



ORBIT



LAUNCHERONE SERVICE GUIDE

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LAUNCHERONE

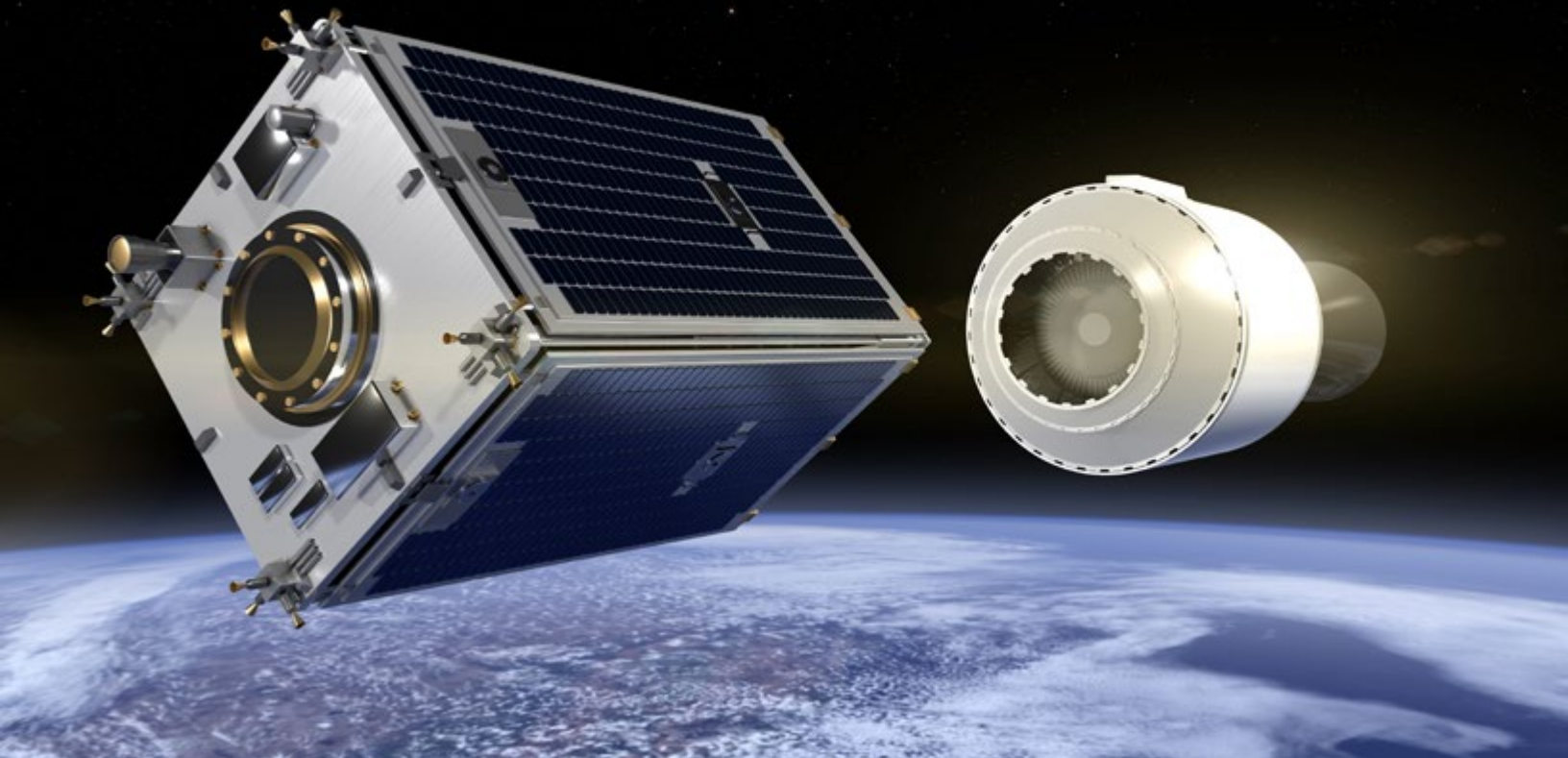


ORBIT

Virgin

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LAUNCHING THE SMALL SATELLITE REVOLUTION

Virgin Orbit is excited about the tremendous potential of small satellites to provide global connectivity, remote sensing, security, and other new, visionary 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

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CONTENTS

1 THE VIRGIN ORBIT EXPERIENCE

1.1	About Virgin Orbit	4
1.2	Corporate Overview	4
1.3	The Extraordinary Powers of Air Launch	6
1.4	Get to Know Our System	7
1.5	Capabilities at a Glance	8

2 DESIGN YOUR MISSION

2.1	Payload Delivery Capability	10
2.2	Mission Profile	11
2.3	Orbit Insertion Accuracy	13
2.4	Payload Accommodations	14
2.5	Mechanical Interfaces	15
2.6	Electrical Interfaces	16
2.7	Electrical Access	17
2.8	General Rules of Thumb for Cubesats	18
2.9	Supported Separation Systems	19

3 THE VIRGIN ORBIT LAUNCH SERVICE PROCESS

3.1	Launch Service Elements	21
3.2	Launch Service Schedule	22
3.3	Customer Responsibilities	22
3.4	Safety and Mission Assurance	23
3.5	Photography Policy	23
3.6	U.S. Import and Export Compliance	23

4 PAYLOAD PROCESSING AND LAUNCH OPERATIONS

4.1	Payload Processing Flow	26
4.2	Payload Processing Facilities	28
4.3	Payload Transport	30
4.4	Launch Locations	31
4.5	Launch Operations Flow	31
4.6	Mechanical and Electrical Access	31

5 PAYLOAD ENVIRONMENTS

5.1	Vehicle Coordinate System	33
5.2	Payload Constraints	33
5.3	Acceleration from Quasi-Static Loads	34
5.4	Shock Environment	34
5.5	Random Vibration	35
5.6	Acoustics	36
5.7	Payload Radio Frequency (RF) Constraints	37
5.8	Spacecraft Intentional Emitters and Receivers	38
5.9	Launch Vehicle and Carrier Aircraft not to exceed RF Electric Field Limit	38
5.10	Thermal and Humidity Environment	39
5.11	Fairing Pressure Environment	40
5.12	Spacecraft Qualification and Compliance	40

6 VIRGIN ORBIT LOCATIONS

6.1	Launch Vehicle Production and Test Facilities	42
6.2	Spaceport Facilities	43

7 DOCUMENT REFERENCE

7.1	List of Acronyms	47
7.2	List of Tables	47
7.3	List of Figures	47

A APPENDIX

A.1	Overview of Virgin Orbit & Customer Deliverables by Milestone	49
A.2	Description of Virgin Orbit Deliverables	50
A.3	Description of Customer Deliverables	50
A.4	Customer Spacecraft Testing Requirements	51



**THE
VIRGIN
ORBIT
EXPERIENCE**

1 — THE VIRGIN ORBIT EXPERIENCE

The rapidly growing small satellite industry requires a launch service that is as agile, flexible, and affordable as the spacecraft themselves. 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.

1.1 — ABOUT VIRGIN ORBIT

Virgin Orbit is developing the LauncherOne small launch platform, which will provide affordable, dedicated rides to orbit for small satellites starting in 2020. Virgin Orbit is striving to be the world's premier small satellite launch service providing dedicated launches to the orbit and schedule of choice. Utilizing an air-launch approach from a 747-400 carrier aircraft, Virgin Orbit's LauncherOne is the launch service that will accelerate the small satellite revolution by offering the agility, flexibility, and affordability necessary to transform the space landscape. Virgin Orbit has invested in the team, technologies, and facilities required to usher in a new era of launch accessibility and is proud to bring the Virgin standard of unparalleled customer service to the space industry.

Virgin Orbit is a United States company with its corporate headquarters, factory, and payload processing activities in Long Beach, California, and propulsion, test and launch operations facilities in nearby Mojave, California. A vertically integrated approach, well-capitalized factory, and the close proximity of engineering, manufacturing, and operations functions enable high-rate production of the LauncherOne vehicle.

In addition to launching from the Mojave Air & Space Port to support high-inclination missions, Virgin Orbit can also conduct LauncherOne missions from Guam to support low- and mid-inclination missions. Furthermore, LauncherOne is capable of operating from a variety of spaceports worldwide, such as Launch and Landing Facility in Florida, Spaceport Cornwall in the United Kingdom and Spaceport Oita in Japan.

1.2 — CORPORATE OVERVIEW

Established in 2017, Virgin Orbit's exclusive focus is serving the small satellite launch market with the disruptive customer-focused DNA that the Virgin Group is known for. Virgin Orbit is part of the Virgin Group's Galactic Ventures family of innovative space companies, along with our sister companies Virgin Galactic and The Spaceship Company (TSC). Virgin Orbit is comprised of nearly 600 dedicated employees led by President and CEO Dan Hart.

Virgin Orbit has two subsidiaries as part of its corporate structure. VOX Space, LLC, is a U.S.-incorporated entity headquartered in Manhattan Beach, CA, that provides the national security community with responsive, dedicated, and affordable launch services for small satellites. In 2020, VOX Space secured the U.S. Space Force's STP-S28 launch contract, a mission for three separate launches to deliver dozens of small satellites to LEO for experiments and technology demonstrations.

Virgin Orbit UK Limited (VO-UK) is the new UK branch of Virgin Orbit LLC. VO-UK aims to enable air launch for small satellites from Spaceport Cornwall. With operations based in the UK, VO-UK intends to serve as the most flexible European launch service provider.

FIGURE 1
THE VIRGIN ORBIT FAMILY



A team photo of the Virgin Orbit staff in October 2018



From left to right: George Whitesides (former CEO), Sir Richard Branson, Dan Hart (current President & CEO)

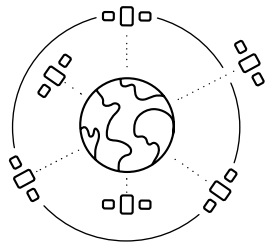
1.3 THE EXTRAORDINARY POWERS OF AIR LAUNCH

Virgin Orbit's LauncherOne system is the most flexible small launch system on the market, combining a reliable and proven 747-400 carrier aircraft with a simple, low-cost rocket architecture. The key tenets of our launch services are as follows:

TAILORED MISSION OPERATIONS

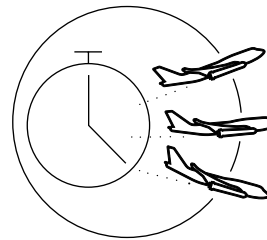
Our 747-400 carrier aircraft, Cosmic Girl, serves as a fully-reusable flying launch pad. With decades of operational excellence, Cosmic Girl is a proven design with a global supply chain and well-characterized performance.

By beginning missions from this mobile asset, LauncherOne can offer tailored mission operations suited to each customer's individual needs. Having a carrier aircraft enables launches from the most optimal drop points, eliminating costly dogleg maneuvers from fixed ground launch locations.



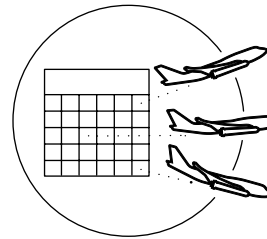
ANY ORBIT

Any Low Earth Orbit and inclination is obtainable via our spaceports and runway access around the globe. This includes our main spaceport in Mojave for high-inclination orbits and Guam for low- and mid-inclination orbits.



ON YOUR SCHEDULE

We are building rockets continuously, not just per mission. This ensures regular development of launch vehicles to provide on-time delivery of launch services. In addition, due to our small footprint and aircraft-like operations, it is possible to move up or back in the manifest depending on schedule requirements. This white-tail approach provides ultimate flexibility for our customers.



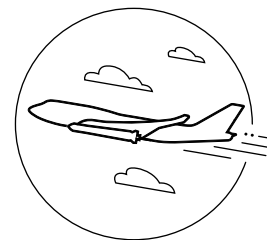
HIGH CADENCE

Our aircraft-like operations, small launch support footprint, and trailerized equipment can be ready to support launches in a short timeframe. As a result, we are capable of getting prepared for launch in a matter of days. This enables a responsive capability for critical assets and populating constellations to enable rapid operational capability or filling in coverage gaps.



MOBILE LAUNCH SYSTEM

We utilize six main mobile trailers to support our launch campaigns. These trailers are fully mobile and can be positioned and readied within a few days. They can be transported to any spaceport around the world. Mobile launch is a true game changer for the launch industry as Virgin Orbit, for the first time in history, can bring a "launch to you." This includes regional access through spaceport hubs or in-country launches where a spaceport license is granted and the regulatory framework and approvals are in place. Mobile launch and regional access to launch will help spur new space economies around the world.



RESPONSIVE LAUNCH

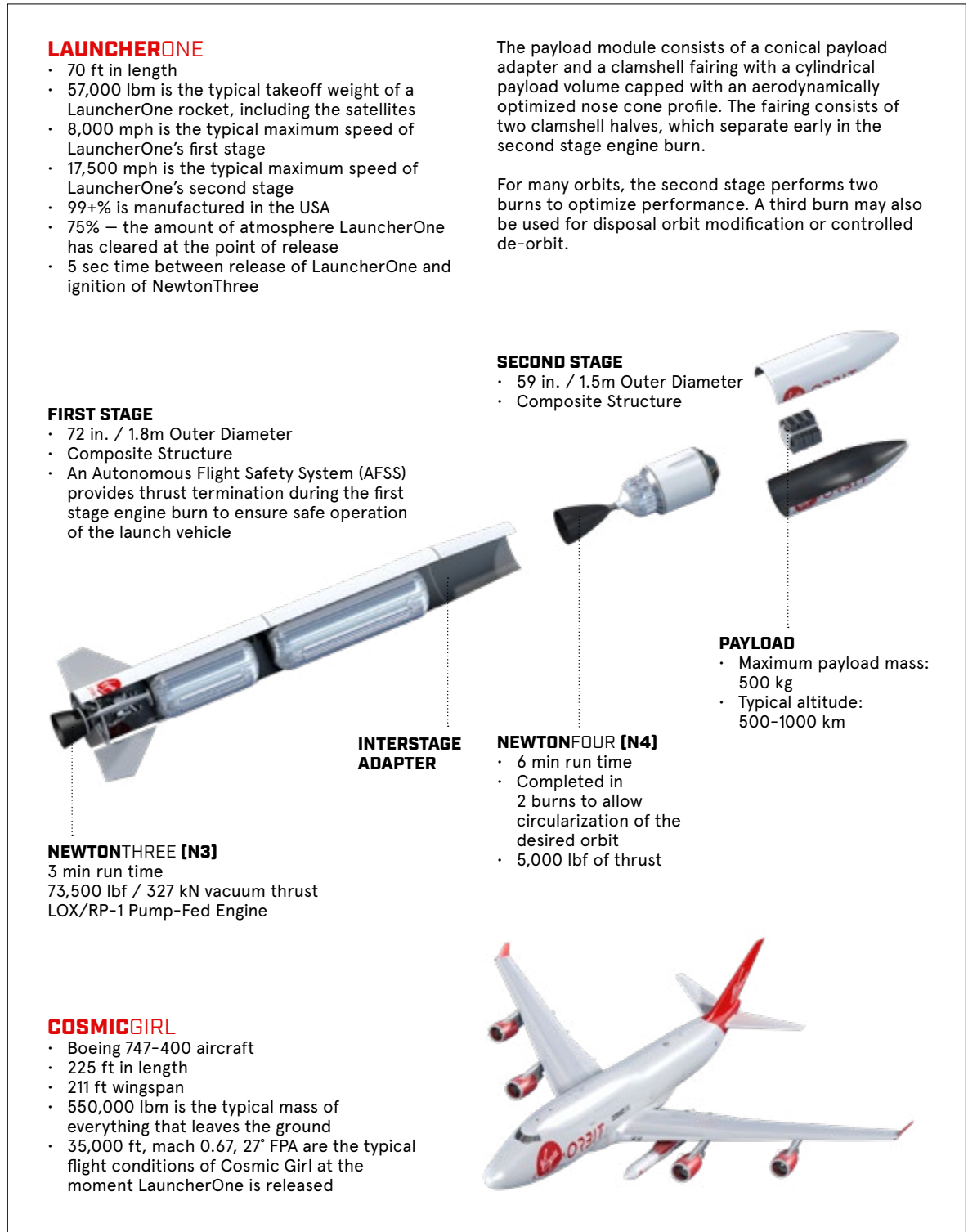
Responsive launch is the culmination of the four flexible capabilities air launch brings to the table. Responsiveness specifically refers to a quick call-up service where a satellite is placed into orbit on timeframes much shorter than with conventional ground launch solutions. This will help with providing resilient space capability for national security purposes (primarily as a deterrent) and enable quick reconstitution of smallsat constellations or individual satellites in the event of an anomaly or widespread fallout. In addition, responsive launch will change the way constellations are planned; constellation operators can plan fewer on-orbit spares knowing that LauncherOne can fill in gaps when satellites reach their end of life or run into anomalies.

1.4 GET TO KNOW OUR SYSTEM

LauncherOne is Your Ride to Space

LauncherOne is a simple, expendable launch vehicle designed to place small satellites of up to 500 kg / 1,100 lbm into a wide range of Low Earth Orbits (LEO). Rather than launching from the ground, LauncherOne is carried to an altitude of approximately 35,000 feet by the 747-400 carrier aircraft, Cosmic Girl, as depicted in **FIGURE 2**.

FIGURE 2
LAUNCHERONE SYSTEM EXPANDED VIEW



1.5 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 / 1,100 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 diameter 2123 mm / 83.6 inch constant cylindrical length 3543 mm / 139.5 inch overall payload fairing envelope length
Launch Altitudes/ Inclinations	<ul style="list-style-type: none"> Capable of accessing any orbital inclination; subject to any launch site-specific population overflight constraints Flexibility to conduct launches from any licensed spaceport facility
Launch Schedule	<ul style="list-style-type: none"> Emphasis on reducing time-to-launch; able to accommodate <12 month launch timeline Flexible launch windows to accommodate schedule changes/variation
Payload Processing	<ul style="list-style-type: none"> Virgin Orbit’s customer payload processing facility with ISO Level 8 (100k class) clean room in Long Beach, CA Additional Payload options include: Receipt of cubesat loaded in dispenser Storage of loaded cubesat Encapsulation of payload at the customer site
Payload Integration	<ul style="list-style-type: none"> Payload Attach Fitting with baseline interface diameter of 609.6 mm / 24.0 inches; other various diameters and bolt patterns available Compatible with ESPA and ESPA Grande class configurations Support for commercially available separation systems and CubeSat dispensers Secondary payloads manifested and managed directly by Virgin Orbit or via payload brokers or aggregators
Regulatory Approach	<ul style="list-style-type: none"> Virgin Orbit’s LauncherOne launch is licensed under the Federal Aviation Administration regulation 14 CFR 431, Launch and Reentry of a Reusable Launch Vehicle (RLV). Compliance with international orbital debris disposal guidelines

DESIGN YOUR MISSION



2 DESIGN YOUR MISSION

LauncherOne's air-launch architecture enables unparalleled flexibility. This section will help you to customize your mission.

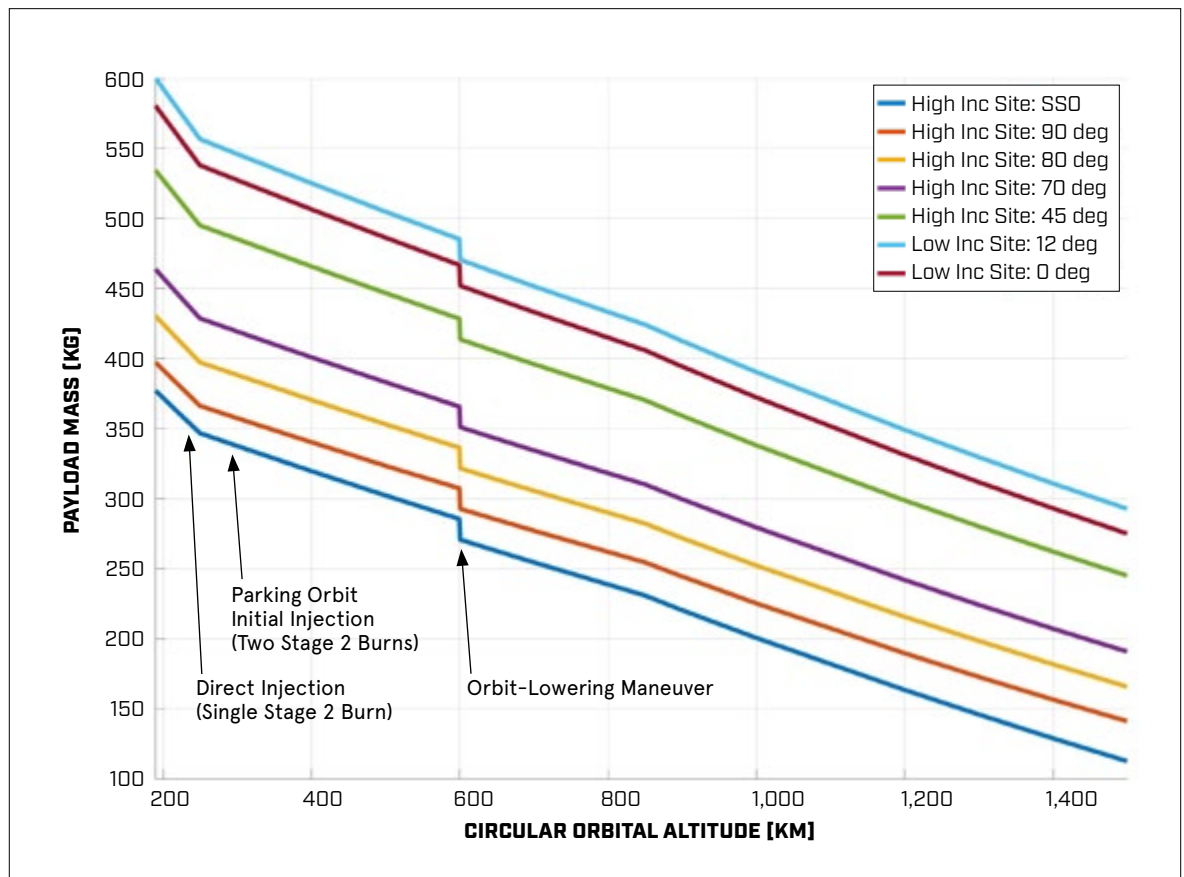
21 PAYLOAD DELIVERY CAPABILITY

Performance curves for LauncherOne payload delivery to several reference orbits are provided in **FIGURE 3**. Due to LauncherOne's high degree of customization, payload capabilities are best calculated for each customer based on their specific requirements. For more detailed payload capabilities, please contact Virgin Orbit.

LauncherOne is designed to meet regulations that require a maximum orbit lifetime of less than 25 years for an upper stage left above approximately 600 km. Meeting this requirement necessitates a disposal burn for orbital altitudes above 600 km, consequently consuming a portion of total propellant. This is represented as the dip in the performance at 600 km in the performance curves. The increased performance below 230 km is for direct-inject orbits where a circularization burn is not required.

The performance curves in **FIGURE 3** provide the total spacecraft 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 refer to Section 2.8 for more information on separation systems.

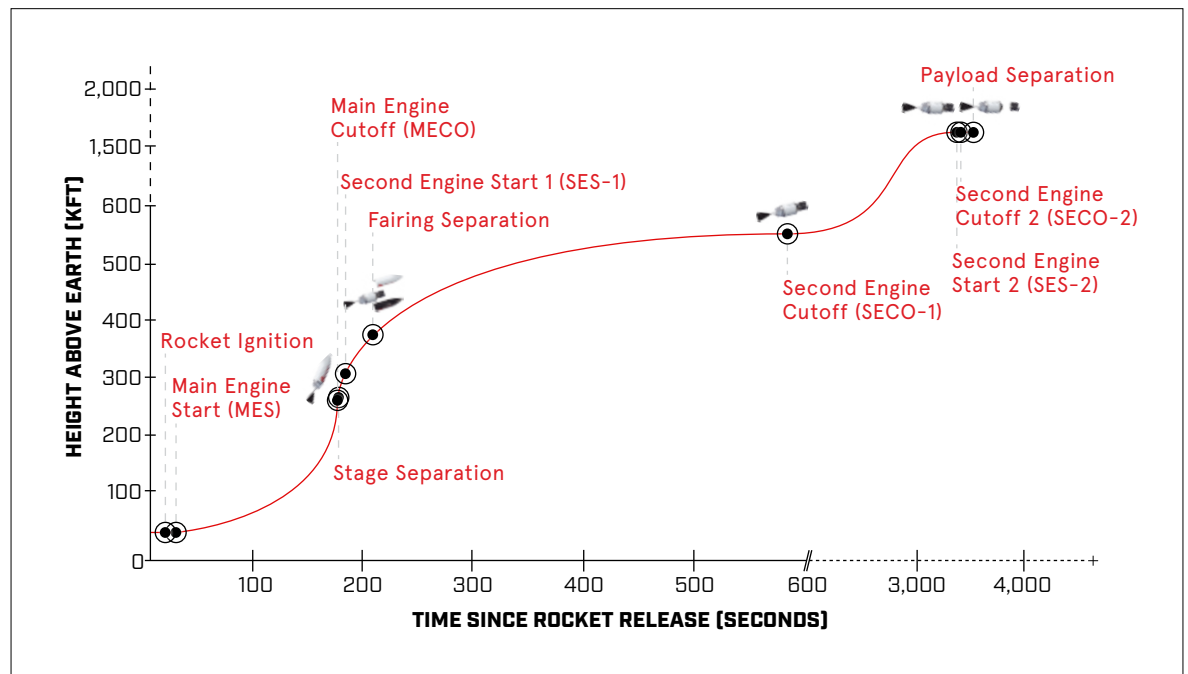
FIGURE 3
ORBITAL PAYLOAD DELIVERY PERFORMANCE CURVES



2.2 MISSION PROFILE

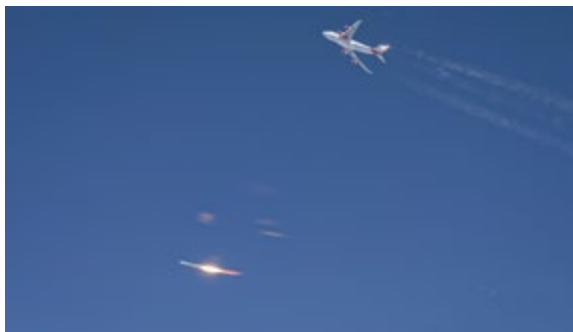
For most LauncherOne missions, the mission profile is as follows. The carrier aircraft Cosmic Girl takes off from the launch site with the fueled LauncherOne and payload. The plane flies out over an unpopulated flight corridor above the ocean to an altitude of 35,000 feet, and releases LauncherOne after Cosmic Girl has entered into a climb maneuver. Approximately 5 seconds later, vehicle ignition occurs and the vehicle ascends several hundred thousand feet before first stage Main Engine Cutoff (MECO) occurs at approximately 3 minutes after drop. The second stage is then ignited following a short coast and carries the payload to a low parking orbit (for missions that are not direct-inject), shedding the payload fairing along the way early during second stage burn. During a coast of approximately half an orbit, passive thermal control is performed with a nominal spin rate of 0.1 RPM. Once at target apogee, a circularization burn is performed to accurately deliver the payload into its target orbit. Payload separation is mission specific and will occur after the final burn. Final verification of correct orbit insertion then occurs within 90 minutes of final payload separation. For missions above 625 km, the second stage performs a third burn to lower the orbit and ensure that the second stage lifetime is less than 25 years.

FIGURE 5
MISSION PROFILE





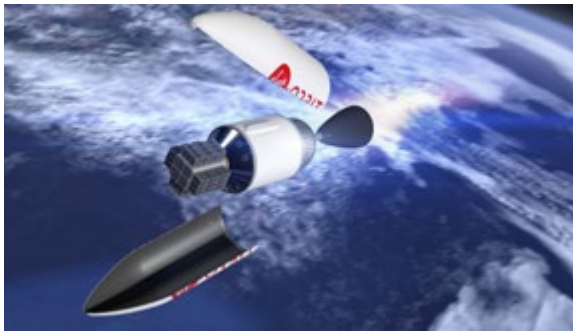
Cosmic Girl at LauncherOne release



LauncherOne ignition



Second Engine Start



Payload separation



Payload deployment

2.3 ORBIT INSERTION ACCURACY

Virgin Orbit takes our commitments seriously and that includes ensuring your payload is accurately deployed. LauncherOne employs a liquid propulsion system for its final stage, which allows for improved orbital insertion control compared 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°
Eccentricity	0.0022

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.

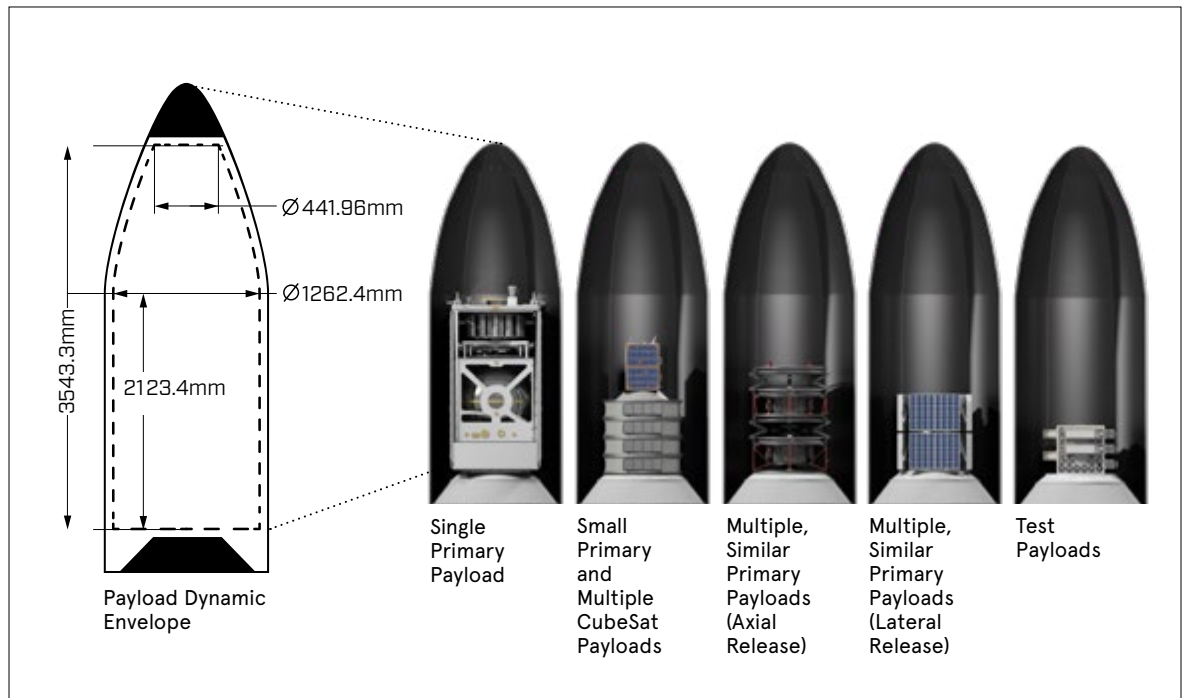
TABLE 3
TYPICAL PRE-SEPARATION ATTITUDE AND SPIN-RATE ACCURACIES (3 SIGMA)

ALTITUDE TYPE	PARAMETER	ANGULAR ERROR	RATE ERROR
3-Axis	Roll	± 7.0°	± 2.0°/sec
	Pitch	± 6.0°	± 0.5°/sec
	Yaw	± 6.0°	± 0.5°/sec

2.4 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 attach fitting interface with the primary payload mounted on top. Side-by-side accommodation of two ESPA class payloads is also 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. Sample Payload Configurations are shown in **FIGURE 6**.

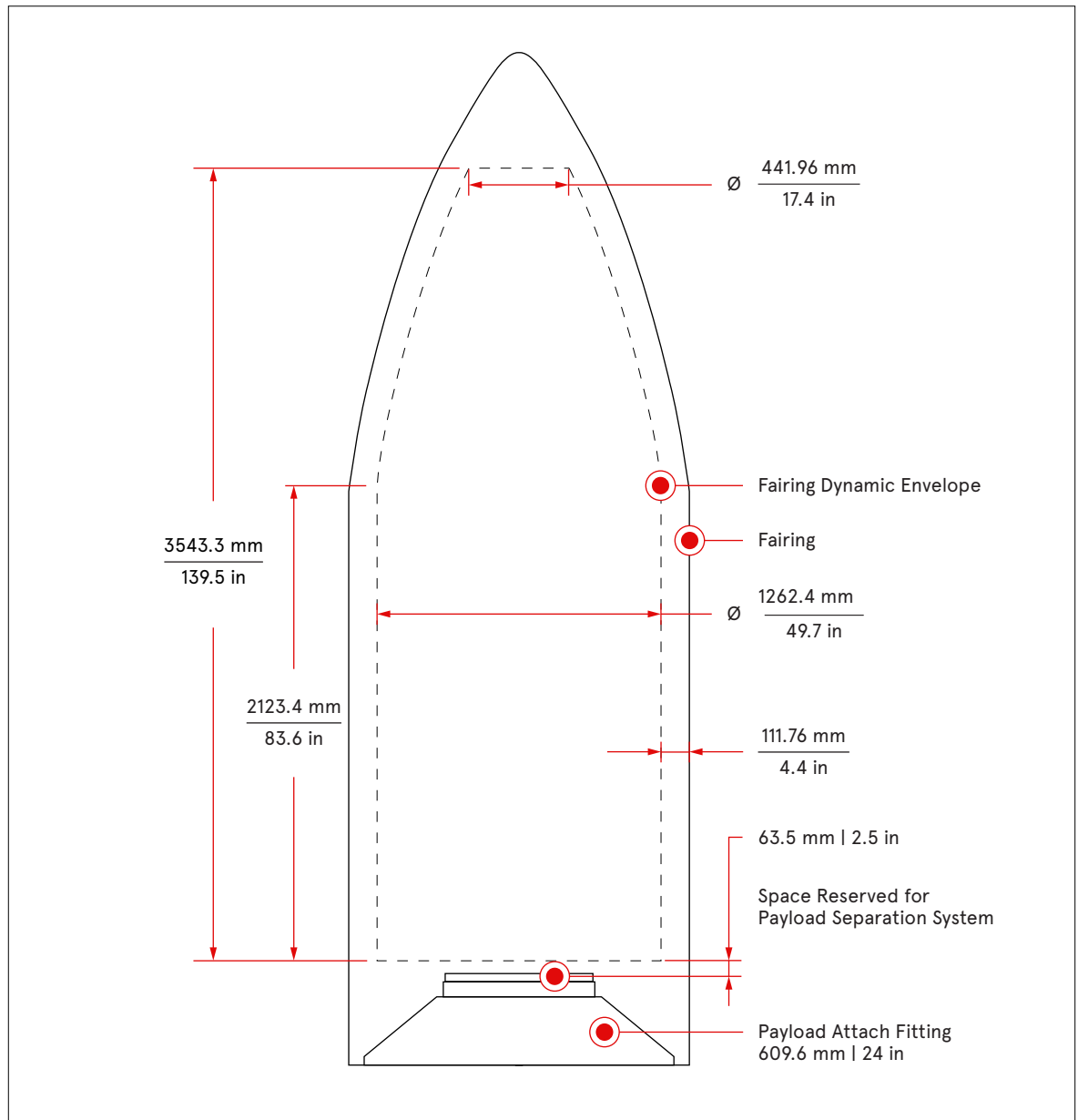
FIGURE 6
LAUNCHERONE SAMPLE PAYLOAD CONFIGURATIONS



*Custom adapter available upon request.
(1) Ready to launch (2 or 3 standards)
(2) Multiple future options - currently in work
(3) Custom adapter for your spacecraft available upon requests

The available payload fairing dynamic envelope and launch vehicle to spacecraft interface for LauncherOne are illustrated in **FIGURE 7** and **FIGURE 8**, respectively. The dynamic envelope consists of a 1.22 m / 49.7 in diameter cylindrical section that is 2.12 m / 83.6 in long resulting in a 3.63 m / 139.5 in 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. Virgin Orbit can perform mission-specific payload dynamic envelope analysis to evaluate your needs and discuss possible payload accommodations for unique requirements. For more information on the mechanical interface to LauncherOne, see section 2.5.

FIGURE 7
PAYLOAD FAIRING DYNAMIC ENVELOPE

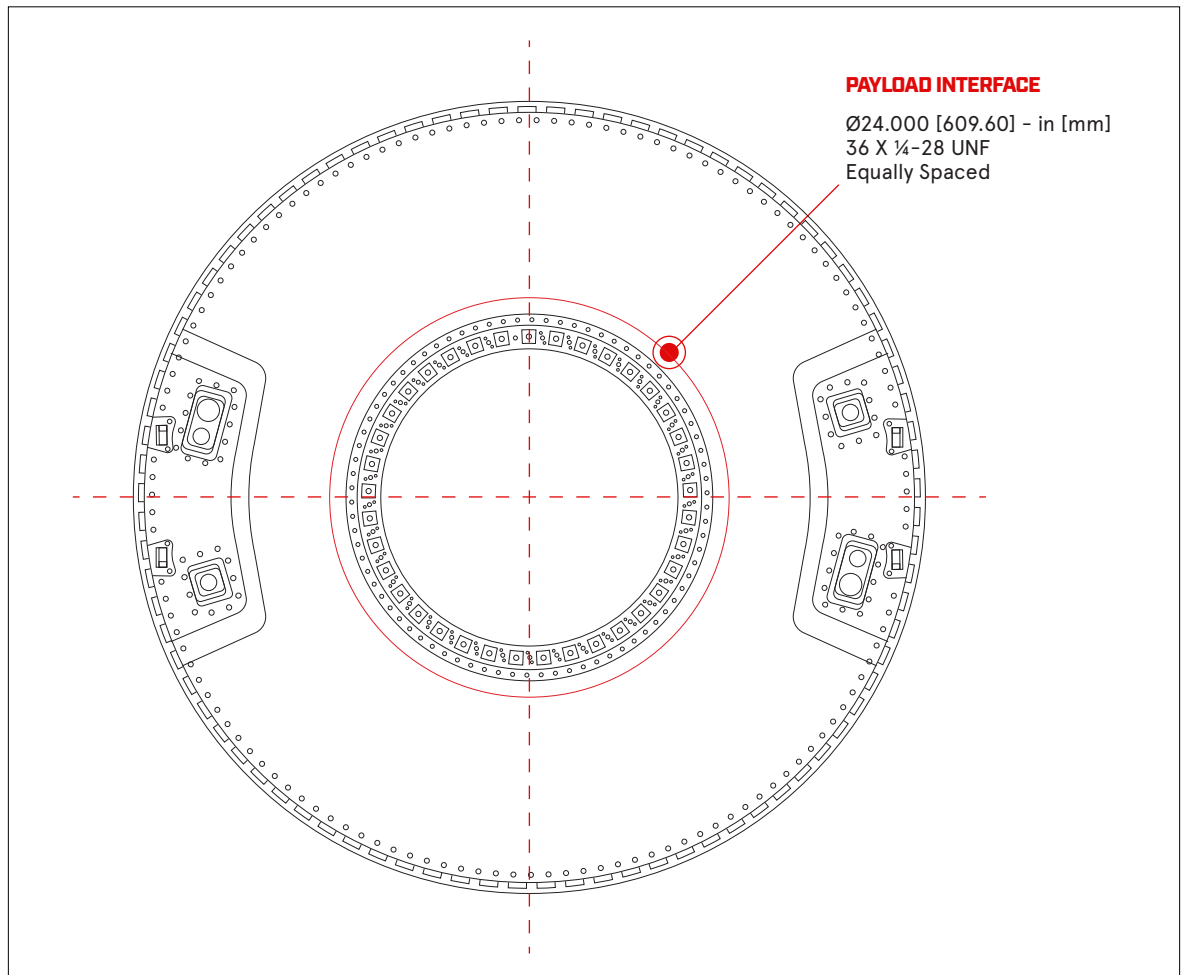


For the standard launch vehicle-to-payload electrical interface scheme, the LauncherOne payload controller provides a primary and redundant separation signal directly to the payload separation system. The payload controller is capable of providing multiple signals enabling multi-spacecraft missions. For more information on the electrical interface to LauncherOne, see section 2.7.

2.5 MECHANICAL INTERFACE

LauncherOne’s standard Payload Attach Fitting (PAF) consists of metallic forward and aft rings with a composite conical section, providing the mechanical interface between the launch vehicle and the payload stack. The baseline PAF interface is a standard 609.6 mm / 24.00 inch bolt pattern with 36 x ¼”-28 bolts evenly spaced out. Mission-specific interface bolt patterns, including those compatible with the ESPA and ESPA Grande class configurations, are available upon request. The dimensions of the standard interface are provided in **FIGURE 8**. Additionally, Virgin Orbit offers two standard-sized Payload Adapters (PLA), reducing the payload interface from 24 inches to an 8 or 13 inch interface. Custom PLAs are available upon request.

FIGURE 8
LAUNCH VEHICLE TO SPACECRAFT INTERFACE



26 ELECTRICAL INTERFACES

The standard interface from the launch vehicle to the payload, including separation, is supported by a standard configuration of:

- Ten (10) breakwires from the launch vehicle to the payload for separation indication.
- Ten (10) breakwires from the payload to the launch vehicle for separation indication.
- One (1) Ethernet Communication line for payload use.
- One (1) RS-422 Communication line for payload use.
- Twenty-four (24) Separation Commands that can be tailored to support bridgewire or motorized light band signals.
 - » Twenty (20) Bridgewire Type Separation Commands.
 - » Four (4) Motorized Type Separation Commands.

Modification for additional Bridgewire or Motorized separation commands are available.

At the customer's request, the Payload Attach Fitting (PAF) 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.

Information about these payload accommodations are defined in **TABLE 4**.

TABLE 4
PAYLOAD ELECTRICAL ACCOMMODATIONS

DESCRIPTION	PROVISION
Voltage	Harnessing capable of supporting 28 Vdc power +/- 4 Vdc up to 3A is provided during ground operations and captive carry. Additional amperage capacity can be made available upon request.
Electrical Bonding	The payload chassis is electrically bonded to L/V structure with no more than 200 milliohms, combined across multiple metal-to-metal and metal-to-composite joints. The carbon fiber composite layup has been evaluated and provides adequate charge-bleed path to prevent on-orbit charging of the Payload Attach Fitting (PAF) and S/V structures for typical L1 mission designs. Alternative electrical bonding requirements shall be negotiated by electromechanical ICD for L/V-P/L interfaces.

2.7 ELECTRICAL ACCESS

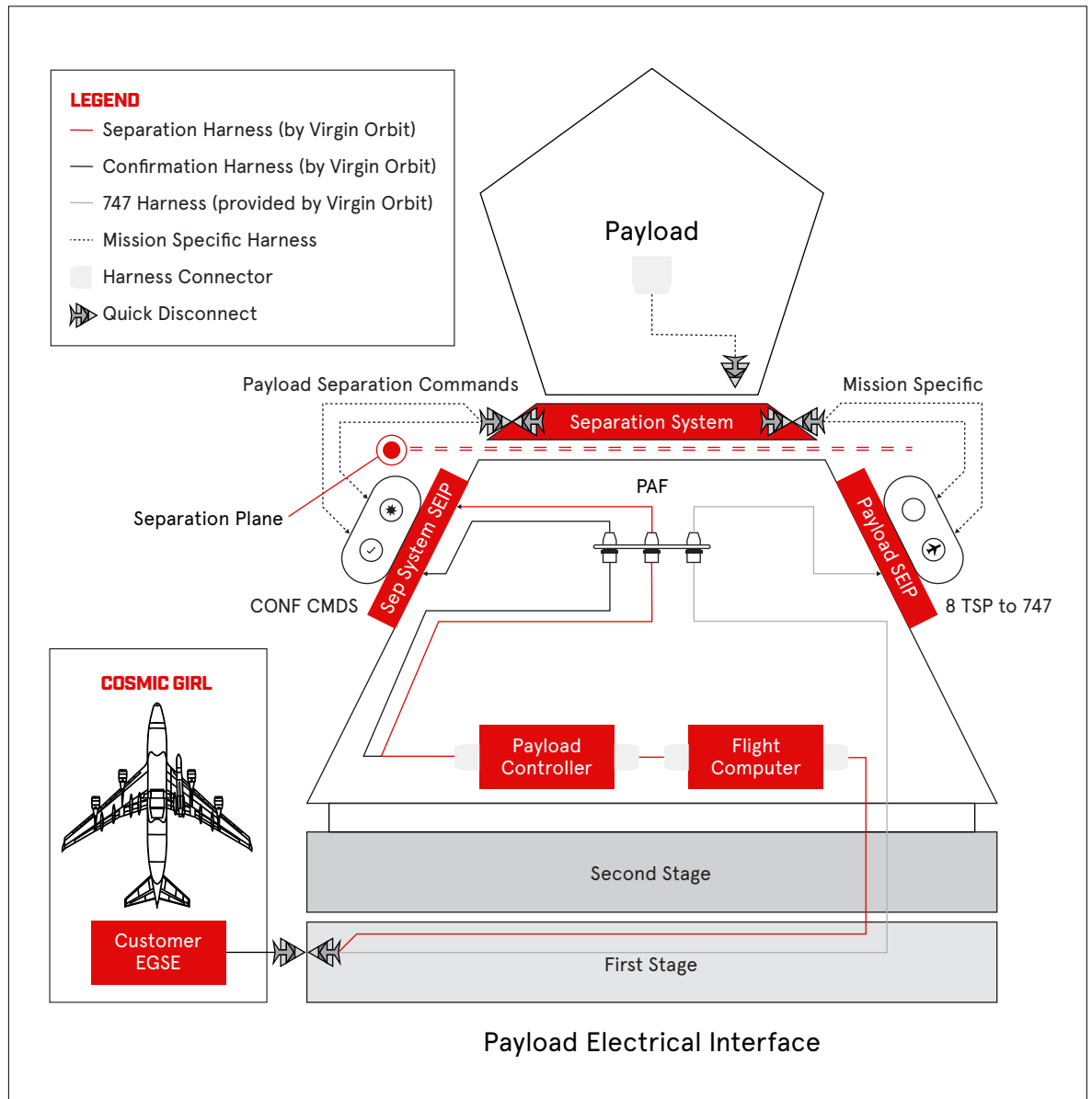
The payload integration and launch operations process is designed to maximize electrical access between the satellite and the customer EGSE. The table below and section 4.6 describe the electrical access in the various phases of payload operations.

TABLE 5
ELECTRICAL ACCESS

CONFIGURATION	INTERFACE CONNECTION	LV CONNECTOR
Mated to the Payload Attach Fitting	Test Connector	D3899/26FC35PA
Encapsulated in the Cleanroom	Test Connector	D3899/26FC35PA
Encapsulated in the Payload Trailer	Test Connector	D3899/26FC35PA
Fairing Mated to the Rocket, Rocket is on the Rocket Trailer	None	N/A
Fairing Mated to the Rocket, Rocket is mated to Cosmic Girl	Cosmic Girl	D3899/26FC35SN

When the satellite is mated to the rocket and the rocket is mated to the Cosmic Girl, EGSE to payload communications is over 8 twisted shielded pairs (TSP) of wires through the Cosmic Girl. The Payload Electrical Interface is shown in **FIGURE 9**. If the customer's EGSE will fly on Cosmic Girl then the equipment must comply with Section 19 of DO-160G. Users who are unfamiliar with Section 19 of DO-160G should solicit guidance from Virgin Orbit.

FIGURE 9
PAYLOAD ELECTRICAL INTERFACE DIAGRAM



2.8 SUPPORTED SEPARATION SYSTEMS

LauncherOne is compatible with many spacecraft separation systems and CubeSat dispensers in order to offer maximum mission flexibility to our customers. Virgin Orbit can assist customers in selecting an appropriate separation mechanism or dispenser for their mission unique needs. Primary spacecraft typically interface with the LauncherOne PAF via an annular or discrete point separation system. CubeSat payloads typically use dispensers designed to the CubeSat design specification. Virgin Orbit can procure the separation system for the customer and perform the integration work.

Virgin Orbit will conduct an analysis of tip off rates and other payload separation dynamics as necessary to ensure safe separation from the launch vehicle and that it meets the customer 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.

2.9 MECHANICAL COMPATIBILITY

The following are best practices for CubeSats to follow:

- Railed CubeSat providers are strongly encouraged to design to the Cal Poly San Luis Obispo CubeSat Design Specification (CDS). Tabbed CubeSat providers are also strongly encouraged to follow the CDS where appropriate while also ensuring conformance to Planetary Science Corporation's (PSC) Payload Spec for 3U 6U 12U (<https://www.planetarysystemscorp.com/product/canisterized-satellite-dispenser/>).
- Railed CubeSat providers are strongly encouraged to conform to the volume envelope specified in the CDS.
- Railed CubeSat providers are strongly encouraged to conform to the allowable protrusions specified in the CDS to ensure compatibility across multiple dispensers, despite the fact that some dispensers allow for greater protrusions.

Virgin Orbit requires the following items:

- Spacecraft providers are responsible for supplying a mass simulator in the event that the spacecraft arrives late or does not fit within the allowable envelope during payload integration.
- A fit check is required prior to payload integration to ensure mechanical and electrical fit of the spacecraft to either the dispenser or separation system.
- Spacecraft providers are responsible for ensuring that their spacecraft do not exceed the mass constraints of the dispenser or separation system.



**THE
VIRGIN
ORBIT
LAUNCH
SERVICE
PROCESS**

3 THE VIRGIN LAUNCH SERVICE PROCESS

Virgin Orbit's launch service offering includes mission planning, accommodation for spacecraft processing, payload-to-launch vehicle integration, delivery of the spacecraft to orbit, and post flight analysis. 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. More detailed information on Virgin Orbit and customer deliverables can be found in the Appendixes A.2 and A.3.

3.1 LAUNCH SERVICE ELEMENTS

All launches are given the high level of service and attention to detail that distinguishes the Virgin brand. To better serve our customers, we offer optional services to further enhance your launch experience and/or accommodate your unique needs.

Standard Services are as follows:

- **Virgin Orbit Mission Manager:** Your concierge for a smooth mission execution and launch. You are assigned a Mission Manager immediately after signing of the Launch Service Agreement.
- **Virgin Orbit Interface Control Document (ICD):** 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:** Confirms that your spacecraft is compatible with the launch environment.
- **Separation Analysis:** Verifies accurate and low risk payload deployment.
- **Post-Launch Status Quick-Look:** The spacecraft state vector and a quick-look assessment of post-launch status from the launch vehicle telemetry data will occur no later than 3 hours 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:

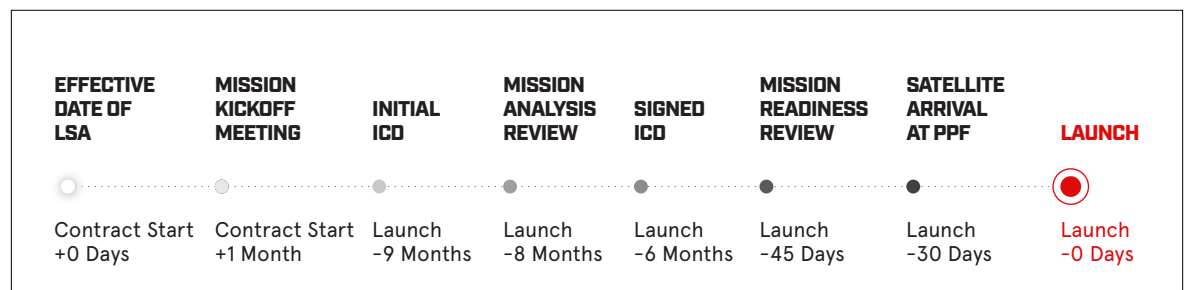
- **Payload Separation System:** Focus on your payload and let us handle the acquisition, delivery, and processing of the separation system to ensure readiness for integration.
- **Thermal Analysis:** Ensure thermal compatibility with sensitive areas of your payload and the launch environment.
- **Spacecraft Licensing:** Assistance with various standard licensing processes is available for customers unfamiliar with spacecraft regulatory compliance.
- **Spacecraft Review:** Peer review for spacecraft design, test, integration, and systems engineering is available from experts who have formerly worked on the relevant spacecraft systems.
- **Propellant Loading Planning:** Assistance with logistics, processes, and procedures for on-site storage and handling is available for spacecraft propellant.
- **Security:** Localized and tailorable security is available, if desired.
- **Insurance:** Various pre-launch and launch insurance options are available through Virgin Orbit corporate partners.

3.2 LAUNCH SERVICE SCHEDULE

Virgin Orbit's dedication to streamlining launch for small satellites includes emphasis on reducing time-to-launch. As such, Virgin Orbit has instituted the 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 as little as 6 months or less from contract execution. Please contact Virgin Orbit for additional information.

A top-level mission timeline is provided in **FIGURE 10**. The relative timing of milestones for each customer varies according to the mission-specific requirements. Contractual launch service begins with signing a Launch Service Agreement (LSA), culminates in launch, and ends with the delivery of the post-mission report. 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. Multiple reviews are held to coordinate the mission analysis and readiness of the vehicle, payload, and facilities to provide a safe and successful launch. See the appendices for a complete list and description of milestones and deliverables.

FIGURE 10
MISSION TIMELINE



3.3 CUSTOMER RESPONSIBILITIES

As the spacecraft owner, the customer is responsible for providing documents to formally communicate the payload system description, mission requirements, 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 ultimately responsible for obtaining licenses, permits, and approval from their national authority and any other necessary regulatory body (e.g. Federal Communications Commission, International Telecommunications Union, National Oceanic and Atmospheric Administration) prior to commencement of any launch integration activities. Virgin Orbit can provide assistance with regulatory needs, such as facilitating the submission of payload information to the FAA and providing information to the U.S. Government for space traffic management.

3.4 SAFETY AND MISSION ASSURANCE

Virgin Orbit has established measures 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 processes and 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.

The Payload provider will cooperate with Virgin Orbit in the investigation of launch accidents, launch anomalies, or other mishaps. If reasonably requested by Virgin Orbit, insurers, or federal and state agencies, the Payload provider will furnish data generated by or related to the Payload. The investigation will be monitored by both FAA and National Transportation Safety Board and other applicable regulatory agencies. The payload provider may not make any public statements, notifications, or announcements related to the mishap and investigation without the review and prior written approval of Virgin Orbit.

3.5 PHOTOGRAPHY POLICY

Whether it's your first mission or your five hundredth, we know that your satellite is your baby. And we know that like every parent, you can never have enough baby photos! From the time your hardware arrives in our facilities until the moment we deploy it into orbit, we will work with you to capture beautiful and useful photos at every step along the way, keeping you informed as your precious cargo moves through the integration and launch process. And when you have teammates on site with us, we'll ensure we've got as streamlined and permissive a photography policy as regulation permits – after all, "parent and baby" selfies are important, too!

3.6 U.S. IMPORT AND EXPORT COMPLIANCE

Virgin Orbit's technology, hardware and launch services are subject to U.S. export control laws, including the International Traffic Arms Regulations (ITAR), (22 CFR Parts 120-130), administered by the U.S. Department of State, and the Export Administration Regulations (EAR), (15 CFR §§730-774), administered by the U.S. Department of Commerce.

Each party must comply with all applicable United States federal, state and local laws, Executive Orders, rules and regulations, and conditions of all United States government licenses, permits or approvals, including without limitation the Commercial Space Launch Act "CSLA", EAR, ITAR, Office of Foreign Assets Control regulations, anti-boycott laws under the U.S. Export Administration Act, Foreign Corrupt Practices Act and/or any regulation promulgated under any of the foregoing laws.

Furthermore, the customer will obtain and maintain, or ensure that the manufacturer of the Spacecraft has obtained and maintained, all licenses, permits or approvals necessary to transfer the Spacecraft and any other items furnished by the manufacturer of the Spacecraft from their country of origin to Virgin Orbit's Payload Processing Facility or any other Launch Facility and in to space, including, if applicable, clearance of the payload and customer-furnished hardware from U.S. Customs and Border Protection.

In support of its provision of launch services for non-U.S. customers and/or Spacecraft manufacturers, Virgin Orbit will obtain and manage a Technical Assistance Agreement (TAA) from the U.S. State Department.

PAYLOAD PROCESSING AND LAUNCH OPERATIONS



4 PAYLOAD PROCESSING AND LAUNCH OPERATIONS

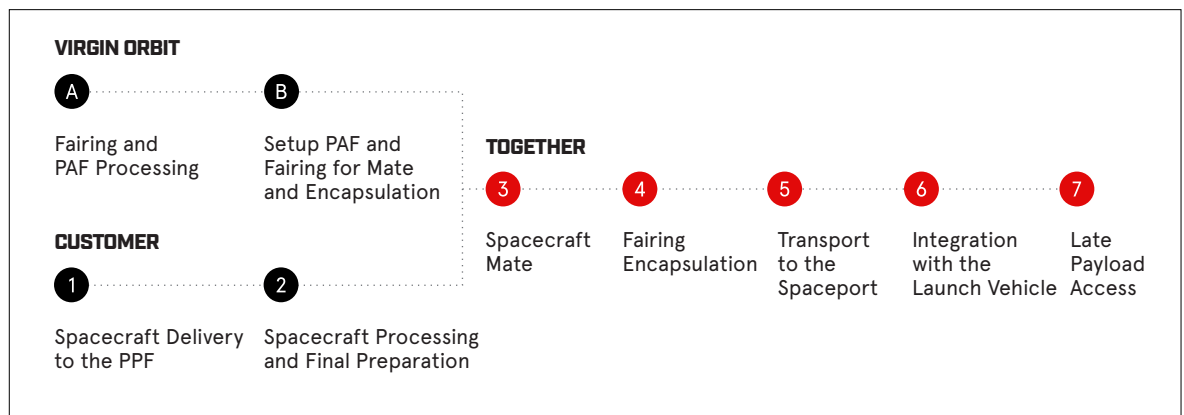
Payload integration and launch operations procedures are designed to minimize complexity, ensure safety of the payload, and increase mission reliability. A typical processing flow is described in this section. Virgin Orbit is able to tailor standard payload processing and launch procedures to the customer's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

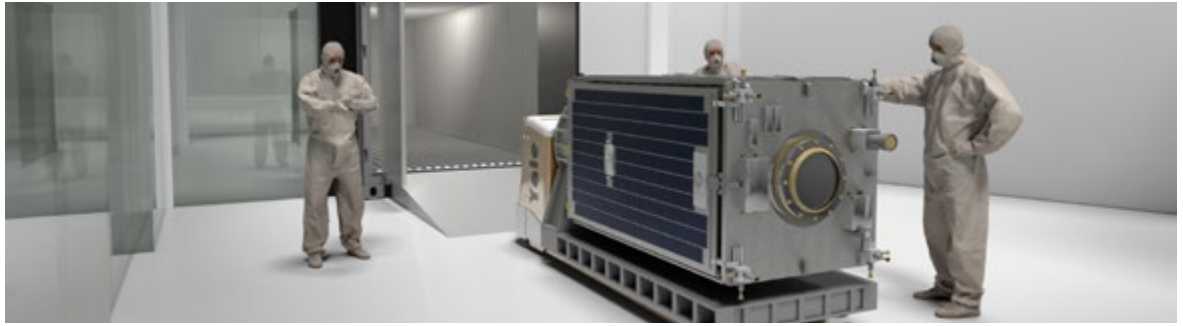
4.1 PAYLOAD PROCESSING FLOW

Virgin Orbit aims to make payload processing operations as smooth and efficient as possible for our customers by simplifying the integration process and offering as many essential resources as possible. Delivery of the payload is nominally 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 and storage in a flight-ready state for rapid "on-demand" launch. Typical procedural steps for payload processing for launches from Mojave Air and Spaceport or from any other contiguous United States (CONUS) locations are depicted **FIGURE 11** and described as follows (for other spaceports, the payload processing facility remains the same but transportation from Long Beach to the spaceport will vary):

- 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, supported as necessary by Virgin Orbit-supplied man lifts and other equipment in the PPF.
- 03. Spacecraft Mate:** A joint operation to mate the customer spacecraft to the separation system and/or payload attach fitting.
- 04. Fairing Encapsulation (vertical orientation) (Long Beach, California):** The integrated spacecraft and separation system on the payload attach fitting is then encapsulated within the payload fairing. This encapsulated assembly is then rotated into a horizontal configuration for transportation to the launch site.
- 05. Transport to the Spaceport:** The encapsulated payload is transported in the Payload Trailer to the spaceport. The trailer is equipped with an ISO 8 cleanroom with a climate-controlled positive pressure environment during transport.
- 06. Integration with the Launch Vehicle:** Virgin Orbit horizontally mates the encapsulated payload assembly to the launch vehicle.
- 07. Late Payload Access:** While not part of the nominal launch process, it is possible to allow late access to the payload for mission-critical needs.

FIGURE 11
PAYLOAD PROCESSING FLOW





1 - Spacecraft Delivery to the PPF, 2 - Spacecraft Processing and Final Preparations



3 - Spacecraft Mate



4 - Fairing Encapsulation



5 - Transport to the Spaceport



6 - Integration with the Launch Vehicle



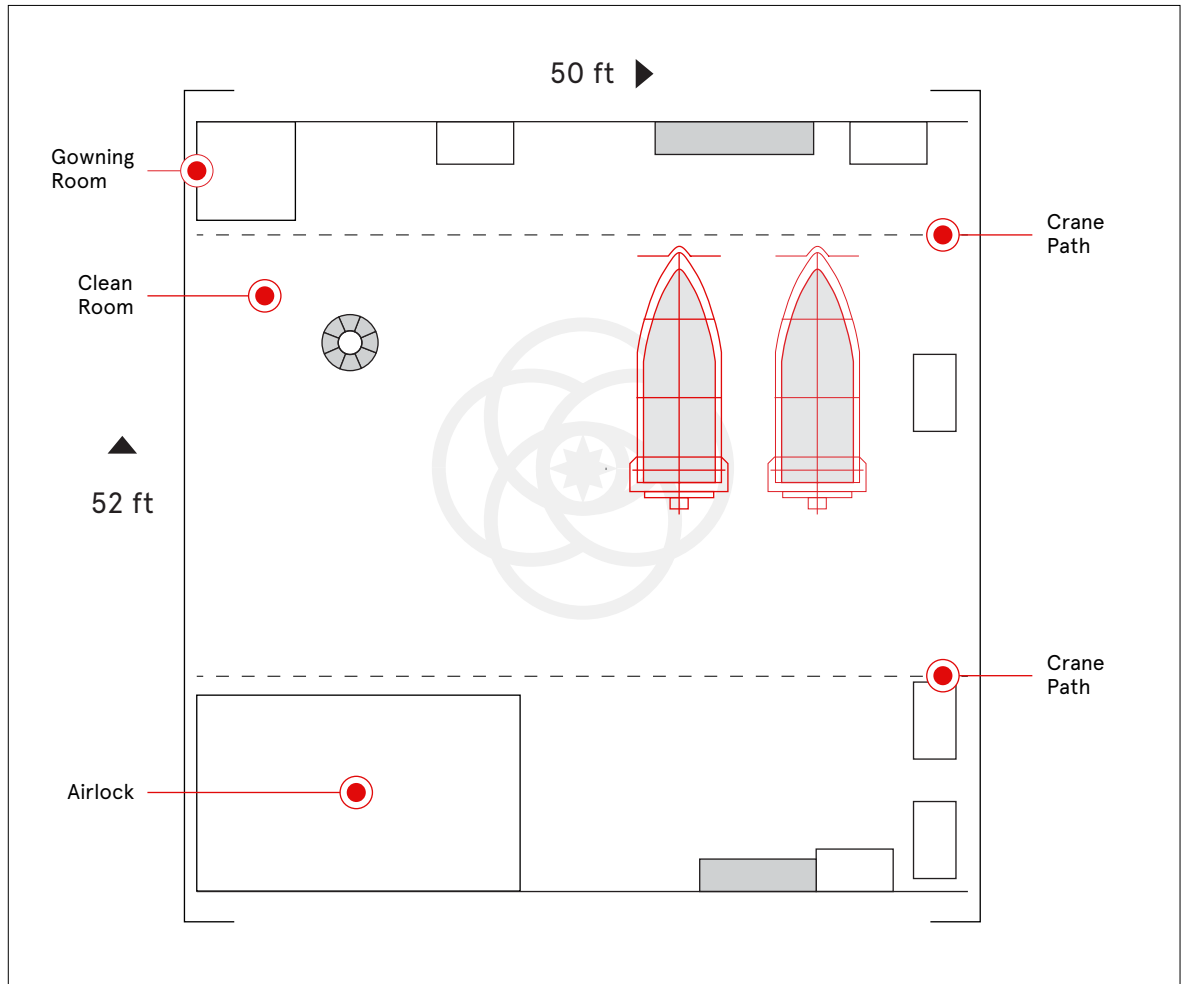
7 - Late Payload Access

4.2 PAYLOAD PROCESSING FACILITIES

Customers can test and process their satellite at Virgin Orbit's state of the art Nebula Payload Processing Facility located in Long Beach, California. The facility includes the Nebula cleanroom and the Nebula Lounge Office all under one roof. Baseline services and equipment available include:

- Close proximity to LAX airport, a major hub serving worldwide destinations, many with direct flights.
- Urban location provides simplified logistics for personnel and resource planning.
- The cleanroom consists of:
 - Gowning room
 - Main ISO 8 cleanroom area
 - Removable air lock
- The cleanroom environment will be:
 - Certified ISO 8 cleanliness level (Class 100K)
 - Relative Humidity: 40-60%
 - Temperature: 63-77°F or 17-25°C
- The cleanroom is equipped with a multi-speed 2T crane, with two hooks on one bridge.
- Power provided for customer electrical ground support equipment at 100V AC, 60 Hz and 230V AC, 50 Hz
- Uninterrupted Power Supplies (UPS), forklift, scissor lifts, rolling ladders, and small handheld tools
- Consumables including compressed air, helium, nitrogen, isopropyl alcohol, lint-free wipes, and gloves.
- Lounge style offices and conference rooms are provided with Wi-Fi, printer, copier, and fax machine.
- Virgin Orbit integration support personnel available up to six (6) days a week for twelve (12) hours a day, and optional 24/7 support
- Security is tailored for customer needs. Available security measures include electronic access IDs, 24-hour facility security guard, and closed circuit television.
- Accommodation for "green" propellant storage and loading. Possible propellants include 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 12
LAYOUT OF PAYLOAD PROCESSING FACILITY IN LONG BEACH, CA



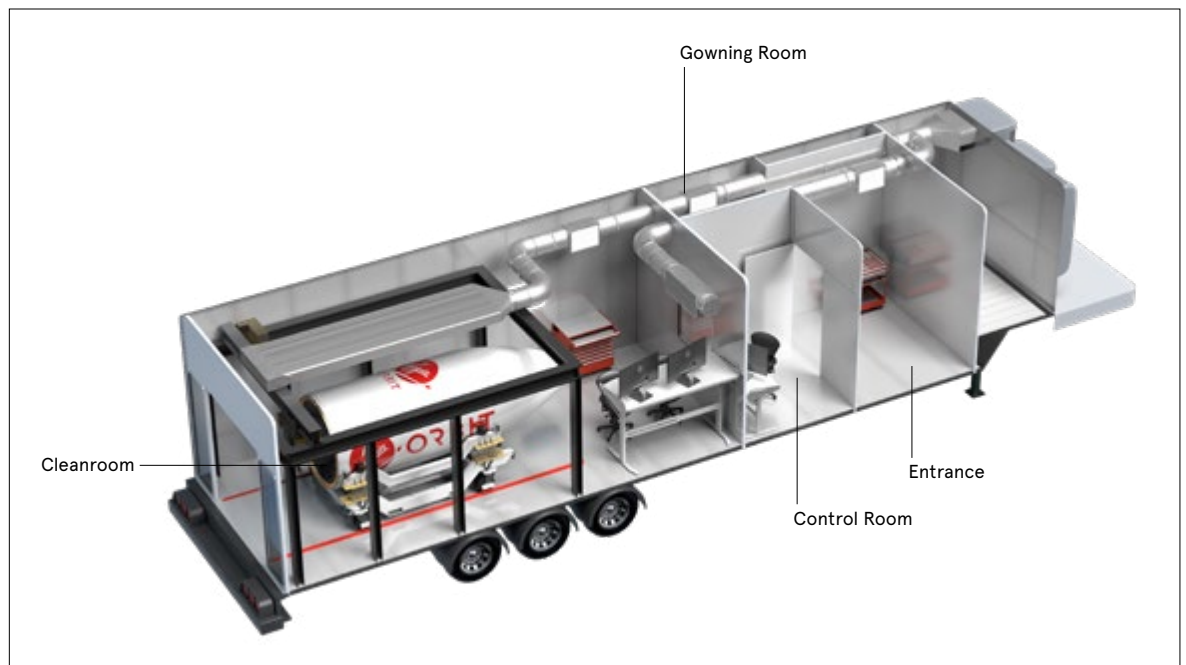
Nebula Payload Processing Facility - Long Beach, CA

4.3 PAYLOAD TRANSPORT

After encapsulation and final closeouts, the payload fairing module is safely and conveniently transported to the launch site in the Payload Trailer. The baseline capabilities of the Payload Trailer include:

- The cleanroom environment will be:
Certified ISO 8 cleanliness level (Class 100K)
Relative Humidity: 40-60%
Temperature: 63-77°F
- The trailer has a Control Room with storage capability for server and test racks.
- The Payload Trailer has a passthrough for cables from the EGSE room into the cleanroom.
- Transportation loads will not exceed flight loads.
- The trailer comes equipped with air ride suspension for a smoother ride and will have Event Data Recorders tracking the actual environments.
- Security is tailored for customer needs. Available security measures include electronic access IDs, 24-hour facility security guard, and closed circuit television.

FIGURE 13
PAYLOAD TRAILER



Payload integration



Payload mate

4.4 LAUNCH LOCATIONS

See Section 6.2 to find out more about the spaceports currently supported and the new ones coming online.

4.5 LAUNCH OPERATIONS FLOW

For standard launch operations, launch occurs within three days after the delivery of the encapsulated payload 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-4 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-2 days)
05. Propellant loading (L-0 day)
06. Cosmic Girl engine start and LauncherOne GSE disconnect (L-0 day)
07. Cosmic Girl take-off; LauncherOne purge provided to payload encapsulated environment by the carrier aircraft (L-0 day)
08. LauncherOne release and launch (L-0 day)

4.6 MECHANICAL AND ELECTRICAL ACCESS

Virgin Orbit understands how valuable late access to the satellite is for our customers. Operations were designed to provide direct access as late as possible.

While the payload is in the Payload Trailer:

- Mechanical access is available through all four of the Fairing access doors
- Electrical access through the Text Connectors on the base of the PAF is available. More detailed electrical interface information is available in Section 2.7.
- Prior to take-off, while the payload is mated to the rocket on Cosmic Girl:
 - » Mechanical access is available through all four of the Fairing access doors
 - » Electrical access from Cosmic Girl is available. More detailed electrical interface information is available in Section 2.7.
 - » Any customer EGSE that flies on Cosmic Girl is required to comply with Section 19 of DO-160G. Users unfamiliar with the specification should contact Virgin Orbit for guidance.

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

The standard LauncherOne launch vehicle coordinate reference frame is provided in **FIGURE 14**. In this right-handed coordinate system, the positive X-axis is 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 14
LAUNCH VEHICLE COORDINATE SYSTEM



5.2 PAYLOAD CONSTRAINTS

LauncherOne accommodates a wide range of payload masses up to 500 kg / 1,100 lbm and can support a payload center of mass up to +/-50mm laterally and 0.6m axially from the payload to launcher separation plane.

5.3 ACCELERATION FROM QUASI-STATIC LOADS

TABLE 6 provides representative maximum predicted quasi-static limit loads for LauncherOne at the payload center of gravity. These are general quasi-static loads predictions for a single spacecraft with mass greater than 60kg. Predictions are further defined and verified by mission-specific Coupled Loads analysis. The values provided in the table bound the maximum acceleration for all phases of flight. As driving load cases are derived during aircraft operations, ultimate safety factors per FAR 25.303 should be applied (F.S. = 1.5).

TABLE 6
LAUNCHERONE PRIMARY PAYLOAD DESIGN LOAD FACTORS

TYPE	AXIAL [X]	LATERAL [Y, Z]
Acceleration [g]	-3g / +7g	+/- 5g

NOTE: POSITIVE AXIAL ACCELERATION INDICATES COMPRESSIVE LOADS

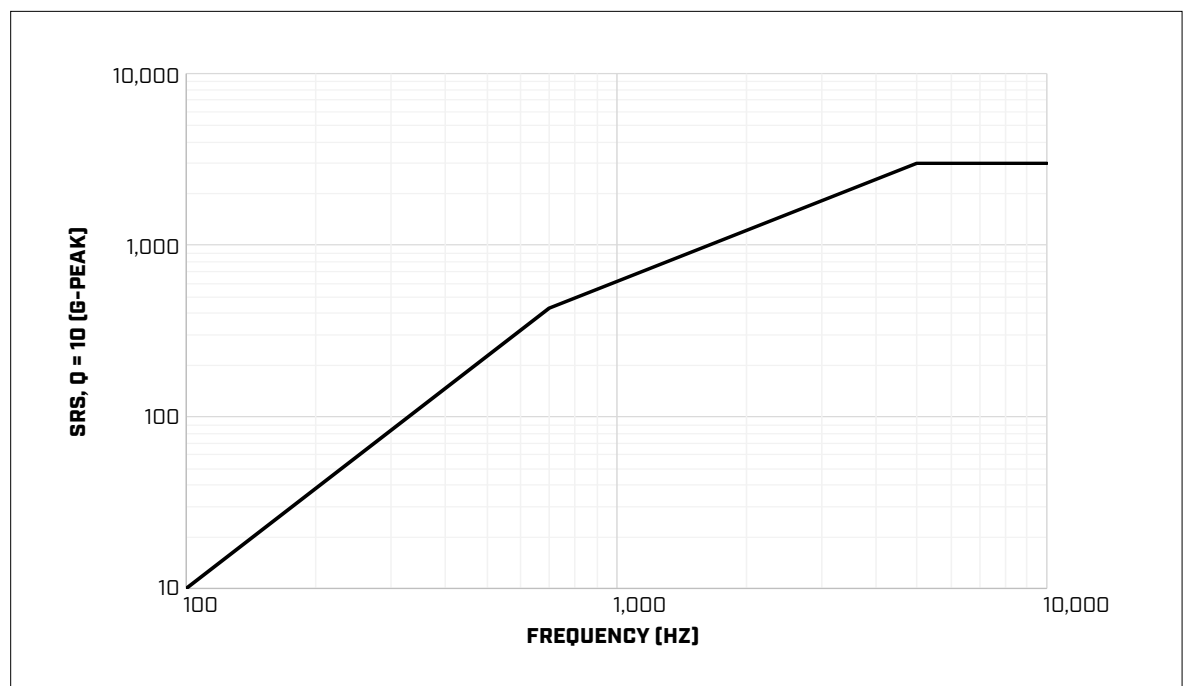
5.4 SHOCK ENVIRONMENT

The maximum predicted shock response spectrum at the standard payload-to-launch vehicle interface from all launch vehicle events is shown below in **TABLE 7** and **FIGURE 15**. 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 7
MAXIMUM PREDICTED SHOCK ENVIRONMENT AT THE STANDARD PAYLOAD INTERFACE

FREQUENCY [HZ]	LAUNCHERONE MAX PREDICTED SHOCK ENVIRONMENT [G-PEAK]
100	10
700	430
5000	3000
10000	3000

FIGURE 15
MAXIMUM PREDICTED SHOCK ENVIRONMENT AT THE STANDARD PAYLOAD INTERFACE



5.5 — RANDOM VIBRATION

The LauncherOne maximum predicted environment for random vibration is shown below for both primary payloads and CubeSats. For primary payloads, the random vibration environment is measured at the standard 24" diameter interface. For mission unique adapters, this environment will be recomputed at the particular interface of your spacecraft.

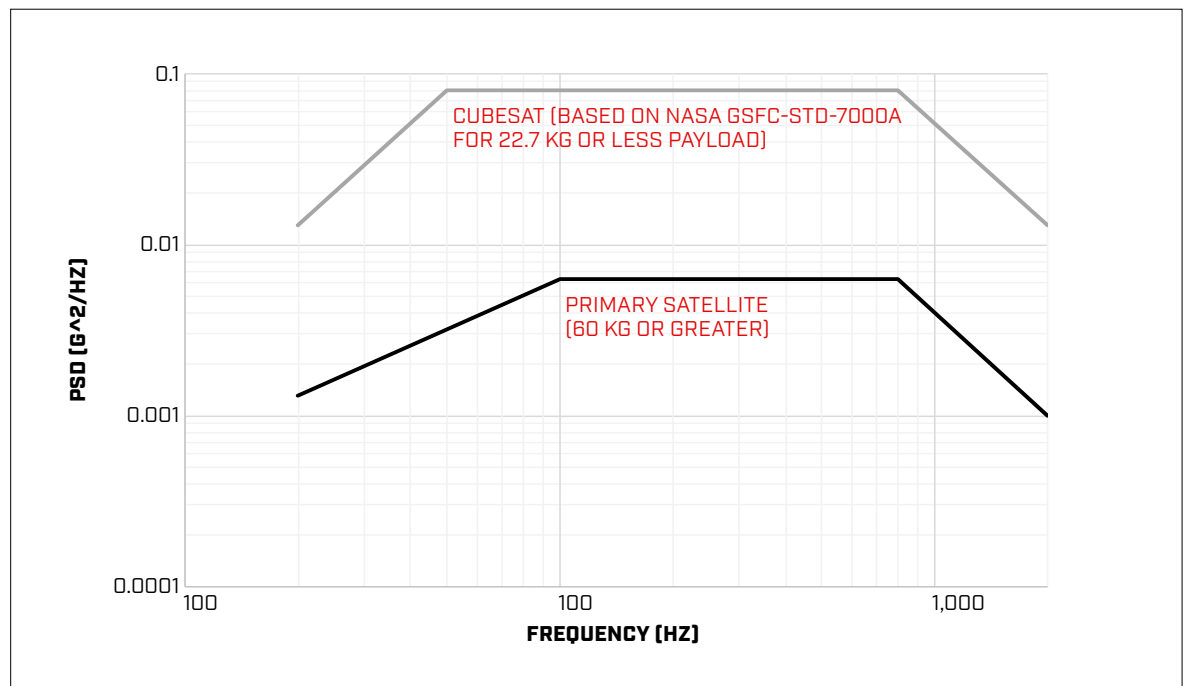
TABLE 8
RANDOM VIBRATION MPE FOR PRIMARY SATELLITE, 60 KG OR GREATER

FREQUENCY [HZ]	POWER SPECTRAL DENSITY (PSD) [G ² /HZ]
20	0.0013
100	0.0063
800	0.0063
2000	0.0010
grms	2.8

TABLE 9
RANDOM VIBRATION MPE FOR CUBESAT, 22.7 KG OR LESS (BASED ON NASA GSFC-STD-7000A)

FREQUENCY [HZ]	POWER SPECTRAL DENSITY (PSD) [G ² /HZ]
20	0.013
50	0.08
800	0.08
2000	0.013
grms	10.0

FIGURE 16
RANDOM VIBRATIONS MPE



5.6 ACOUSTICS

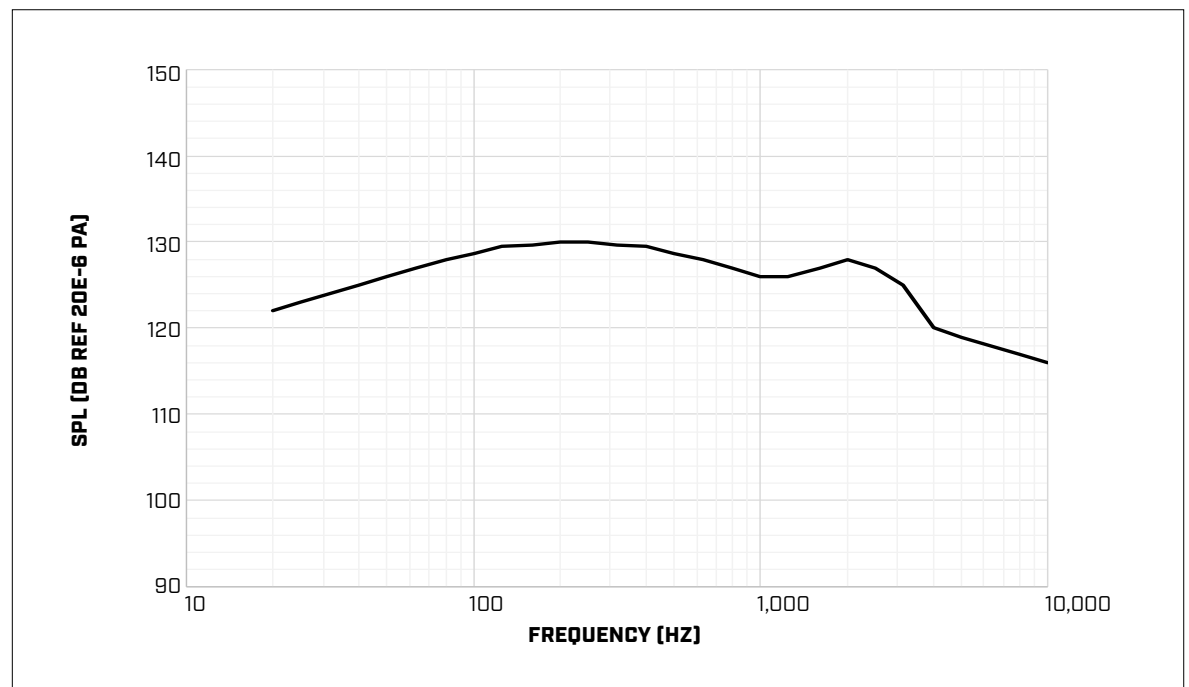
The maximum predicted acoustic environment for a typical payload fill factor is defined in **TABLE 10** and **FIGURE 17**. For missions of very large or small fill factors, a mission-unique acoustic analysis is performed.

TABLE 10
MAXIMUM PREDICTED ACOUSTIC ENVIRONMENT

FREQUENCY (HZ)	SOUND PRESSURE LEVEL (SPL) (DB, REFERENCE: 2E-5 PA)	FREQUENCY (HZ)	SOUND PRESSURE LEVEL (SPL) (DB, REFERENCE: 2E-5 PA)
20	122.0	500	128.7
25	123.0	630	128.0
31.5	124.0	800	127.0
40	125.0	1,000	126.0
50	126.0	1,250	126.0
63	127.0	1,600	127.0
80	128.0	2,000	128.0
100	128.7	2,500	127.0
125	129.5	3,150	125.0
160	129.7	4,000	120.0
200	130.0	5,000	119.0
250	130.0	6,300	118.0
315	129.7	8,000	117.0
400	129.5	10,000	116.0

Overall Sound Pressure Level [OASPL] = [dB RE: 2e-5 PA] Overall Sound Pressure Level [OASPL] = 141.40

FIGURE 17
MAXIMUM PREDICTED ACOUSTIC ENVIRONMENT



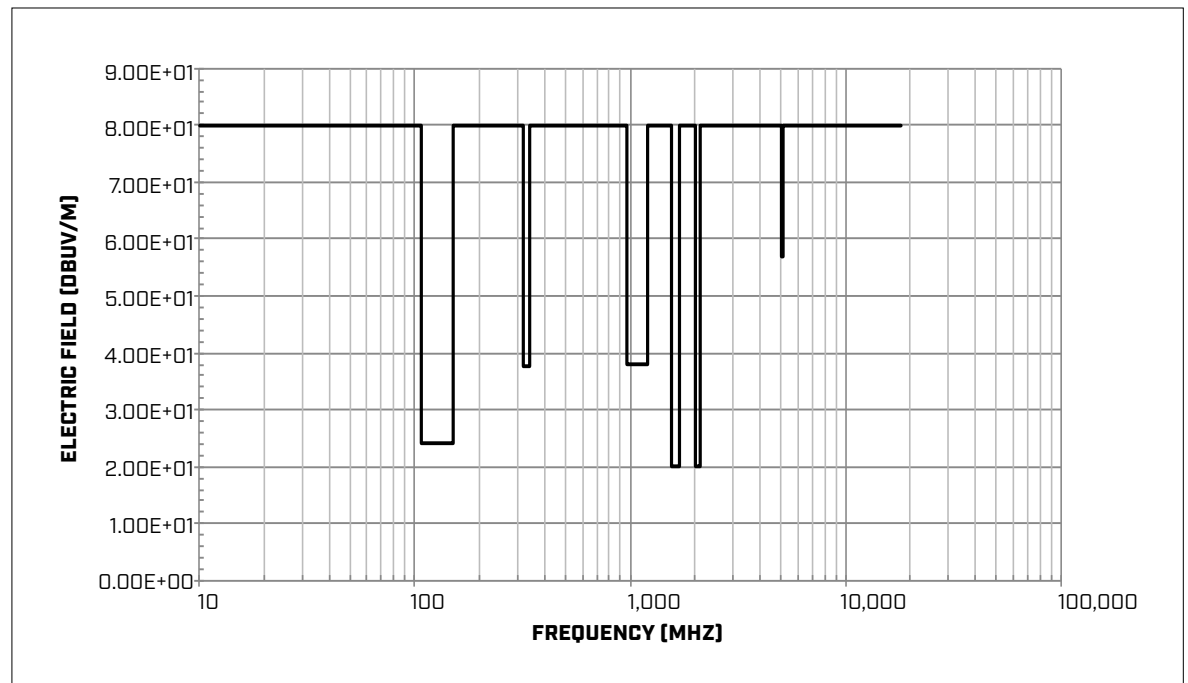
5.7 SPACECRAFT RADIO FREQUENCY (RF) CONSTRAINTS

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 11** and **FIGURE 18**, and provided here as guidance for the customer. Generally, this will also include spurious general emission from the spacecraft bus. A radiated emission report may be required to verify compatibility.

TABLE 11
MAXIMUM SPACECRAFT ELECTRIC FIELD EMISSIONS

FREQUENCY (RF SUSCEPTIBILITY, MHZ)	ELECTRIC FIELD (DBUV/M)	FREQUENCY (MHZ)	ELECTRIC FIELD (DBUV/M)
10	8.00E+01	1,559	8.00E+01
108	8.00E+01	1,559	2.00E+01
108	2.40E+01	1,680	2.00E+01
152	2.40E+01	1,680	8.00E+01
152	8.00E+01	2,015	8.00E+01
320	8.00E+01	2,015	2.00E+01
320	3.77E+01	2,120	2.00E+01
340	3.77E+01	2,120	8.00E+01
340	8.00E+01	5,020	8.00E+01
960	8.00E+01	5,020	5.68E+01
960	3.80E+01	5,100	5.68E+01
1,215	3.80E+01	5,100	8.00E+01
1,215	8.00E+01	18,000	8.00E+01

FIGURE 18
MAXIMUM ALLOWABLE SPACECRAFT ELECTRIC FIELD EMISSIONS



5.8 SPACECRAFT INTENTIONAL EMITTERS AND RECEIVERS

For spacecraft with intentional emitters (transmitters) and receivers: additional information must be provided if the user intends to transmit intentionally during any phase of processing/integration, captive carry flight, or free-flight. Following the guidance of FCC DA:13-445 "GUIDANCE ON OBTAINING LICENSES FOR SMALL SATELLITES" and the EELV-SIS; the collected information includes:

- Center frequency
- Peak power
- Occupied bandwidth & data rate
- Modulation
- Emitter/signal Identifier (traceable to FCC Emissions Designator)
- Antenna gain characteristics
- ConOps plan for ground test and activation after deployment

A spacecraft receiver list with known in-band and out-of-band susceptibilities must be provided to Virgin Orbit.

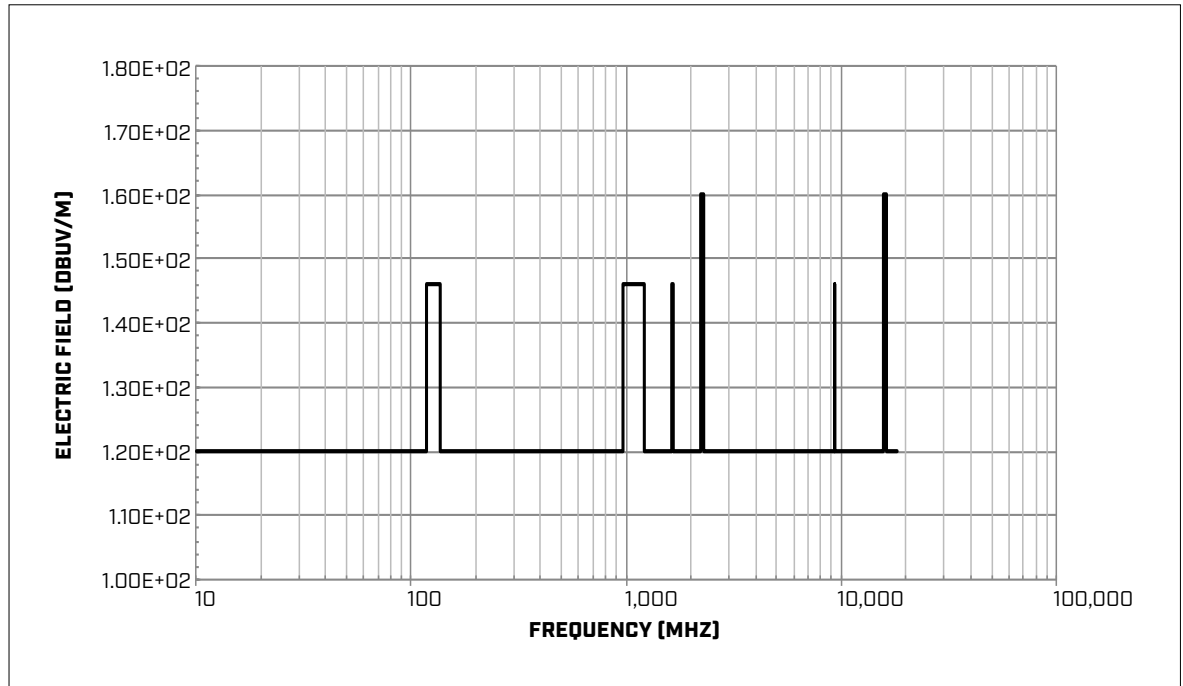
5.9 LAUNCH VEHICLE AND CARRIER AIRCRAFT NOT TO EXCEED RF ELECTRIC FIELD LIMIT

The maximum launch vehicle and carrier aircraft electric field emissions are listed in **TABLE 12** and **FIGURE 19**. Customers are to ensure that their spacecraft is not susceptible to these levels.

TABLE 12
MAXIMUM LAUNCH/CARRIER VEHICLE ELECTRIC FIELD EMISSIONS

FREQUENCY (RF EMISSIONS, MHZ)	ELECTRIC FIELD (DBUV/M)	FREQUENCY (MHZ)	ELECTRIC FIELD (DBUV/M)
10	1.20E+02	2,200	1.20E+02
118	1.20E+02	2,200	1.60E+02
118	1.46E+02	2,290	1.60E+02
137	1.46E+02	2,290	1.20E+02
137	1.20E+02	9,310	1.20E+02
960	1.20E+02	9,310	1.46E+02
960	1.46E+02	9,350	1.46E+02
1,215	1.46E+02	9,350	1.20E+02
1,215	1.20E+02	15,700	1.20E+02
1,637	1.20E+02	15,700	1.60E+02
1,637	1.46E+02	16,200	1.60E+02
1,642	1.46E+02	16,200	1.20E+02
1,647	1.46E+02	18,000	1.20E+02
1,647	1.20E+02		

FIGURE 19
MAXIMUM ALLOWABLE LAUNCH VEHICLE/ CARRIER AIRCRAFT ELECTRIC FIELD EMISSIONS



5.10 THERMAL AND HUMIDITY ENVIRONMENT

Once the customer payload arrives at the Nebula Payload Processing Facility, it will remain in a temperature and humidity controlled environment from the time the shipping container is opened through captive carry until drop.

TABLE 13
THERMAL AND HUMIDITY ENVIRONMENT

CONFIGURATION	TEMPERATURE	RELATIVE HUMIDITY	CLEAN ROOM STANDARD
Virgin Orbit's Nebula Payload Processing Facility	63-77°F (17-25 °C)	40-60%	ISO Class 8 (100K)
Payload Trailer (for transport to spaceport)	63-77°F (17-25 °C)	40-60%	ISO Class 8 (100K)
Mated to the launch vehicle (Ground Conditioning System)	63-77°F (17-25 °C)	≤60%	Supplied air consistent with ISO Class 8 (100K)
Captive Carry – GN2	40-80°F (4-27°C)	≤60%	Supplied air consistent with ISO Class 8 (100K)
Captive Carry – Bleed Air	40-80°F (4-27°C)	≤60%	Supplied air consistent with ISO Class 8 (100K)

Short outages of conditioned air may be required when changing configurations.

Electrical power can be provided to the payload during captive carry for internal spacecraft thermal control. This is an optional service and will only be included as a capability at the customer's request.

During powered flight and until fairing separation, with aluminized Kapton on the interior of the fairing, the payload will be exposed to an equivalent radiative heat flux emanating from a 200 deg F surface with an emissivity of 0.9.

5.11 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 there is a time-averaged decay rate that is no higher than 0.55 psi/sec for no more than 5 seconds.

5.12 SPACECRAFT QUALIFICATION AND COMPLIANCE

In order to validate the design requirement compliance and qualification of the spacecraft to the flight environments, verification documents detailing the test and analysis levels are mandatory to ensure spacecraft survivability on launch and overall mission success. Required design requirement verifications include (but are not limited to):

- Safety Factors
- Mass Properties
- Volume
- Structural Fundamental Frequency
- Dynamic Loads and Environments

Additionally, information regarding verification logic, safety & handling, and qualification/acceptance for interfaces and integrated system tests may be required. See the Appendix A.4 for a detailed list of Customer Spacecraft Testing Requirements.



***VIRGIN
ORBIT
LOCATIONS***

6 VIRGIN ORBIT LOCATIONS

6.1 LAUNCH VEHICLE PRODUCTION AND TEST FACILITIES

The Virgin Orbit headquarters is an 180,000 sq ft / 16,700 sq m 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, which features state-of-the-art manufacturing equipment and custom-built test rigs.

FIGURE 20
HEADQUARTERS IN LONG BEACH, CALIFORNIA FOR MANUFACTURING AND INTEGRATION



Long Beach Headquarters



Manufacturing and Integration

Nebula, our Payload Processing Facility (PPF), is located just down the road from our main headquarters in Long Beach. The facility is where payloads are encapsulated after spacecraft unpacking and testing is complete. For details on payload processing, see Section 4.1.



Nebula Payload Processing Facility - Long Beach, CA

The Virgin Orbit team conducts high-energy testing near the Mojave Air and Space Port in Mojave, California, where there are multiple custom-built test stands for liquid propulsion, composite tank, component, and overall stage testing. Acceptance testing for LauncherOne's Newton family of engines occur at our horizontal test stands, and stage tests are performed on vertical test stands.

FIGURE 21
LIQUID PROPULSION TEST SITE AND NEWTONTHREE HOT FIRE TEST ON TEST STAND TWO



Stage Test



NewtonThree Hot Fire Test

6.2 SPACEPORT FACILITIES

The unique modularity of the LauncherOne system enables launches from any government licensed horizontal spaceport with a long enough runway for a 747-400 aircraft. Virgin Orbit leverages a fully Transportable Ground Operating System (TGOS) to eliminate the need for extensive infrastructure traditionally associated with ground launch. The TGOS consists of a set of trailers capable of traversing public roads used to transport LauncherOne, mate LauncherOne to the carrier aircraft, fuel and pressurize the rocket, and service the LauncherOne payload in a mobile, cleanroom environment. Virgin Orbit successfully proved out the TGOS during the LauncherOne Demo in May 2020. Customers can leverage LauncherOne's modularity to unlock a relatively low-cost sovereign launch capability.



LauncherOne TGOS setup - Mojave, CA

High-inclination launches take place out of Mojave Air and Space Port (MHV), California. Low- and mid-inclination launch services take place out of Guam. Both sites are FAA licensed spaceports for commercial horizontal launch operations of reusable vehicles, such as our 747-400 aircraft.

Virgin Orbit is also in the process of bringing flexible launch for small satellites to a global network of spaceports and countries across the world. Currently, Virgin Orbit is in the process of commencing LauncherOne operations from both Spaceport Cornwall at Cornwall Airport Newquay (NQY) in the UK and at Oita Airport (OIT) in Japan in the coming years. Virgin Orbit is in discussions with many other countries on the prospects of expanding the number of international LauncherOne-ready spaceports.

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

Because we are not reliant on a federal launch range, we are unaffected by many of the external factors that can delay ground-based launches 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 baseline flight profile of a LauncherOne mission from Mojave involves release of the LauncherOne launch vehicle over the Pacific Ocean, tens of kilometers from the California coastline, after a flight of approximately one hour. For low-inclination launches from Guam, the drop point is optimally located based on the inclination desired for the mission.

FIGURE 22
MAP OF LAUNCH LOCATIONS



FIGURE 23
FULLY-INTEGRATED LAUNCHERONE VEHICLE





DOCUMENT REFERENCE

71 LIST OF ACRONYMS

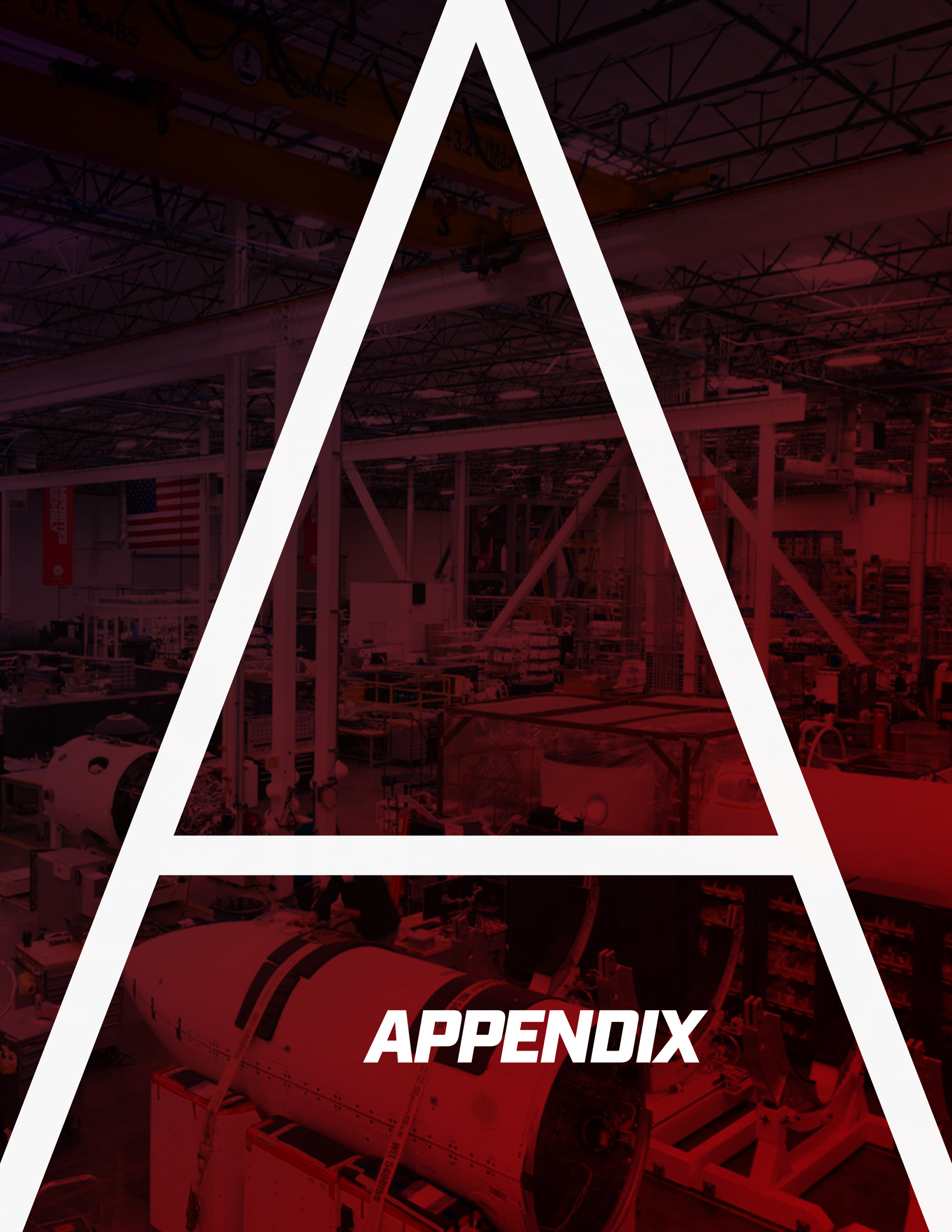
CAD	Computer-Aided Design
CCAFS	Cape Canaveral Air Force Station
C/CAM	Collision/Contamination Avoidance Maneuver
CLA	Coupled Loads Analysis
EGSE	Electrical Ground Support Equipment
ESPA	EELV Secondary Payload Adapter
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
GSE	Ground Support Equipment
ICD	Interface Control Document
LEO	Low Earth Orbit
LOX	Liquid Oxygen
LSA	Launch Services Agreement
MHV	Mojave Air and Space Port
NGY	Spaceport Cornwall at Cornwall Airport Newquay
N3	NewtonThree [1st stage engine]
N4	NewtonFour [2nd stage engine]
OIT	Oita Airport
OSHA	Occupational Safety and Health Administration
PAF	Payload Attach Fitting
PPF	Payload Processing Facility
PSC	Planetary Systems Corporation
PSD	Power Spectral Density
RAAN	Right Ascension of Ascending Node
RF	Radio Frequency
RP	Rocket Propellant
SLF	Shuttle Landing Facility
SSO	Sun-Synchronous Orbit

72 LIST OF TABLES

Table 1	Launch Services Quick Reference
Table 2	Typical Orbital Injection Accuracy (3 sigma)
Table 3	Typical Pre-Separation Attitude and Spin-Rate Accuracies (3 sigma)
Table 4	Payload Electrical Accommodations
Table 5	Electrical Access
Table 6	LauncherOne Primary Payload Design Load Factors
Table 7	LauncherOne Design Load Factors at the Standard Interface
Table 8	Random Vibration MPE for Primary Satellite, 60 kg or Greater
Table 9	Random Vibration MPE for CubeSat, 22.7 Kg or Less (Based on NASA GSFC-STD-7000A)
Table 10	Maximum Predicted Acoustic Environment
Table 11	Maximum Spacecraft Electric Field Emissions
Table 12	Maximum Launcher/Carrier Vehicle Electric Field Emissions
Table 13	Thermal and Humidity Environment

73 LIST OF FIGURES

Figure 1	The Virgin Orbit Family
Figure 2	LauncherOne System Expanded View
Figure 3	Orbital Payload Delivery Performance Curves - Mojave
Figure 4	Orbital Payload Delivery Performance Curves - Guam
Figure 5	Mission Profile
Figure 6	LauncherOne Sample Payload Configurations
Figure 7	Payload Fairing Dynamic Envelope
Figure 8	Payload Separation Interface
Figure 9	Payload Electrical Interface Diagram
Figure 10	Mission Timeline
Figure 11	Payload Processing Flow
Figure 12	Layout of Payload Processing Facility in Long Beach, CA
Figure 13	Payload Trailer
Figure 14	Launch Vehicle Coordinate System
Figure 15	Maximum Predicted Shock Environment at the Standard Payload Interface
Figure 16	Maximum Predicted Random Vibration Environment
Figure 17	Maximum Predicted Acoustic Environment
Figure 18	Maximum Allowable Spacecraft Electric Field Emissions
Figure 19	Maximum Allowable Launch Vehicle/Carrier Aircraft Electric Field Emissions
Figure 20	Headquarters in Long Beach, California for Manufacturing and Integration
Figure 21	Liquid Propulsion Test Site and NewtonThree Hot Fire Test on Test Stand Two
Figure 22	Map of Launch Locations
Figure 23	Fully-integrated LauncherOne vehicle



APPENDIX

A1 OVERVIEW OF VIRGIN ORBIT & CUSTOMER DELIVERABLES BY MILESTONE

MILESTONE DATE	VIRGIN ORBIT DELIVERABLES	CUSTOMER DELIVERABLES
LSA +4 Weeks Kick-off Meeting	<ul style="list-style-type: none"> Draft ICD Requirements for CAD, dynamics, and thermal models Mission schedule 	<ul style="list-style-type: none"> Completed Payload Questionnaire Spacecraft CAD model and initial mass properties
Launch -10 Months		<ul style="list-style-type: none"> Mission-specific ICD inputs Spacecraft dynamics model (can be either a FEM or Craig-Bampton model - depends on type/size)
Launch -9 Months	<ul style="list-style-type: none"> Initial ICD release 	
Launch -8 Months Mission Analysis Review	<ul style="list-style-type: none"> Draft verification matrix Updated mission schedule Preliminary engineering analyses Payload stack configuration 	<ul style="list-style-type: none"> Updated CAD & FEM models Spacecraft Con-Ops Spacecraft program/production schedules Spacecraft qualification plan Spacecraft thermal model (if payload specific thermal analysis is performed) Spacecraft safety inputs Spacecraft processing inputs
Launch -6 Months	<ul style="list-style-type: none"> Signed ICD Updated verification matrix Updated mission schedule Updated engineering analyses 	<ul style="list-style-type: none"> Signed ICD Updated spacecraft program/production schedules Completed template that supports document for the FAA Launch License Definition of fit check goals and requirements
Launch -3 Months	<ul style="list-style-type: none"> Updated dispersed trajectory and re-contact analysis results Spacecraft processing plan 	<ul style="list-style-type: none"> Spacecraft FCC license confirmation Spacecraft processing schedule
Launch -2 Months	<ul style="list-style-type: none"> ICD verifications 	<ul style="list-style-type: none"> ICD verifications Environmental test reports Security and logistics forms
Launch -45 days Mission Readiness Review	<ul style="list-style-type: none"> Updated integration schedule Updated engineering analyses (if applicable) Launch vehicle readiness confirmation Launch Campaign Overview 	<ul style="list-style-type: none"> Final mass properties Confirmation of all licenses for transport Spacecraft pre-ship readiness verification
Launch -30 Days		<ul style="list-style-type: none"> Spacecraft delivery
Launch -3 Days	<ul style="list-style-type: none"> Day of launch schedule 	
Launch +3 Hours Spacecraft Separation	<ul style="list-style-type: none"> Separation confirmation and separation vector; Post-Launch Status Quick-Look 	
Launch +60 Days Post-Launch	<ul style="list-style-type: none"> Post-Launch Evaluation Report 	

A.2 DESCRIPTION OF VIRGIN ORBIT DELIVERABLES

DELIVERABLE	DESCRIPTION
Interface Control Document	Document that summarizes all mission requirements to ensure launch service complies with spacecraft requirements.
Engineering Analyses	Includes (but is not limited to) the following: <ul style="list-style-type: none"> • Trajectory and Performance Analysis: this analysis ensures that the payload is delivered to the required mission orbit. • Environments Analyses: these analyses (CLA, Random Vibration, Shock, and Acoustics) confirm that spacecraft is compatible with the launch vehicle environment. • Separation Analysis: this analysis verifies accurate and low risk payload deployment.
Post-Launch Status Quick-Look	The spacecraft state vector and a quick look assessment of post launch status from the launch vehicle telemetry data will occur no later than 3 hours 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.

A.3 DESCRIPTION OF CUSTOMER DELIVERABLES

DELIVERABLE	DESCRIPTION
Payload Questionnaire	Initial basic information about the payload and the mission.
Spacecraft Mass Properties and CAD Model	Mass, CG, and Inertia Matrix for Virgin Orbit to evaluate launch vehicle integration and flight dynamics.
Spacecraft Dynamics Model	Model to enable payload-to-launch vehicle Coupled Loads Analysis. Virgin Orbit will provide detailed guidance on the model requirements.
Spacecraft ConOps	A basic description of the spacecraft Concept of Operations to enable Virgin Orbit to better understand if any spacecraft requirements may impact launch vehicle requirements.
Spacecraft Program/ Production Schedules	Summary and timing of key program milestones such as PDR, CDR, Assembly, Integration, and Test (AIT) and spacecraft delivery to inform Virgin Orbit of schedule interdependencies.
Spacecraft Qualification Plan	Summary of approach taken towards qualification testing (i.e. will there be a dedicated qualification unit or is there only a flight unit to be used for testing)?
Completed Template That Supports SMA-28 Document for FAA Launch License	Questionnaire that supports documentation required for FAA Launch License. This questionnaire requires inputs on launch date, objects to achieve orbit, orbital parameters, etc.
Definition of Fit Check Goals and Requirements	Overview of what is expected for the Fit Check (e.g. location of fit check, procedures, etc.)

A4 CUSTOMER SPACECRAFT TESTING REQUIREMENTS

	METHOD	QUALIFICATION MARGIN	CRITERIA	METHOD	PROTOQUALIFICATION MARGIN	CRITERIA	METHOD	ACCEPTANCE MARGIN	CRITERIA
Quasi-Static Loads	Test	Limit x 1.5 manned Limit x 1.25 unmanned	No Failure	Test	Limit x 1.5 manned Limit x 1.25 unmanned	No Yield	Test	Limit x 1.1	No Yield
Minimum Natural Frequency	Analysis or Test	N/A	> 35 Hz	Analysis or Test	N/A	> 35 Hz	N/A	N/A	N/A
⁵ Mechanical Shock	Analysis or Test	3 exposures at MPE + 3dB	No Failure	Analysis or Test	1 exposure at MPE + 3dB	No Failure	N/A	N/A	N/A
⁴ Acoustics	Test	120 sec. at MPE + 3dB	No Failure	Test	60 sec. at MPE + 3dB	No Yield	N/A	N/A	N/A
Random Vibration	Test	180 sec. at MPE + 3dB	No Failure + Post Functional Performance	Test	120 sec. at MPE + 3dB	No Yield + Post Functional Performance	Test	60 sec. at MPE + 0dB	No Yield + Post Functional Performance
⁴ Sine Vibration	Test	Limit x 1.5 manned Limit x 1.25 unmanned 2 oct/min	No Failure	Test	Limit x 1.5 manned Limit x 1.25 unmanned 4 oct/min	No Yield	N/A	N/A	N/A
Mechanical Fatigue	N/A	N/A	N/A	Analysis	Proto-qualification Test Levels	CDI < 0.5	N/A	N/A	N/A
Strength Requirement	N/A	N/A	N/A	Analysis	Qualification Test Levels	MS > 0	N/A	N/A	N/A
Thermal (TVAC)	Test	±10°C Beyond ATP 8 Cycles	Post Functional Performance	Test	±5°C Beyond ATP 4 Cycles	Post Functional Performance	Test	MPT 4 Cycles	Post Functional Performance

1. A qualification test verifies that the design of the space vehicle meets strength and fatigue requirements with margin necessary to account for build-to-build variability. Qualification test durations are calculated to provide an equivalent 4x life-cycle fatigue and are subject to change due to payload specific analysis. The qualification test article may not be used for flight.
2. A protoqualification test is a modified qualification test performed on a single space vehicle at reduced duration that verifies the design is qualified. The protoqualification test article may be used for flight if a mechanical fatigue analysis shows a cumulative damage index (CDI) of less than 0.5 for protoqualification loads and durations and a mechanical strength analysis shows positive minimum margin of safety to qualification loads.
3. An acceptance test verifies the workmanship of the flight space vehicles.
4. Acoustic and sine vibration testing may be waived if the predicted space vehicle loads are enveloped by random vibration testing.
5. Mechanical shock testing is optional.

Tolerances per SMC-S-016 (version 5 September 2014) Table 4.7.1 apply with following exceptions:

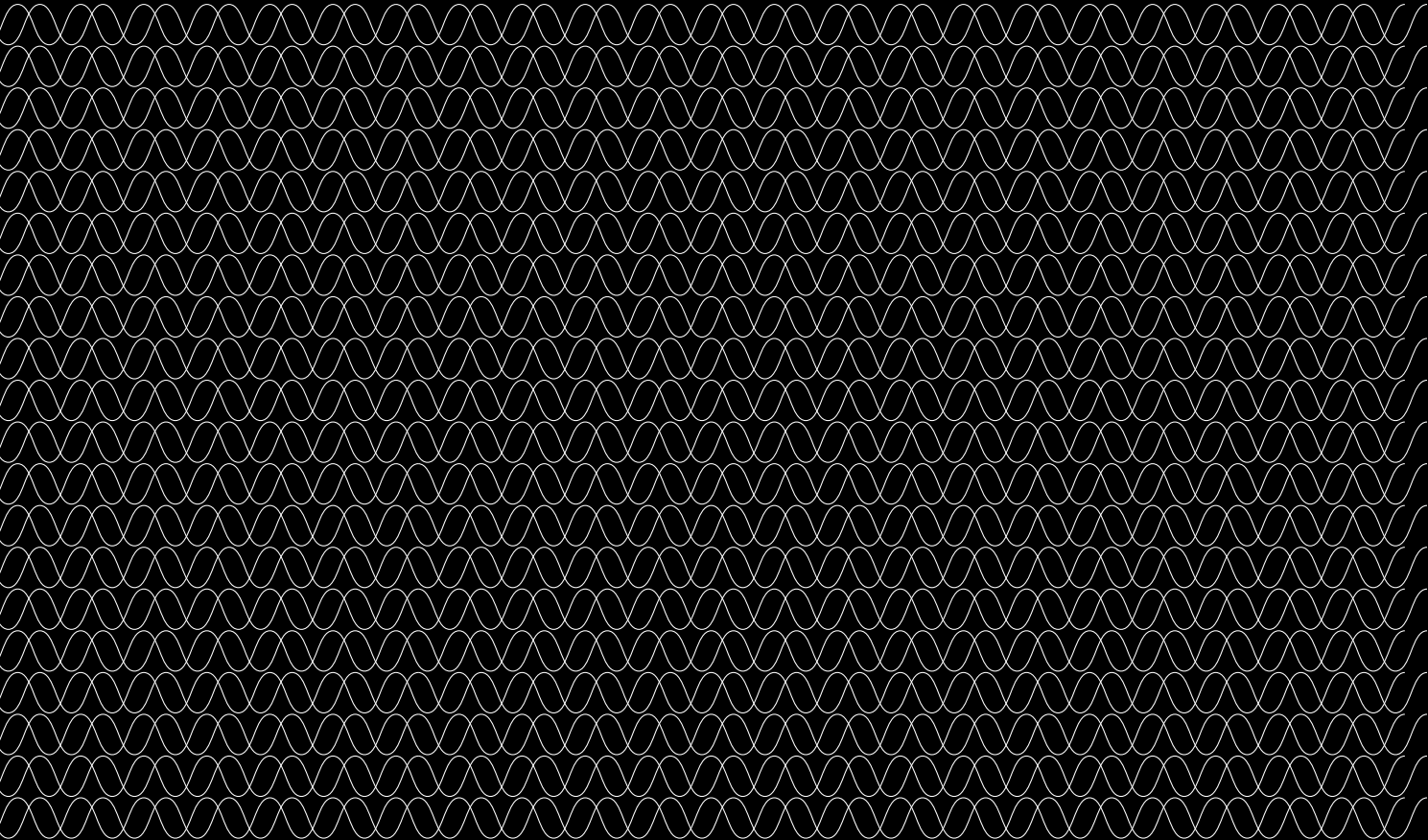
Shock Lower Tolerance: -3dB





LAUNCHER ONE





ORBIT

LAUNCHERONE SERVICE GUIDE

Virgin Orbit, LLC / Version 2.1 / August 2020

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