems and CubeSat dispensersSecondary payloads manifested and managed directly by Virgin Orbit or via payload brokers or aggregators
Regulatory Approach	<ul style="list-style-type: none">U.S. Federal Aviation Administration Part 431 Launch LicenseCompliance with international orbital debris disposal guidelines



DESIGN
YOUR
MISSION

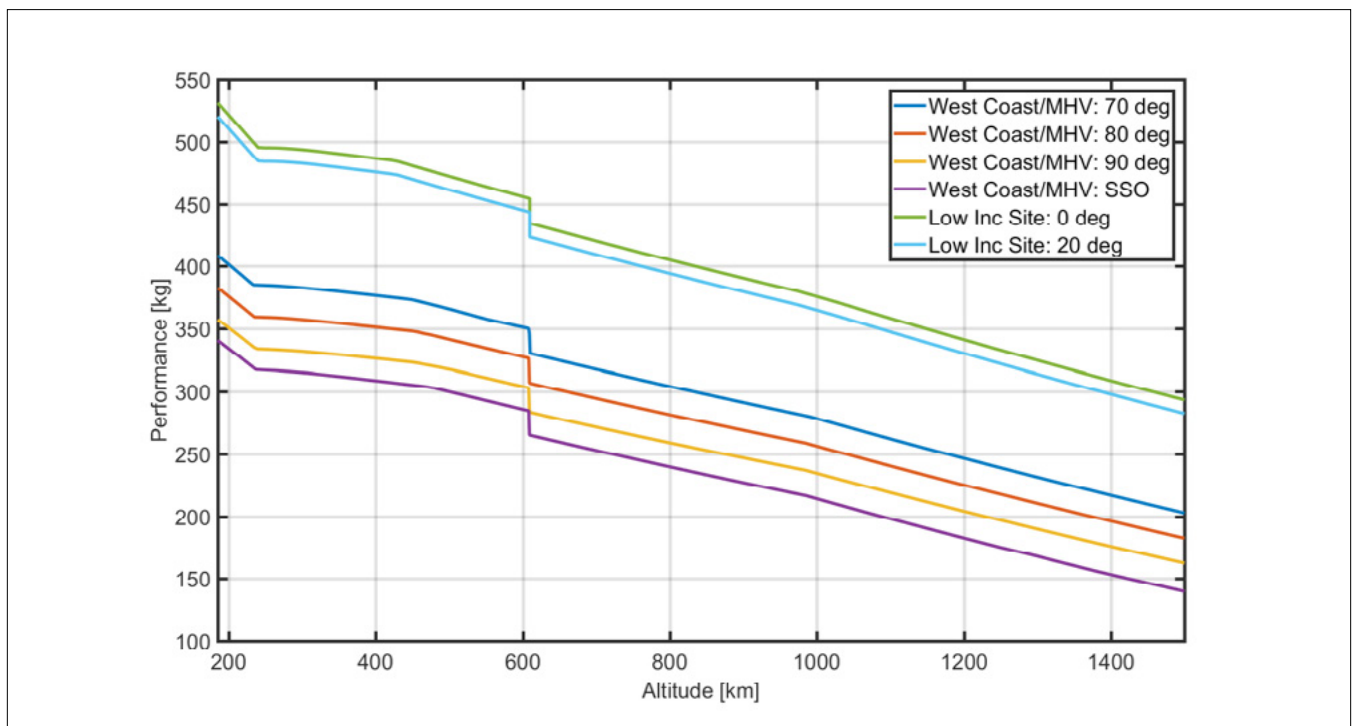
2 DESIGN YOUR MISSION

Let us get you to where you want to go. LauncherOne's air-launch architecture enables unparalleled flexibility in orbital definition. We even have the capability to efficiently deliver payloads to inclinations as low as 0-degree equatorial orbit.

2.1 PAYLOAD DELIVERY CAPABILITY

Performance curves for LauncherOne payload delivery to several reference orbits are provided in the figure below. Due to LauncherOne's high degree of customization, payload capabilities are best calculated for each customer based on their specific requirements.

FIGURE 3/
ORBITAL PAYLOAD DELIVERY
PERFORMANCE CURVES



LauncherOne is designed to meet FAA regulations that require a maximum orbit lifetime of 25 years for an upper stage left at an altitude less than 2,000 km. Meeting this requirement necessitates a disposal burn for orbital altitudes above 625 km, consequently consuming a portion of total propellant.

The performance curves in **FIGURE 3** provide the total payload mass above the payload interface. Thus, the mass of any required separation system or dispenser must be included along with the payload in accounting for total mass. LauncherOne is compatible with a variety of small satellite separation systems and CubeSat dispensers. Please see Section 2.3 or contact a LauncherOne Mission Manager for more information.

2.2 ORBIT INSERTION ACCURACY

We take our commitments seriously and that includes making sure your payload is deployed to where you need it to be. LauncherOne employs a liquid propulsion system for its final stage which allows for improved orbital insertion control, as opposed to solid propellant upper stages. Deployment of multiple payloads into orbits of different altitudes, eccentricities and slightly differentiated inclinations can also be accommodated. Orbit injection accuracy is dependent on payload mass, orbit altitude, and other mission-specific factors. Typical errors in injection accuracy for LauncherOne are provided in **TABLE 2** for a 500 km circular sun-synchronous orbit. Virgin Orbit's standard mission analysis includes refinement of these accuracy predictions based on customer-specified mission parameters.

TABLE 2/
TYPICAL ORBITAL INJECTION
ACCURACY (3 SIGMA)

Orbital Parameter	Accuracy
Altitude	± 15 km
Inclination	± 0.15°
Right Ascension of Ascending Node (RAAN)	± 0.2°

Prior to payload separation, the LauncherOne second stage can orient itself and the payload to the desired attitude. Typical accuracies for pointing and angular velocity are shown in **TABLE 3**. Missions with multiple payload deployments may select different separation attitudes.

TABLE 3/
TYPICAL PRE-SEPARATION
ATTITUDE AND SPIN-RATE
ACCURACIES (3 SIGMA)

Altitude Type	Parameter	Angular Error	Rate Error
3-Axis	Roll	± 7.0°	± 1.0°/sec
	Pitch	± 4.0°	± 0.5°/sec
	Yaw	± 4.0°	± 0.5°/sec

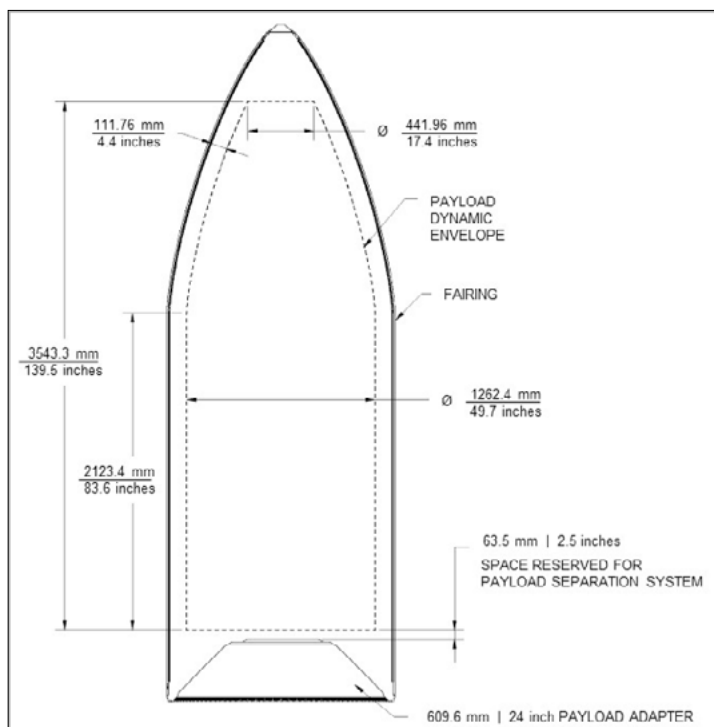
2.3 PAYLOAD ACCOMMODATIONS

LauncherOne offers one of the largest payload envelopes in the industry for its class. LauncherOne has the ability to multi-manifest satellites, employing the large fairing volume in a variety of ways to best meet customer requirements. For multi-satellite missions with primary and secondary payloads, typically a secondary payload adapter is attached to the standard payload adapter interface with the primary payload mounted on top. Side-by-side accommodation of two ESPA class payloads is possible as a custom configuration. The LauncherOne fairing can also accommodate a single ESPA-Grande class payload. Secondary payloads can be manifested and managed directly by Virgin Orbit, or via payload aggregators.

The LauncherOne fairing incorporates standard payload access doors near the base of the fairing composite structure. The fairing access door allows for late access to key portions of a customer spacecraft prior to launch vehicle propellant loading.

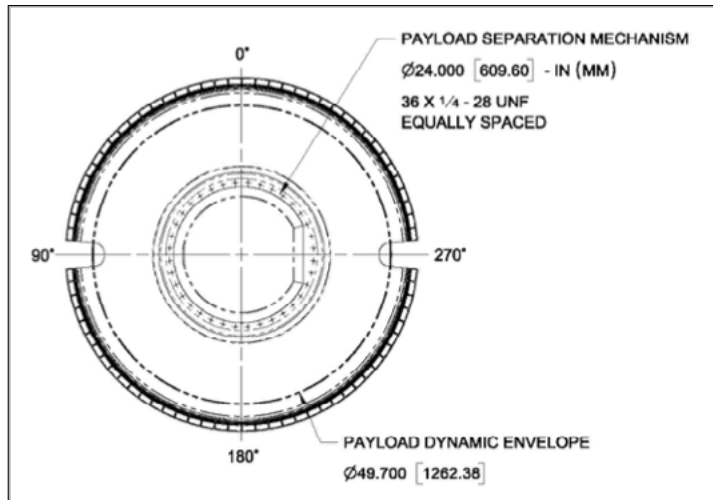
The available payload fairing dynamic envelope and spacecraft separation interface schematic for LauncherOne are illustrated in **FIGURE 4** and **FIGURE 5**, respectively. The dynamic envelope consists of a 1.36 m / 53.5 inch diameter cylindrical section that is 2.28 m / 89.8 inch long resulting in a 3.63 m / 142.9 inch overall payload dynamic envelope length. The LauncherOne payload dynamic envelope is the net volume available for the payload after accounting for the axial height of a payload separation system and the thickness of acoustic blankets lining the conical and ogive sections of the fairing inner wall. These blankets may be reduced or removed to increase the available volume for spacecraft that exceed this dynamic envelope and are compatible with the changes to acoustic and thermal environments as a result of this removal. Virgin Orbit can perform mission specific analysis to evaluate your specific mission needs and discuss possible payload accommodations for specific requirements.

FIGURE 4/
PAYLOAD FAIRING
DYNAMIC ENVELOPE



LauncherOne's standard payload adapter consists of composite forward and aft rings with a composite conical section, providing the mechanical interface between the launch vehicle and the payload stack. The baseline payload adapter interface is a standard 609.6 mm / 24.00 inch bolt pattern. Various interface bolt patterns are available, including those compatible with the ESPA and ESPA-Grande class configurations. The dimensions of the standard interface are provided in **FIGURE 5**.

FIGURE 5/
PAYLOAD SEPARATION INTERFACE



2.4 SUPPORTED SEPARATION SYSTEMS

Virgin Orbit will assist the customer in selecting an appropriate separation/deployer system. LauncherOne is compatible with multiple spacecraft separation systems and CubeSat dispensers in order to offer maximum mission flexibility to our customers. Primary spacecraft typically interface with the LauncherOne payload adapter, described above, via an annular or discrete point separation system. CubeSat payloads typically use dispensers designed to the CubeSat design specification.

Supported annular payload separation systems include, but are not limited to: Planetary Systems Corporation (PSC) Motorized Lightband, RUAG PAS separation systems, and Sierra Nevada Corporation QwkSep Low Profile Separation System.

CubeSat dispensers are commercially available in various sizes to accommodate the common 1U, 2U, 3U, 6U, 12U, 16U, and 27U CubeSat configurations. These dispensers are usually capable of simultaneous or independent deployment of multiple CubeSats. Cubesat dispensers supported by LauncherOne include, but are not limited to: Cal-Poly P-POD, Tyvak Rail-POD, Nanosatellite Launch Adapter System (NLAS), Innovative Solutions in Space (ISIS) DuoPack and QuadPack, PSC Containerized Spacecraft Deployer, Xtenti FANTM RAiL, XPOD Separation System, Astrofein GmbH Picosatellite Launcher, and D-Orbit's DPOD.

Virgin Orbit will conduct analysis of tip off and other payload separation dynamics as necessary to ensure safe separation from the launch vehicle and one that meets your mission requirements. For multi-payload missions, LauncherOne ensures that the deployment sequence allows for adequate separation between all deployed payloads. Following the separation event, the second stage of LauncherOne will perform a Collision/Contamination Avoidance Maneuver (C/CAM), if necessary, in order to minimize contamination and limit the potential for re-contact with the deployed payload.

3

THE VIRGIN ORBIT LAUNCH SERVICE PROCESS

3 THE VIRGIN LAUNCH SERVICE PROCESS

Virgin Orbit's launch service includes mission planning, accommodation for spacecraft processing, payload-to-launch vehicle integration, and delivery of the spacecraft to orbit. Mission integration activities ensure that customer requirements are met or exceeded and the mission is conducted in a safe, expeditious, and reliable manner. Typical schedule, documentation, and safety considerations are described in the following sections.

3.1 LAUNCH SERVICE ELEMENTS

All launches are given the high level of service and attention to detail that comes standard with what you would expect from a Virgin company. To better serve our customers, we offer optional services to further enhance your launch experience and/or accommodate your unique needs.

Standard Services:

- **Virgin Orbit Mission Manager:** Your concierge for a smooth spacecraft integration and launch.
- **Virgin Orbit Interface Control Document:** Ensures all of your mission requirements are documented and the launch service complies with your spacecraft needs.
- **Trajectory and Performance Analysis:** Ensures your payload is delivered to your mission orbit.
- **Coupled Loads Analysis:** Ensures that your spacecraft is compatible with the launch environment.
- **Separation Analysis:** Ensures accurate and low risk payload deployment.
- **Post-Launch Status Quick-Look:** Spacecraft state vector will be made available within 90 minutes after separation based on the L1 navigation solution at separation. A Quick-Look assessment of post-launch status from launch vehicle telemetry data, as well as a preliminary evaluation of mission success, will occur no later than 180 minutes after separation.
- **Post-Launch Evaluation Report:** A full report will be delivered within 60 days after launch, containing details of launch trajectory, events, and environments.
- **Export Compliance:** In the case of a non-U.S. Customer and/or Spacecraft Manufacturer, Virgin Orbit will obtain and manage a Technical Assistance Agreement (TAA) from the U.S. State Department.

Optional Services:

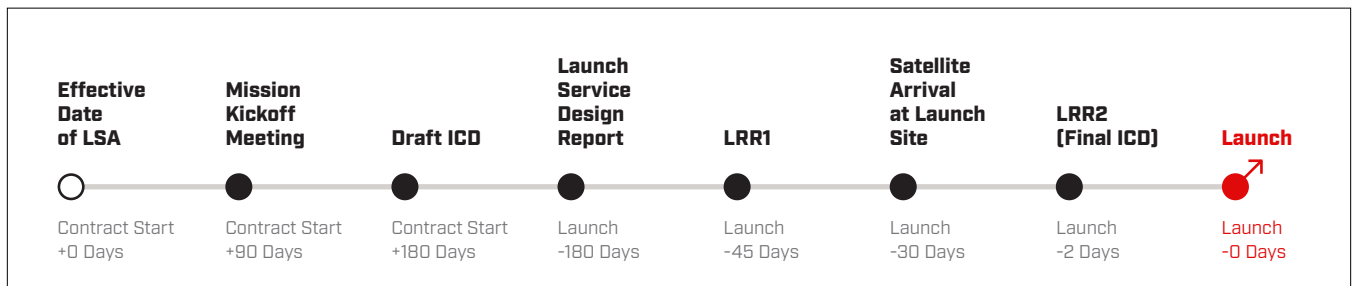
- **Payload Separation System:** Focus on your payload and let us handle the acquisition, delivery, and processing of your separation system to ensure that you are ready for integration.
- **Thermal Analysis:** Ensure thermal compatibility with sensitive areas of your payload and the launch environment.
- **Chase Plane:** Watch your launch live from the air!

3.2 LAUNCH SERVICE SCHEDULE

Virgin Orbit's dedication to streamlining launch for small satellites includes emphasis on reducing time-to-launch. Virgin Orbit has instituted the corporate culture, processes, and supporting infrastructure to launch your payload as quickly and reliably as possible. For a standard engagement of a primary payload, payloads can launch in as little as 9 months from contract execution. Small secondary rideshare payloads can launch in 6 months or less from contract execution.

A top-level schedule for a complete launch service engagement is provided in **FIGURE 6**. The relative timing of milestones for each customer varies according to mission-specific requirements. Contractual launch service begins with signing a Launch Service Agreement and culminates in launch and delivery of a post-mission report. Each customer receives a Mission Manager as the primary point of contact and facilitator for all activities leading to launch. An Interface Control Document is jointly developed by Virgin Orbit and the customer to communicate requirements and ensure compatibility of the payload and the launch vehicle. Launch Readiness Reviews (LRR) are held to coordinate and assess overall readiness of the vehicle, payload, and facilities to provide a safe and successful launch. The outline schedule shown in **FIGURE 6** serves as the basis for a detailed schedule of all key technical milestones necessary for successful completion of the launch service.

FIGURE 6/
NOMINAL SCHEDULE
FOR LAUNCH SERVICE



3.3 CUSTOMER RESPONSIBILITIES

As the payload owner, the customer is responsible for providing documents to formally communicate the payload system description, mission requirements, payload safety data, and processing plans. This information facilitates coordination between the customer and Virgin Orbit ensuring smooth launch operations, and is used to satisfy FAA reporting requirements. Typical documentation requirements are as follows:

- **Responses to Payload Questionnaire:** Initial basic information about the payload and mission.
- **Inputs to the Launch Vehicle-to-Spacecraft ICD:** Spacecraft configuration, mission orbital parameters, mechanical and electrical interface definition, RF characteristics, ground operations' needs, unique requirements, and other design considerations that encompass the overall mission.

- **Spacecraft mass properties and CAD model:** Mass, CG, and moments & products of inertia data, for Virgin Orbit to evaluate launch vehicle integration and flight dynamics.
- **ICD Verification Documentation:** Verification evidence indicating how each customer ICD requirement was verified (e.g. inspection, analysis, test, demonstration).
- **Finite Element Model:** Model to enable payload-to-launch vehicle Coupled Loads Analysis.
- **Payload Processing Plan:** Plan for payload processing and intended use of Virgin Orbit Payload Processing Facilities.
- **Safety Documentation:** Identification of hazardous materials and quantity of each; and identification of hazardous operations during payload processing.

The customer is separately responsible for obtaining licenses from the appropriate regulatory commission for communication and/or imagery from space (e.g. Federal Communications Commission, International Telecommunications Union, National Oceanic and Atmospheric Administration).

3.4 SAFETY AND MISSION ASSURANCE

Measures are in place to ensure safety of personnel and property throughout all aspects of payload processing, vehicle integration, and launch operations. Virgin Orbit strives to exceed the requirements of the Federal Aviation Administration (FAA), the Occupational Safety and Health Administration (OSHA), and other applicable regulatory agencies. Both a Safety Policy and formal Safety and Mission Assurance Process are in place to ensure risks and resulting hazards are methodically identified, and either eliminated or appropriately mitigated. Customer payloads and payload operations are responsible for compliance with these requirements. Virgin Orbit can provide guidance regarding specific safety requirements. The entry point for communication of payload safety data is the payload questionnaire and it contains all questions needed for an FAA Launch License submittal. Virgin Orbit will review the payload documentation for compliance with applicable safety standards, and safety status is assessed during all readiness review meetings.

4

PAYLOAD PROCESSING AND LAUNCH OPERATIONS

4 PAYLOAD PROCESSING AND LAUNCH OPERATIONS

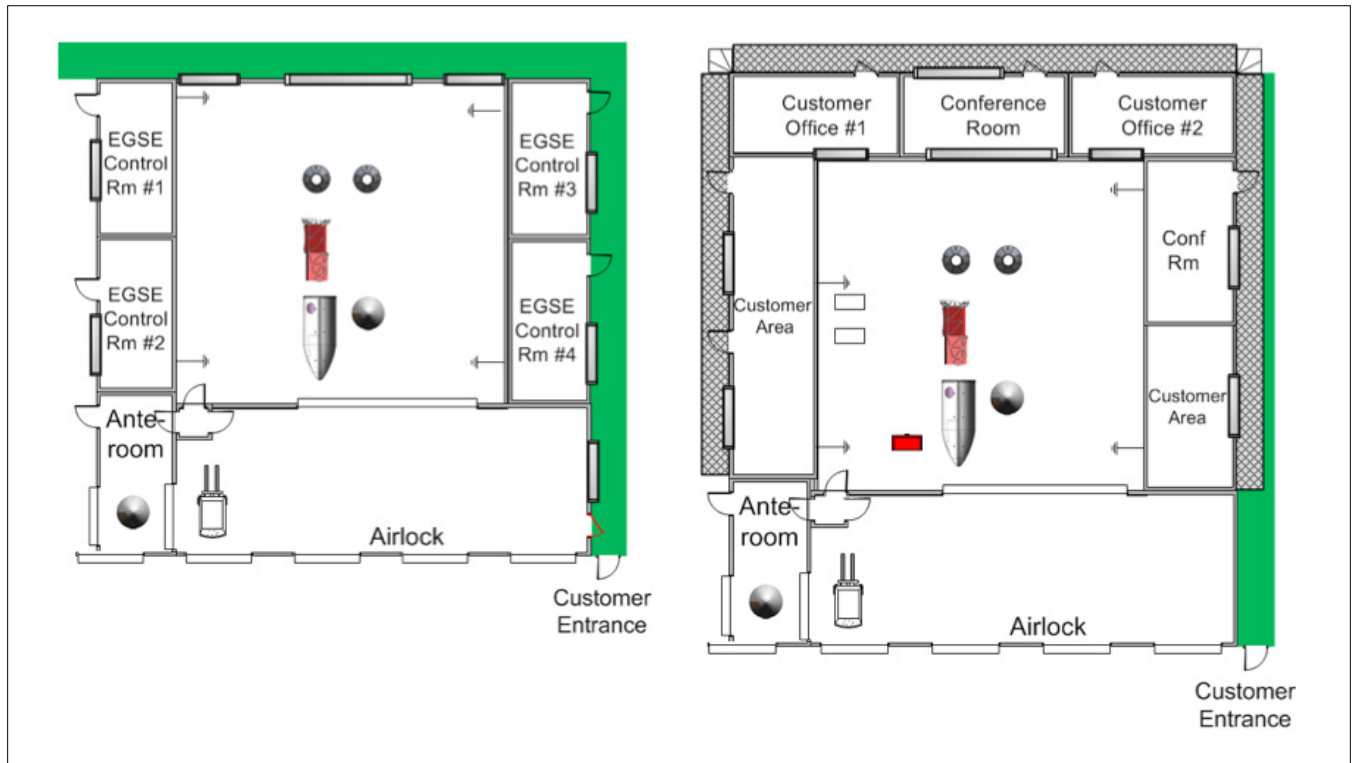
Payload integration and launch operations procedures are designed to minimize complexity, ensure system safety, and increase mission reliability. A typical processing flow is described in this section. Virgin Orbit is able to tailor standard payload processing and launch procedures to the customer's specific mission requirements.

4.1 PAYLOAD PROCESSING FACILITIES

Virgin Orbit offers a secure, climate-controlled Payload Processing Facility (PPF) at its headquarters in Long Beach, California, for checkout and preparation of customer payloads prior to encapsulation and integration with the launch vehicle. The PPF consists of office spaces and electrical ground support equipment control rooms adjacent to a clean room where payload processing takes place. Common mechanical ground support equipment is available for customer use and customer unique support equipment can be accommodated as well. Baseline services and equipment available at the PPF include:

- Office space, office support functions (print, copy, and fax), and with wired and/or wireless internet access
- Climate-controlled storage space
- Class 100,000 clean room (ISO 8) for customer spacecraft processing and fairing encapsulation
- Power provided for customer electrical ground support equipment at 100V AC, 60 Hz and 230V AC, 50 Hz
- Forklift, scissor lifts, rolling ladders, and small handheld tools
- Consumables including compressed air, helium, and nitrogen
- Virgin Orbit integration support personnel available up to six (6) days a week for ten (10) hours a day, and optional 24/7 support Security measures including electronic access IDs, 24-hour facility security guard, and CCTV.
- Accommodation of payload propellant fueling including cold gas, xenon/krypton, and various "green" propellants. Fully-fueled payload delivery will promote the most efficient integration process, but Virgin Orbit is able to address customer fueling requirements upon request. Fueling of hazardous propellants will occur at an external, Virgin Orbit-procured processing facility.

FIGURE 7/
FLOOR PLAN OF PAYLOAD PROCESSING
FACILITY IN LONG BEACH (1ST AND 2ND FLOORS)



4.2 PAYLOAD PROCESSING FLOW

Virgin Orbit aims to make payload processing operations as efficient and smooth as possible for our customers, by simplifying the integration process and offering as many essential resources as possible. Delivery of the payload is typically planned for 30 days prior to launch, but this timeline can be reduced upon request. Additionally, options exist for encapsulation of the payload at customer facilities if desired, and/or storage in a flight-ready state for rapid “on-demand” launch. Typical procedural steps of payload processing for launches from Mojave are as follows (for East Coast launches the PPF and Spaceport locations will differ):

01. **Spacecraft Delivery to the PPF (Long Beach, California):**
 Virgin Orbit places the customer-crated hardware and associated ground checkout equipment into the designated work areas, and provides unpacking/packing support as needed.
02. **Spacecraft Standalone Processing and Final Preparation (Long Beach, California):** The customer completes independent verification of the spacecraft and makes final flight preparations such as solar panel cleaning and removal of covers/pins, supported as necessary by Virgin Orbit-supplied EGSE and other equipment in the PPF.
03. **Spacecraft Mate:** A joint operation to mate the customer spacecraft to the separation system and/or payload adapter and then to the payload attachment fitting.
04. **Fairing Encapsulation (vertical orientation) (Long Beach, California):** The integrated spacecraft and separation system on the payload attachment fitting is then encapsulated within the payload fairing. This encapsulated assembly is then reoriented to horizontal for transport.

- 05. **Transport to the Spaceport:** The encapsulated payload is maintained in a climate controlled, positive pressure environment during transport to the launch port by a Virgin Orbit-supplied transportation system.
- 06. **Integration with the Launch Vehicle (Mojave, California):** Virgin Orbit horizontally mates the encapsulated payload assembly to the launch vehicle at the Mojave Spaceport.
- 07. **Late Payload Access (Mojave, California):** If required, late access to the payload is available with advance planning.

4.3 LAUNCH LOCATIONS

LauncherOne operates independently, and because we are not reliant on a government maintained launch range, we are unaffected by many of the external factors that can delay ground based launches from federal ranges such as weather, offline radar tracking assets, vehicles in the launch pad keep-out zone, and manifest jams on the increasingly crowded Eastern and Western ranges. The primary spaceport for LauncherOne is the Mojave Air and Space Port (MHV) in California. Virgin Orbit has completed launch assessments for MHV and is assessing requirements for a variety of lower latitude operating locations, including the Shuttle Landing Facility (SLF) at the Kennedy Space Center (KSC) in Florida, Kona International Airport (KOA) in Hawaii, and former Roosevelt Roads Naval Station in Puerto Rico. Virgin Orbit can also assess alternative launch locations and will pursue approvals to operate from these locations as necessary to support our customers' needs.

The baseline flight profile involves release of the LauncherOne launch vehicle over the Pacific Ocean, tens of kilometers from the California coastline, after a flight of approximately 30 minutes from Mojave. For low inclination launches, the drop point is optimally located based on the inclination desired for the mission. Due to the large range of the carrier aircraft and the flexible locations for spaceports, the drop point can be as low as 0 degrees latitude for 0 degree inclined orbits. In this case, the drop point could be over 1000 km from the launch port.

4.4 LAUNCH OPERATIONS FLOW

For standard launch operations, launch occurs within three days of payload encapsulation and transport to the spaceport. Key events in the launch schedule and typical timing relative to takeoff are as follows:

- 01. LauncherOne vehicle integration and checkout (L-3 days and earlier)
- 02. Payload mate to LauncherOne (L-3 days)
- 03. Launch Readiness Review (L-2 days)
- 04. Rollout and mate of LauncherOne with payload to carrier aircraft (L-1 day)
- 05. Propellant loading (T-6 hours to T-60 minutes)
- 06. 747 aircraft engine start and L1 GSE disconnect (T-30 minutes)
- 07. 747 aircraft take-off; LauncherOne purge provided to payload encapsulated environment by the carrier aircraft (T-30 minutes)
- 08. LauncherOne release and launch (T+0 minutes)
- 09. Second stage ignition (T+ 3 minutes)
- 10. Payload injection (Mission dependent, but approximately T+60 min)

5

PAYLOAD
ENVIRONMENTS

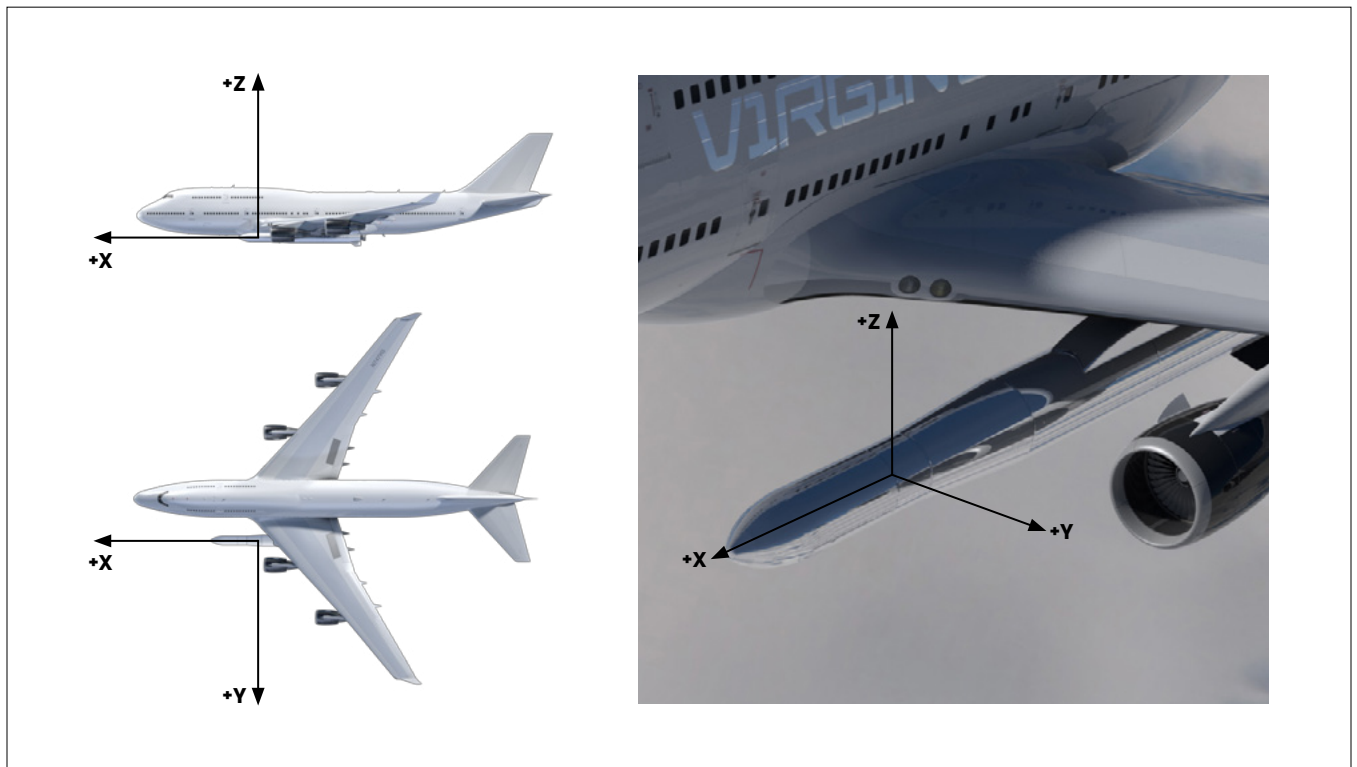
5 PAYLOAD ENVIRONMENTS

LauncherOne's payload environments are competitive with other similar launch vehicles throughout the flight profile, including ground segments, captive carry, and launch vehicle ascent. The predicted environmental conditions experienced by a typical payload are detailed in the following subsections. This payload environment data is provided for initial planning purposes only. Mission-specific analysis of expected payload environments is performed by Virgin Orbit as a standard service, and documented in the ICD.

5.1 VEHICLE COORDINATE SYSTEM

For interpretation of the quasi-static acceleration and random vibration environments relative to the LauncherOne payload orientation, the standard LauncherOne launch vehicle coordinate reference frame is provided in **FIGURE 8**. In this right-handed coordinate system, with the positive X-axis aligned with the launch vehicle longitudinal centerline. Roll is defined about the X-axis, pitch is about the Y-axis, and yaw is about the Z-axis. When in a horizontal, captive-carry configuration, the Z-axis is oriented inverse to the gravity vector and the Y-axis is parallel to the ground pointing out of the left side of the launch vehicle and carrier aircraft.

FIGURE 8/
LAUNCH VEHICLE
COORDINATE SYSTEM



5.2 PAYLOAD CONSTRAINTS

LauncherOne accommodates a wide range of payload masses up to 500 kg / 1100 lbm with a center of mass 1.25 m / 49 inches above the payload adapter interface.

5.3 ACCELERATION FROM QUASI-STATIC LOADS

TABLE 4 provides a representative maximum predicted quasi-static loads environment for LauncherOne at the payload interface. These are general quasi-static loads predictions which are further defined and verified by the mission-specific Coupled Loads Analysis. The values provided in the table bound the maximum acceleration for all phases of flight.

TABLE 4/
LAUNCHERONE PRIMARY PAYLOAD
DESIGN LOAD FACTORS

Type	Axial [x]	Lateral [y]	Lateral [z]
Acceleration [g]	-4g / +8g	+/- 5g	+/- 8g

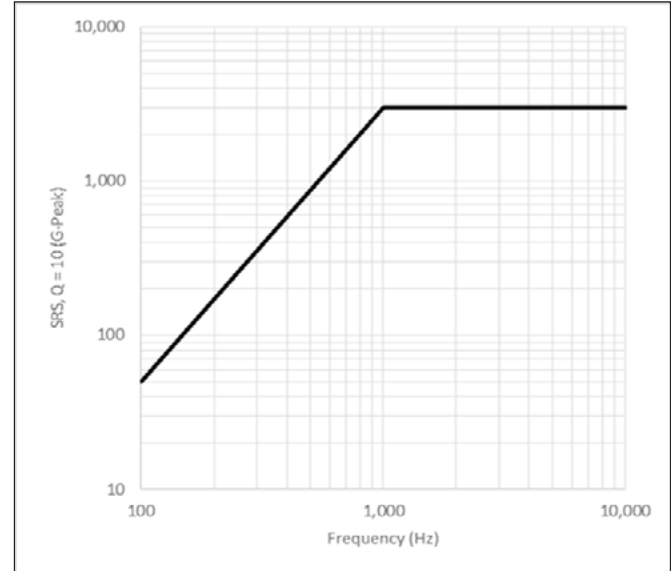
5.4 SHOCK ENVIRONMENT

The maximum predicted shock response spectrum at the standard payload-to-launch vehicle interface from all launch vehicle events is shown below in **TABLE 5** and **FIGURE 9**. For mission unique adapters, this shock value will be recomputed at the specific interface of your spacecraft. In many cases, due to the addition of payload adapter structure, this value is lower.

TABLE 5/
LAUNCHERONE DESIGN LOAD FACTORS
AT THE STANDARD INTERFACE

Frequency [Hz]	Shock Maximum Predicted Environment, All Axes [Shock Response Spectrum g-peak, Q=10]
100	50
1,000	3,000
10,000	3,000

FIGURE 9/
MAXIMUM PREDICTED SHOCK ENVIRONMENT
AT THE STANDARD PAYLOAD INTERFACE



5.5 RANDOM VIBRATION

The LauncherOne primary payload predicted maximum random vibration environment in the axial and lateral direction are shown below. For mission unique adapters, this shock value will be recomputed at the particular interface of your spacecraft.

TABLE 6/
LAUNCHERONE MAXIMUM PREDICTED
RANDOM VIBRATION ENVIRONMENT
(AXIAL) AT THE STANDARD PAYLOAD

Frequency (Hz)	Power Spectral Density (PSD) (g ² /Hz)
20	0.007
50	0.016
80	0.050
2,000	0.050

9.86 g root mean squared (grms)

FIGURE 10/
MAXIMUM PREDICTED RANDOM VIBRATION
ENVIRONMENT (AXIAL) AT THE STANDARD
PAYLOAD INTERFACE

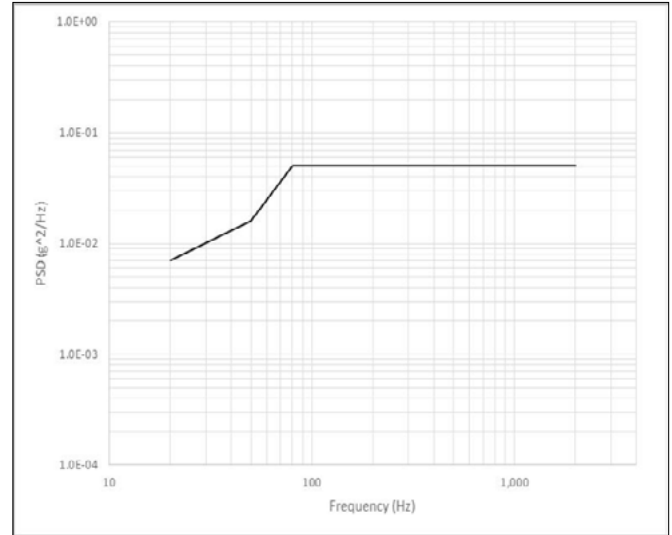
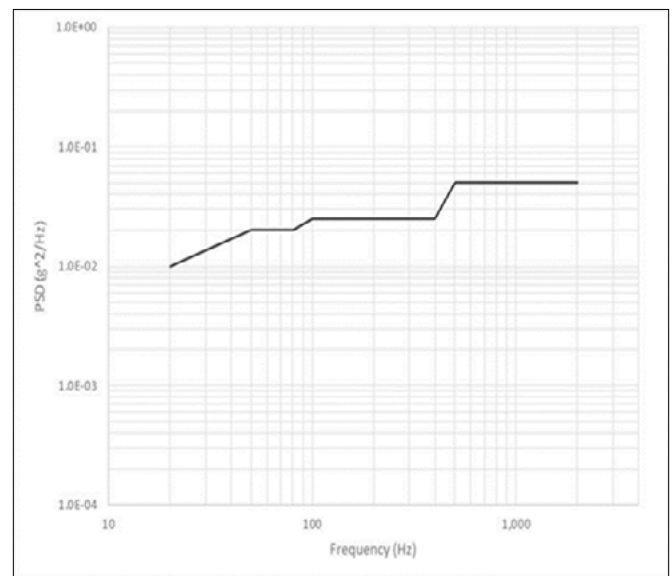


TABLE 7/
LAUNCHERONE MAXIMUM PREDICTED RANDOM
VIBRATION ENVIRONMENT (LATERAL) AT THE
STANDARD PAYLOAD INTERFACE

Frequency (Hz)	Power Spectral Density (PSD) (g ² /Hz)
0	0.010
50	0.020
85	0.020
100	0.025
400	0.025
525	0.050
2000	0.050

9.34 grms

FIGURE 11/
MAXIMUM PREDICTED RANDOM VIBRATION
ENVIRONMENT (LATERAL) AT THE STANDARD
PAYLOAD INTERFACE



5.6 ACOUSTICS

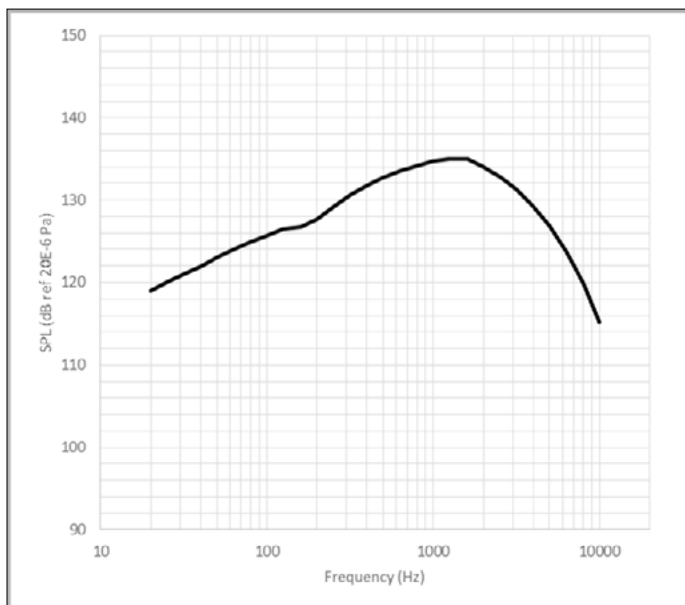
The maximum predicted acoustic environment for a typical payload fill factor is defined in **TABLE 8** and **FIGURE 12**. For missions of very large or small fill factors, a mission unique acoustic analysis is performed.

TABLE 8/
MAXIMUM PREDICTED
ACOUSTIC ENVIRONMENT

Frequency [Hz]	Sound Pressure Level [SPL] [dB, Reference: 2e-5 Pa]	Frequency [Hz]	SPL [dB, Reference: 2e-5 Pa]
20	119.0	500	132.7
25	120.0	630	133.5
31.5	121.0	800	134.2
40	122.0	1,000	134.7
50	123.0	1,250	135.0
63	124.0	1,600	135.0
80	125.0	2,000	134.0
100	125.7	2,500	132.8
125	126.5	3,150	131.3
160	126.8	4,000	129.2
200	127.7	5,000	126.9
250	129.2	6,300	123.8
315	130.5	8,000	119.8
400	131.7	10,000	115.2

Overall Sound Pressure Level
[OASPL] = 144.77 dB

FIGURE 12/
MAXIMUM PREDICTED
ACOUSTIC ENVIRONMENT



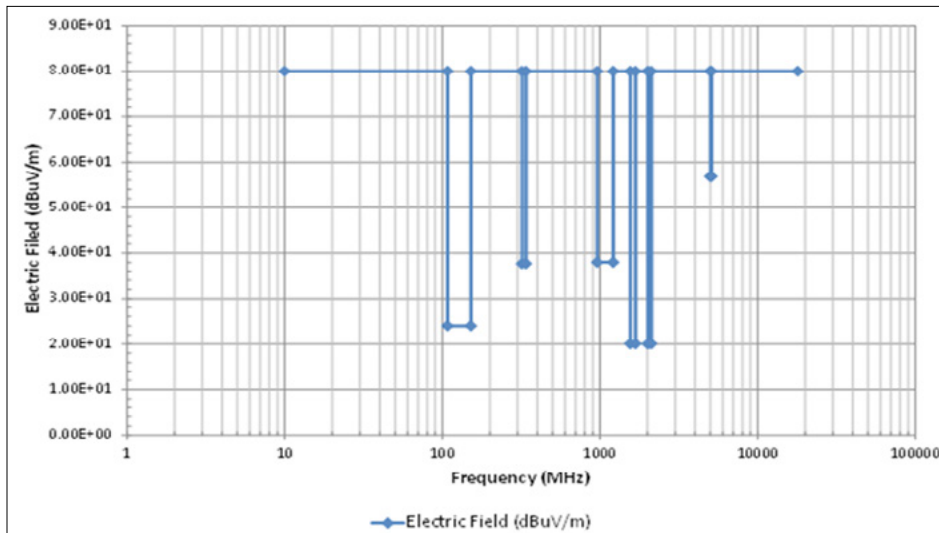
5.7 PAYLOAD RADIO FREQUENCY (RF) CONSTRAINTS

As with most modern launch vehicles, there is potential for electromagnetic interference (EMI) with launch vehicle avionics given the proximity of launch vehicle communications systems to the payload. Payload RF transmissions are permitted during captive carry, ascent, and shortly after separation but are subject to the results of an EMI/EMC compatibility analysis conducted by Virgin Orbit. Maximum permissible payload electric field emissions are defined in **TABLE 9** and **FIGURE 13**, and provided here as guidance for the customer.

**TABLE 9/
MAXIMUM SPACECRAFT
ELECTRIC FIELD EMISSIONS**

Frequency [RF susceptibility, MHz]	Electric Field [dBuV/m]	Frequency [Hz]	SPL [dB, Reference: 2e-5 Pa]
10	80.0	1,559	80.0
108	80.0	1,559	20.0
108	24.0	1,680	20.0
152	24.0	1,680	80.0
152	80.0	2,015	80.0
320	80.0	2,015	20.0
320	37.7	2,120	20.0
340	37.7	2,120	80.0
340	80.0	5,020	80.0
960	80.0	5,020	56.8
960	38.0	5,100	56.8
1,215	38.0	5,100	80.0
1,215	80.0	18,000	80.0

**FIGURE 13/
MAXIMUM ALLOWABLE SPACECRAFT
ELECTRIC FIELD EMISSIONS**



5.8 THERMAL AND HUMIDITY ENVIRONMENT

Conditioned air is provided to the payload during all phases of operations until receipt of the payload container to separation from the carrier aircraft. The payload thermal environment is maintained at 21 ± 3.5 degrees Celsius (69.8 ± 6.3 degrees Fahrenheit), and relative humidity is controlled from 40-60%. There will be short outages (up to 30 minutes) for connections to different configurations for the various phases of ground operations. These outages will not result in a violation of the previously described thermal environment.

During captive carry flight, the fairing is purged with temperature and contamination controlled air to maintain adequate temperature and cleanliness in the fairing volume. The bulk air temperature in the payload fairing is controlled from 15.5 ± 11.1 degrees Celsius (60 ± 20 degrees Fahrenheit). At the customer's request, electrical power is provided to the payload during captive carry for internal spacecraft thermal control.

5.9 FAIRING PRESSURE ENVIRONMENT

During ascent, the maximum depressurization rate for LauncherOne is less than 2758 Pa/second (0.4 psi/second) from liftoff through immediately prior to fairing separation, except for a brief period during the transonic spike, in which a time-averaged decay rate that is no higher than 0.55 psi/sec for no more than 5 seconds.

5.10 SEPARATION SYSTEM SIGNAL

For the standard launch vehicle-to-payload electrical interface scheme, the LauncherOne payload controller provides a primary and redundant separation signal directly to the payload separation system. The payload controller is capable of providing multiple signals enabling multi-spacecraft missions.

5.11 SPACECRAFT ELECTRICAL INTERFACE

At the customer's request, the payload adapter wire harness can include a spacecraft umbilical connector to provide a connection from the spacecraft to customer electrical ground support equipment (EGSE). This extra harness can be used to supply power and provide a data connection to the payload during storage and vehicle-level integration. These payload accommodations are defined in **TABLE 10** and **TABLE 11**.

FIGURE 14/
PAYLOAD ELECTRICAL
INTERFACE DIAGRAM

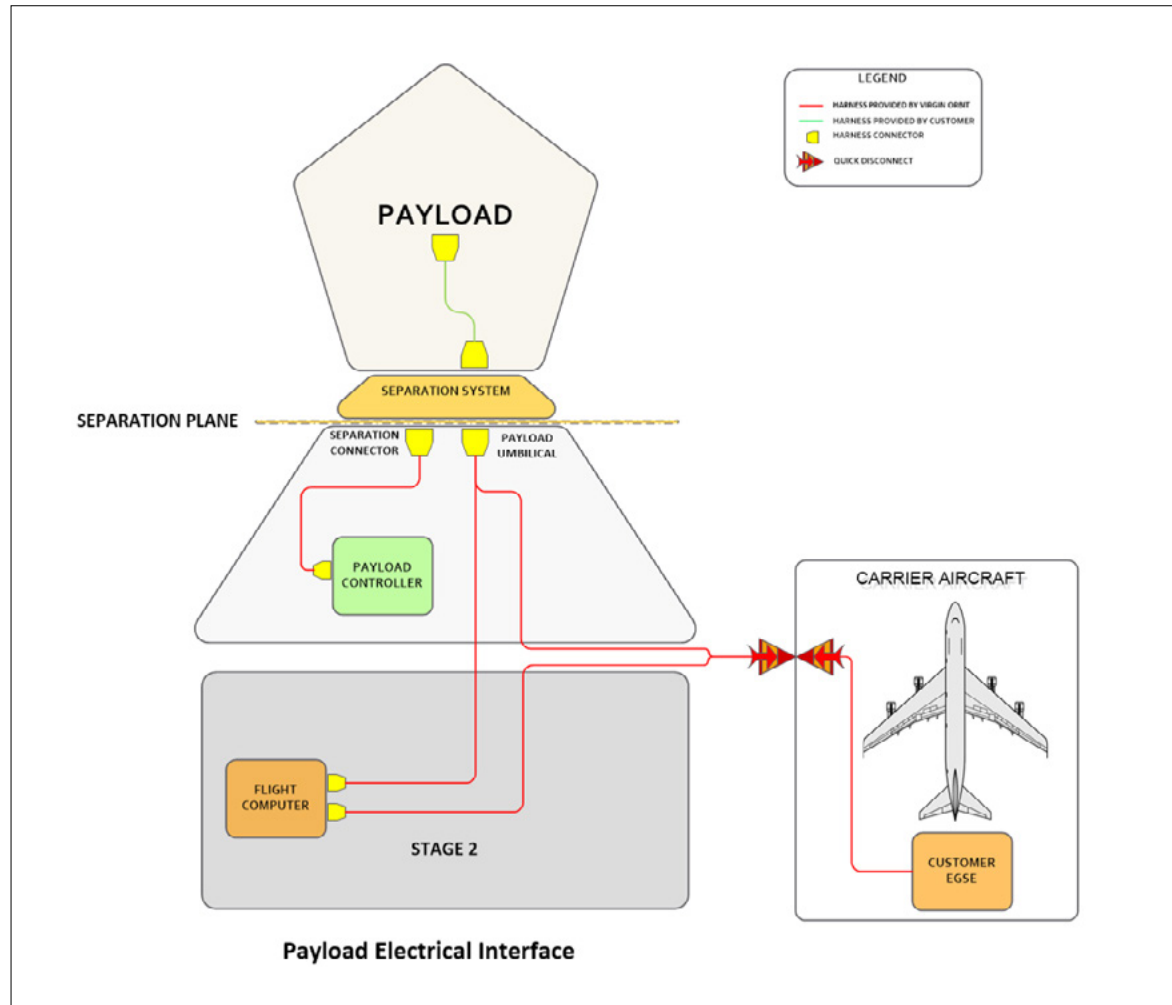


TABLE 10/
PAYLOAD POWER SERVICES

Description	Provision
Voltage	28V power (regulated to within 18-36 V) can be provided to the payload at the customer's request.
	28V power is capable of 1A current during captive carry flight. During ground operations, 3 Amps is available to the payload.

TABLE 11/
PAYLOAD COMMUNICATIONS
SERVICES

Description	Provision
Unprocessed Twisted Pairs	Payload communication over 8 twisted pair to GSE can be supported to provide Command and Telemetry during ground processing at the customer's request.
EGSE Telemetry, Captive Carry	100 Kbps payload telemetry, stored to aircraft Data Acquisition Storage, is supported during captive carry.
EGSE Telemetry, Ground Operations	1 Mbps payload telemetry is supported during ground operations.



ABOUT
VIRGIN
ORBIT

6 ABOUT VIRGIN ORBIT

Virgin Orbit is a United States company with corporate headquarters and production in Long Beach, California, and propulsion, test and launch operations facilities in nearby Mojave, California. A vertically integrated approach and the close proximity of engineering, manufacturing, and operations functions are our keys to the production of reliable, low-cost launch vehicles. In addition to launches originating from Mojave, LauncherOne is capable of operating from a variety of spaceports worldwide.

6.1 CORPORATE OVERVIEW

Virgin Orbit is part of the Galactic Ventures family, along with our sister companies Virgin Galactic and The Spaceship Company (TSC). With over 300 dedicated employees, Virgin Orbit's exclusive focus is on the small satellite launch market. Virgin Orbit maintains separate manufacturing and test facilities from Virgin Galactic and TSC.

FIGURE 15/
THE VIRGIN ORBIT FAMILY



6.2 LAUNCH VEHICLE PRODUCTION AND TEST FACILITIES

The Virgin Orbit headquarters is an 180,000 square foot / 16,700 square meter facility in Long Beach, California, housing office space and a large manufacturing floor. The vast majority of our design, engineering, manufacturing, integration, assembly, and test activities occur in this facility. The Virgin Orbit engineering team works directly adjacent to the LauncherOne production and assembly line featuring state-of-the-art manufacturing equipment and custom-built test rigs.

FIGURE 16/
HEADQUARTERS IN LONG BEACH,
CALIFORNIA FOR MANUFACTURING
AND INTEGRATION



Virgin Orbit's Necker liquid propulsion test site in Mojave, California leverages existing facilities from our sister company Virgin Galactic, along with new facilities built specifically for LauncherOne. Liquid propulsion, composite tank, and overall stage testing is performed here at one of eight test stands. LauncherOne engine development and maturation is supported by horizontal test stands permitting full duration hot fire testing. Propulsion testing culminates in full duration, mission duty cycle hot fire testing of the completed Stage 1 and Stage 2 assemblies on vertical tests stands. Stage integration testing performed at the Necker test site includes a fully mated vehicle, hung horizontally from a simulated 747 aircraft wing.

FIGURE 17/
NECKER LIQUID PROPULSION TEST
SITE AND NEWTON 3 HOT FIRE TEST
ON TEST STAND TWO



6.3 SPACEPORT FACILITIES

The primary launch location for West Coast U.S. launch service is the Mojave Air & Space Port (MHV), a spaceport licensed by the FAA for commercial horizontal launch operations of reusable vehicles, such as our 747 aircraft. The mobile launch capability provided to LauncherOne eliminates the need for extensive infrastructure associated with ground launch. "Clean pad" operations are entirely mobile and involve only the Cosmic Girl carrier aircraft, with LauncherOne mated underwing, and ground support trailers.

Launch operations for all spaceports are managed from Virgin Orbit's mobile control room. Launch operations are additionally supported by a launch engineer on console in the 747-400 and teams on console at the headquarters facility in Long Beach. Software operated by vehicle controllers in the mobile control room receives telemetry and commands the launch vehicle, as well as ground systems aboard the tractor-trailers as needed prior to separation from the 747 aircraft.



DOCUMENT REFERENCE

7.1 LIST OF ACRONYMS

AFSS	Autonomous Flight Safety System
CAD	Computer-Aided Design
CCAFS	Cape Canaveral Air Force Station
C/CAM	Collision/Contamination Avoidance Maneuver
CLA	Coupled Loads Analysis
EGSE	Electrical Ground Support Equipment
ESPA	EELV Secondary Payload Adapter
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
GSE	Ground Support Equipment
ICD	Interface Control Document
KOA	Kona International Airport
KSC	Kennedy Space Center
LEO	Low Earth Orbit
LOX	Liquid Oxygen
LSA	Launch Services Agreement
MHV	Mojave Air and Space Port
N3	Newton 3 [1st stage engine]
N4	Newton 4 [2nd stage engine]
OSHA	Occupational Safety and Health Administration
PPF	Payload Processing Facility
PSC	Planetary Systems Corporation
PRR	Payload Readiness Review
PSD	Power Spectral Density
RAAN	Right Ascension of Ascending Node
RF	Radio Frequency
RP	Rocket Propellant
SLF	Shuttle Landing Facility
SSO	Sun-Synchronous Orbit

7.2 LIST OF TABLES

Table 1.	Launch Services Quick Reference 6
Table 2.	Typical Orbital Injection Accuracy [3 sigma] 9
Table 3.	Typical Pre-Separation Attitude and Spin-Rate Accuracies [3 sigma] 9
Table 4.	LauncherOne Primary Payload Design Load Factors 23
Table 5.	LauncherOne Design Load Factors at the Standard Interface 23
Table 6.	LauncherOne Maximum Predicted Random Vibration Environment [Axial] at the Standard Payload Interface 24
Table 7.	LauncherOne Maximum Predicted Random Vibration Environment [Lateral] at the Standard Payload Interface 24
Table 8.	Maximum Predicted Acoustic Environment 25
Table 9.	Maximum Spacecraft Electric Field Emissions 26
Table 10.	Payload Power Services 28
Table 11.	Payload Communications Services 28

7.3 LIST OF FIGURES

- Figure 1. LauncherOne System Expanded View 4
- Figure 2. LauncherOne Sample Payload Configurations 5
- Figure 3. Orbital Payload Delivery Performance Curves 8
- Figure 4. Payload Fairing Dynamic Envelope 10
- Figure 5. Payload Separation Interface 11
- Figure 6. Nominal Schedule for Launch Service 15
- Figure 7. Floor Plan of Payload Processing Facility in Long Beach (1st and 2nd floors) 19

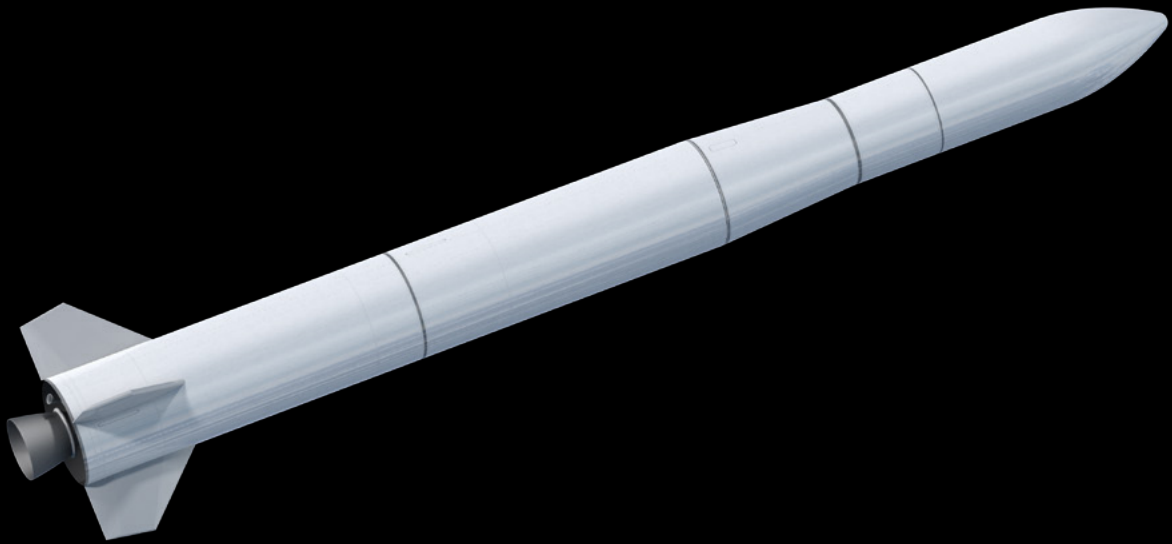
- Figure 8. Launch Vehicle Coordinate System 22
- Figure 9. Maximum Predicted Shock Environment at the Standard Payload Interface 23

- Figure 10. Maximum Predicted Random Vibration Environment (Axial) at the Standard Payload Interface 24
- Figure 11. Maximum Predicted Random Vibration Environment (Lateral) at the Standard Payload Interface 24

- Figure 12. Maximum Predicted Acoustic Environment 25
- Figure 13. Maximum Allowable Spacecraft Electric Field Emissions 26
- Figure 14. Payload Electrical Interface Diagram 28
- Figure 15. The Virgin Orbit Family 30
- Figure 16. Headquarters in Long Beach, California for Manufacturing and Integration 31

- Figure 17. Necker Liquid Propulsion Test Site and Newton 3 Hot Fire Test on Test Stand Two 31







ORBIT

LAUNCHERONE SERVICE GUIDE

Virgin Orbit, LLC / Version 1.0 / 7 August 2017

For questions about bookings, capabilities, or this User's Guide itself, please do not hesitate to contact Virgin Orbit at info@virginorbit.com. Please note that this customer brochure is a working document, and as such is revised and updated periodically. Virgin Orbit encourage readers to visit virginorbit.com frequently to ensure they have the latest revision.