INTERSTELLAR TECHNOLOGIES

ZERO
PAYLOAD USER'S GUIDE

VERSION 2.0 | JULY 2024

CHANGING
ROCKETS, SATELLITES, AND FUTURE OF THE EARTH

Rockets: The Backbone of the Space Transportation Industry

Rockets serve as the only method of reaching orbit.
As a private space technology start-up, our focus is on designing cost-effective rockets and providing space launch services to meet global demands.

VISION

Aspire to a future where the wonders of space are accessible to all

MISSION

Empower the world with rocket solutions

REVISION HISTORY

Version	Date	Update
1.0	July 2023	First Release
2.0	July 2024	Updated Release

CONTACT

https://www.istellartech.com/en	launch@istellartech.com

CONTENTS

ACRONYMS

ICD	Interface Control Document
LC-1	Launch Complex - 1
LEO	Low Earth Orbit
LCH4	Liquid Methane
LOX	Liquid Oxygen
MAXQ	Maximum Dynamic Pressure
PSD	Power Spectral Density
S1	Stage 1
S2	Stage 2
SPL	Sound Pressure level
SSO	Sun-Synchronous Orbit
VAB	Vehicle Assembly Building

01

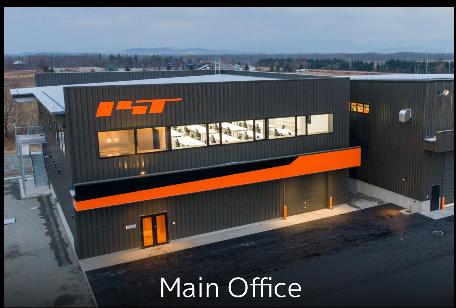
ORBITAL CLASS LAUNCH VEHICLE
ZERO

1.1 COMPANY PROFILE

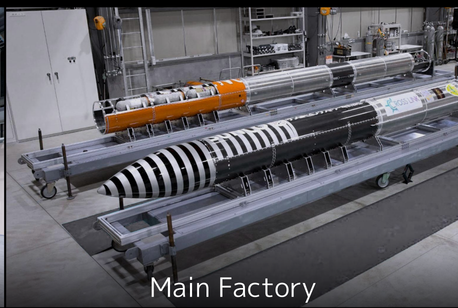
Interstellar is a dynamic Japanese start-up with a vision of making space accessible to everyone through low-cost and convenient space transportation services. Headquartered in Taiki, Hokkaido, Interstellar's product development extends across five locations, including branches in Tokyo, Fukushima, and Obihiro, as well as a laboratory at the Muroran Institute of Technology.

Interstellar has achieved three successful spaceflights with suborbital launch vehicle MOMO, making it Japan's first private company to reach space. Currently, Interstellar is developing the orbital-class launch vehicle ZERO. Additionally, Interstellar leads Our Stars, a satellite development project, pioneering Japan's vertically integrated rocket-satellite service.

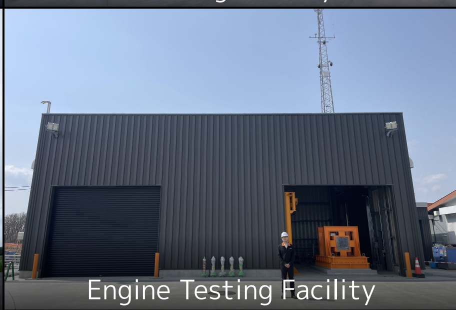
Location：149-7 Memu, Taiki, Hiroo-gun, Hokkaido, Japan
Representative：Takahiro Inagawa (Chief Executive Officer)


Main Office

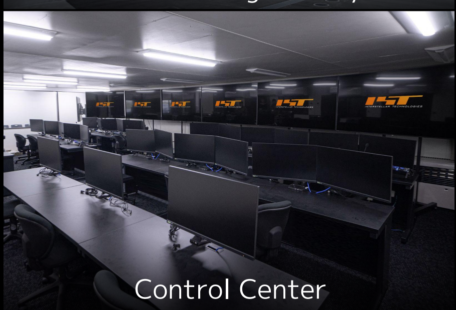

Welding Factory


Main Factory


Tank Testing Facility


Engine Testing Facility


Propellant Storage Tanks


Control Center

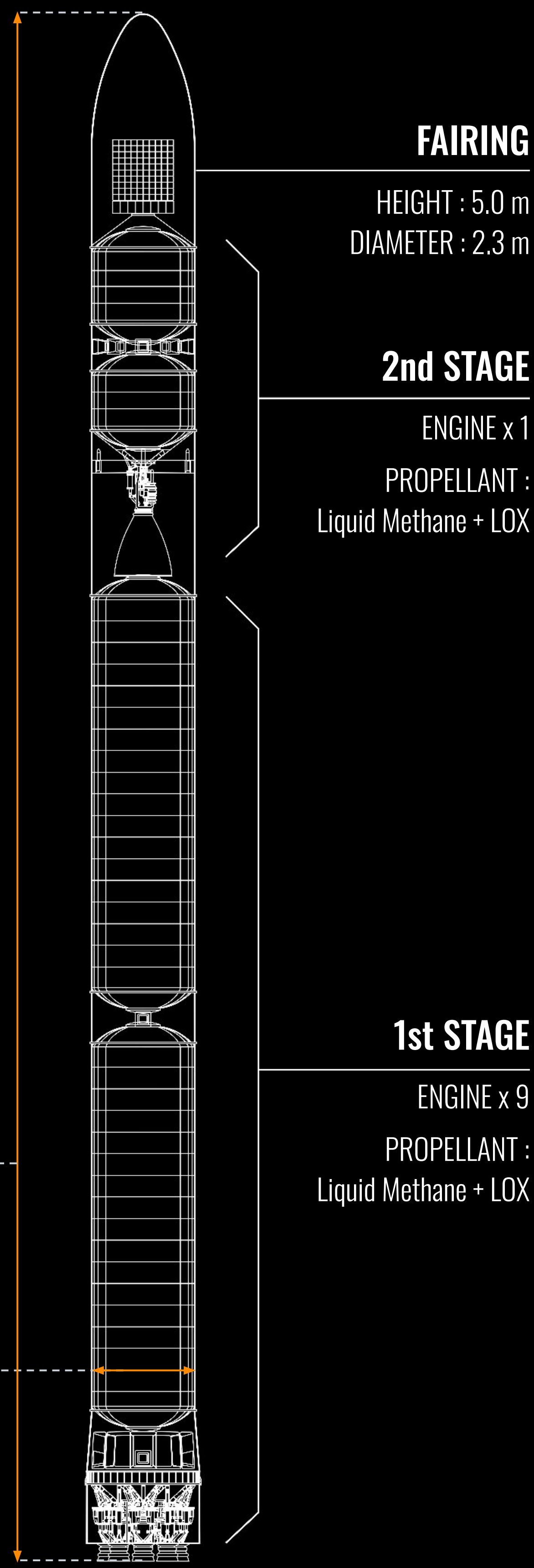

Machinery


Tokyo Office

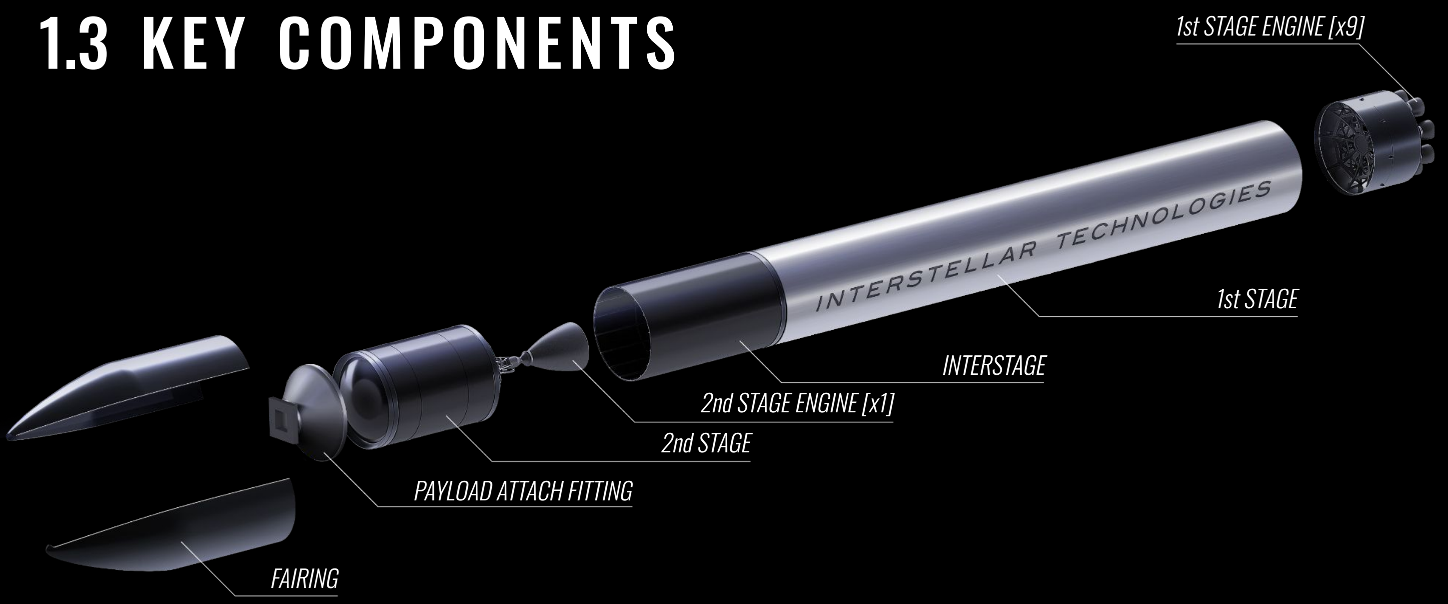
1.2 VEHICLE OVERVIEW

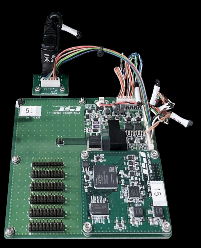
Interstellar's strength lies in its comprehensive in-house capabilities for design, manufacturing, testing, and launch. By managing all development stages internally, Interstellar eliminates unnecessary elements, accelerates development and manufacturing, and achieves significant cost reductions.

As a result of these streamlined processes, Interstellar proudly introduces ZERO, an orbital class launch vehicle. ZERO operates as an expendable two-stage launch vehicle, using liquid methane and liquid oxygen (LOX) as propellants. It offers flexible space transportation services, including dedicated launches and ridesharing, ensuring your satellite is placed into the desired orbit on your preferred schedule.



1.3 KEY COMPONENTS





AVIONICS

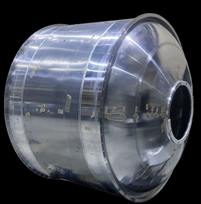
Reliable Systems for Mission Safeguarding

The avionics system serves a mission critical role in ZERO as it holds the responsibility of monitoring and controlling the safety of the vehicle. The architecture, mechanical hardware, electronic hardware, FPGA, and software development of the avionics system of ZERO are all done in-house at Interstellar.

GIMBAL MECHANISM

Enhancing Mission Safety

Gimbal mechanism controls the direction of each engine and consequently the launch vehicle trajectory and orientation. This allows engine adjustments mid-flight, improving safety for the missions. This technology has been demonstrated in our suborbital launch vehicle MOMO.



PROPELLANT TANKS

Crafting High-Performance Tanks

Design, manufacturing, welding, and testing of the tanks are done at Interstellar. High-strength aluminum alloy is used for the tanks that will store the liquid biomethane fuel and liquid oxygen oxidizer. A proof and a burst pressure test were done to ensure its capability to withstand design pressures and to gauge the pressure endurance limits.

ENGINE

Engine Systems Developed In-House

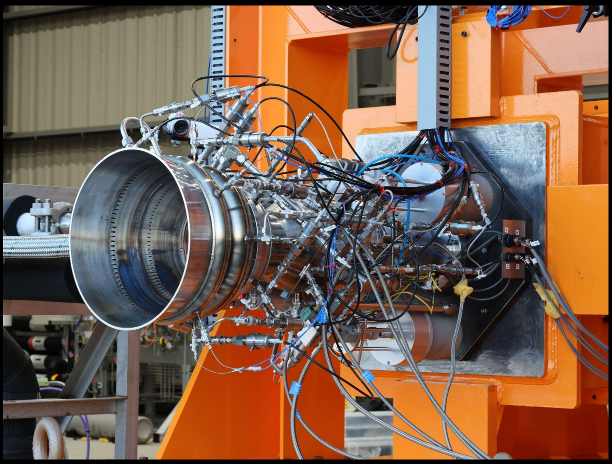
Interstellar adopted a liquid methane with liquid oxygen engine for ZERO. A cluster of 9 of the same engines will be used on the first stage, and a single engine of the same design with a vacuum optimized nozzle will be used on the second stage.

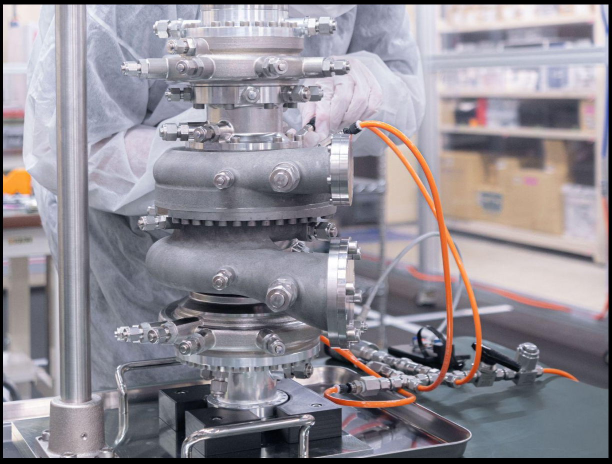
1.4 COSMOS ENGINE

GAS GENERATOR CYCLE & REGENERATIVE COOLING SYSTEMS

ZERO is a bipropellant rocket that uses liquid bio-methane as fuel and liquid oxygen as an oxidizer. This represents Interstellar's first use of a gas generator cycle, where part of the propellants is burned in a gas generator to drive a high-speed turbopump. This turbopump operates at tens of thousands of rotations per minute, delivering fuel to the combustion chamber under high pressure. The rocket also employs regenerative cooling, utilizing the fuel to effectively cool the combustion chamber walls.

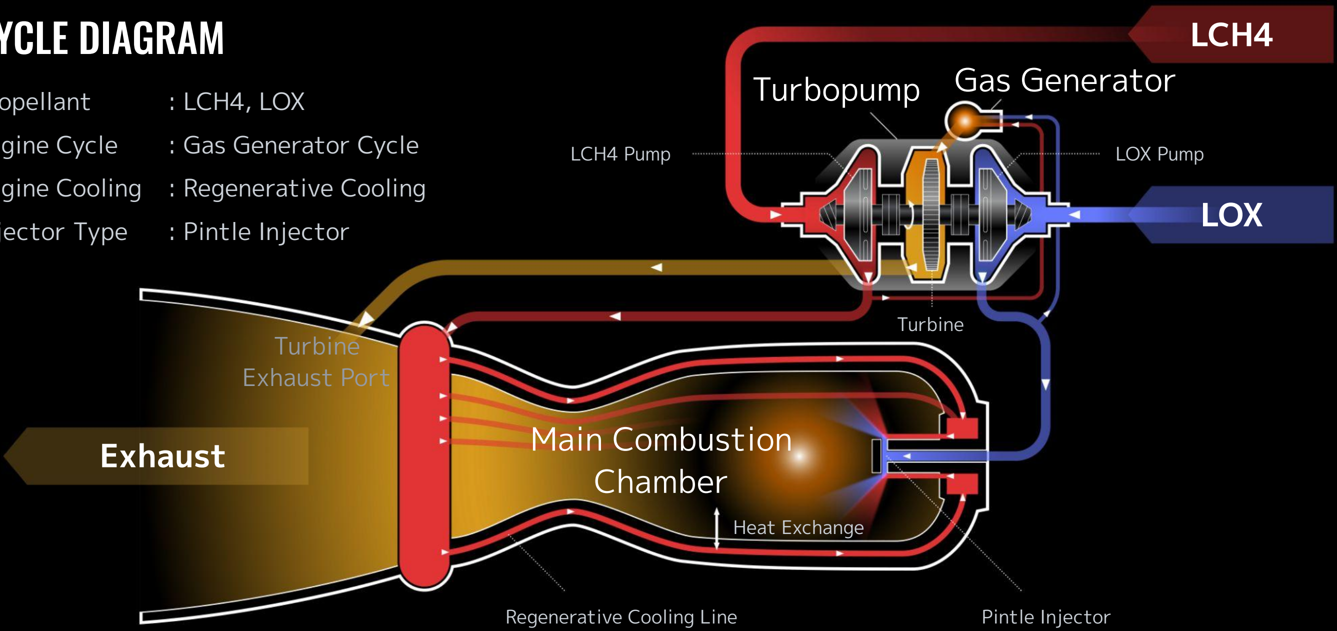
The engine for ZERO has been named COSMOS by the development team, inspired by the COSMOS flower, the official flower of Taiki. The engine's pintle injector spray pattern resembles the petals of this flower, making the name a fitting tribute.





CYCLE DIAGRAM

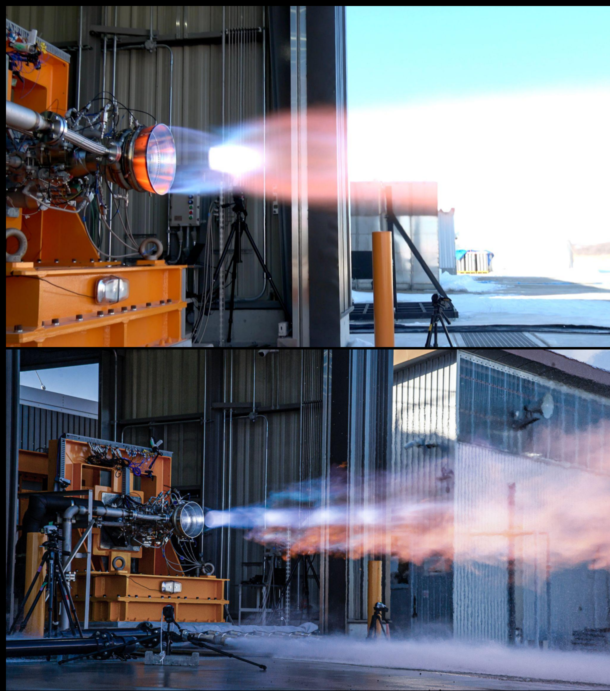
Propellant	: LCH4, LOX
Engine Cycle	: Gas Generator Cycle
Engine Cooling	: Regenerative Cooling
Injector Type	: Pintle Injector

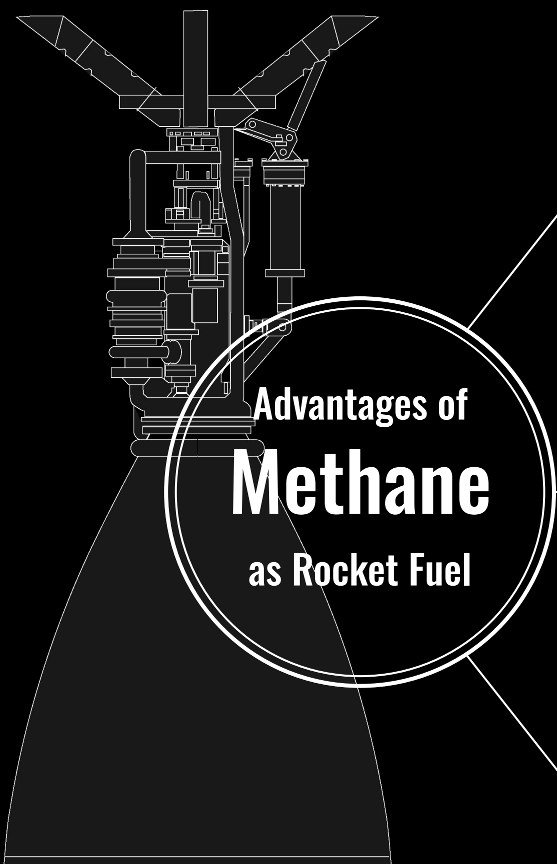


1.4 COSMOS ENGINE

HIGH-PERFORMANCE & SUSTAINABLE ROCKET FUEL for ENVIRONMENTALLY-CONSCIOUS LAUNCHES

Interstellar's rockets select liquid methane as a fuel due to its high performance and cost-effectiveness. Unlike traditional rocket fuels like kerosene, which are toxic and difficult to handle, liquid methane is easier to manage. This makes it an excellent choice for both rocket production and operations. Additionally, using liquid biomethane derived from cow manure significantly contributes to carbon neutrality. This initiative not only addresses odor issues in Hokkaido's dairy farming regions but also supports local energy self-sufficiency, promoting environmentally friendly development.





OPTIMIZED COST PERFORMANCE

Methane > Kerosene > Solid > Hydrogen

LOW ENVIRONMENTAL FOOTPRINT

Ocean : Methane <<< Kerosene
Atmosphere : Methane < Hydrogen < Solid

SUPERIOR SPECIFIC IMPULSE

Methane offers a higher specific impulse than kerosene

02 PERFORMANCE

2.1 FLIGHT PERFORMANCE

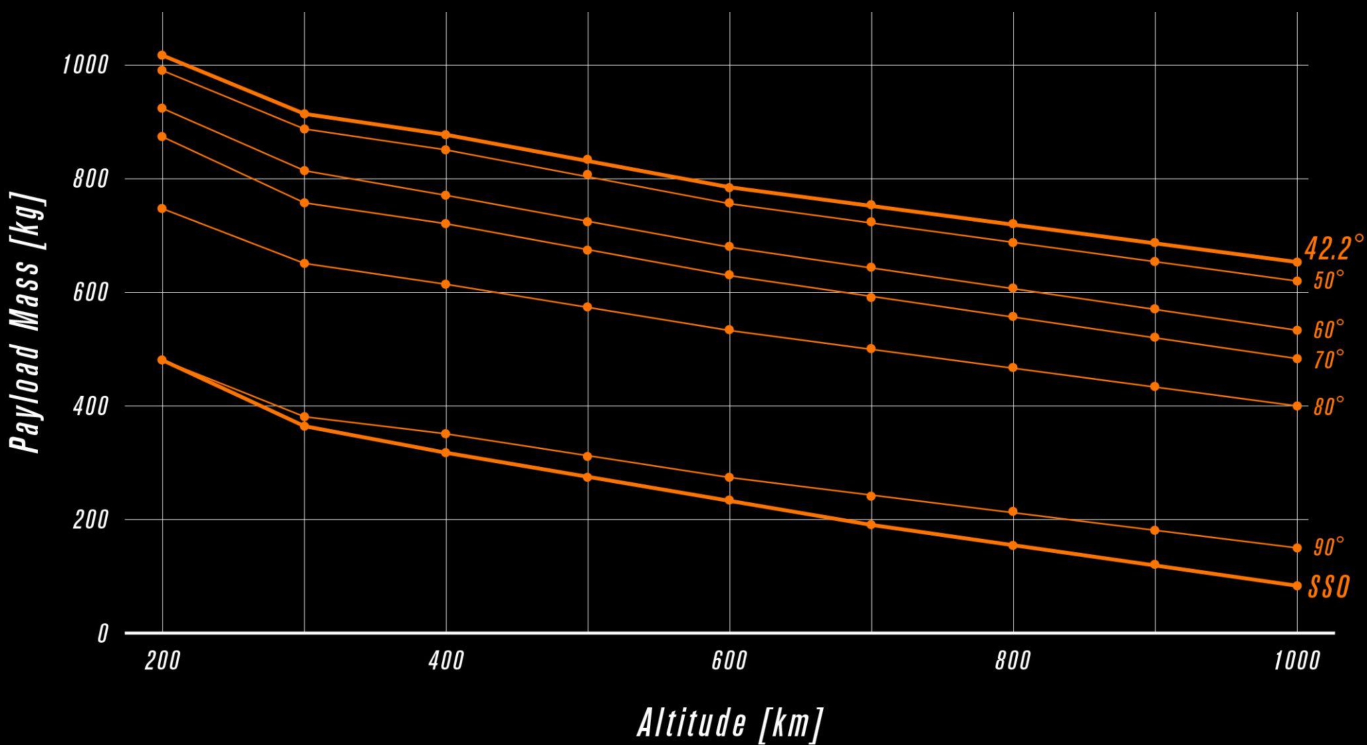
ZERO can carry payloads up to 800 kg to a mid-inclination Low Earth Orbit (LEO) at 561 km, while maintaining the flexibility to meet various payload and orbit requirements. In the demanding Sun Synchronous Orbit (SSO), it can efficiently launch payloads of up to 250 kg at 561 km. Refer to the performance curve below for more detailed information.

Orbit	LEO 42.2°- 561 km	SSO 97.6°- 561 km
Payload Mass	– 800 kg	– 250 kg

ZERO uses Hokkaido Spaceport as its main launch site. Facing the ocean to the east and south, this location provides an advantageous setting for accommodating a wide range of inclination options.

Available Inclinations	42° – 98°

ZERO FLIGHT PERFORMANCE CURVE



2.2 ORBIT INJECTION ACCURACY

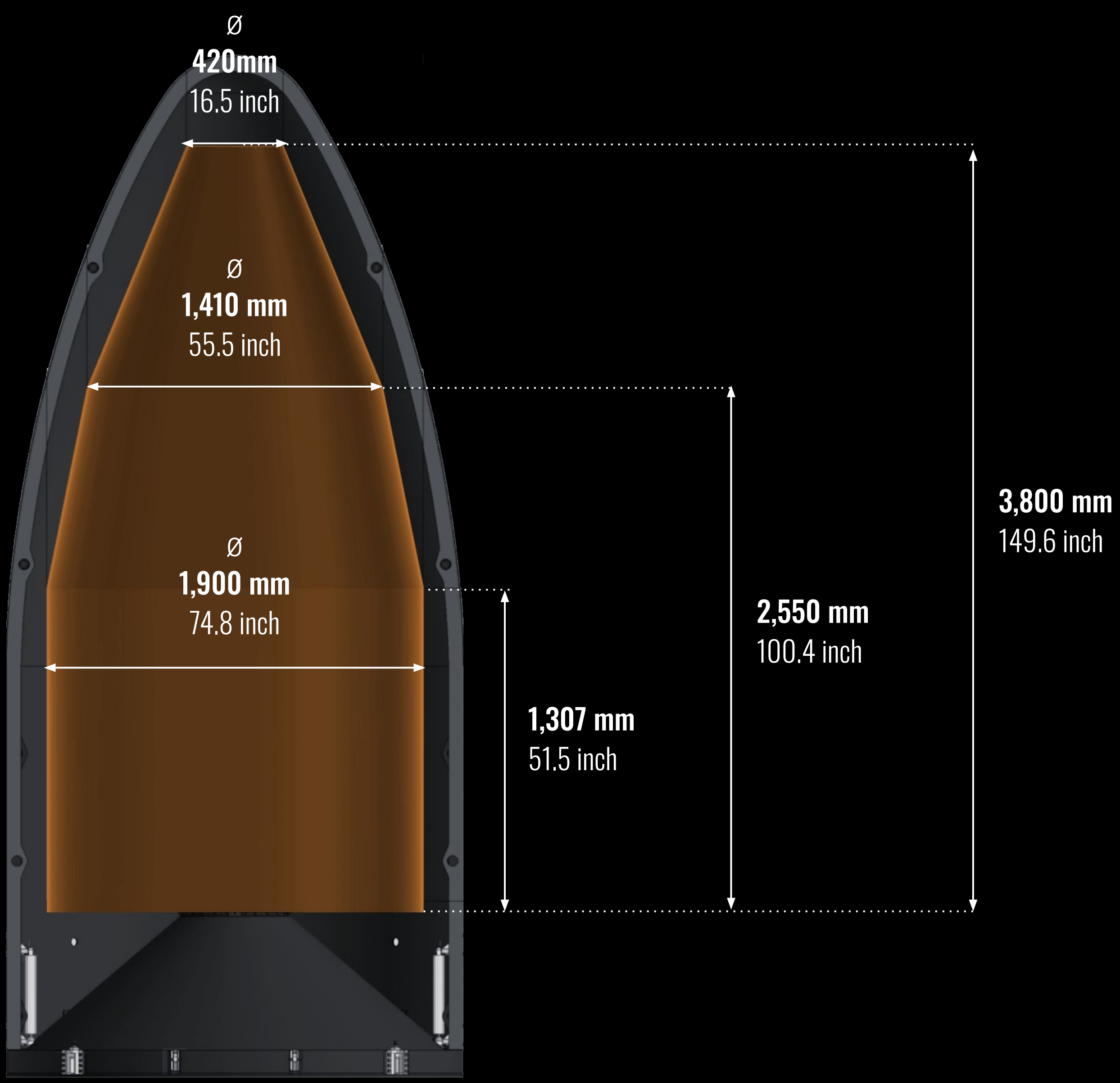
The target injection accuracies of ZERO for a typical mission are as follows. These estimates will be further refined with collected flight data.

Perigee	± 10 km
Apogee	± 15 km
Inclinations	± 0.1 deg

03 PAYLOAD ACCOMMODATION

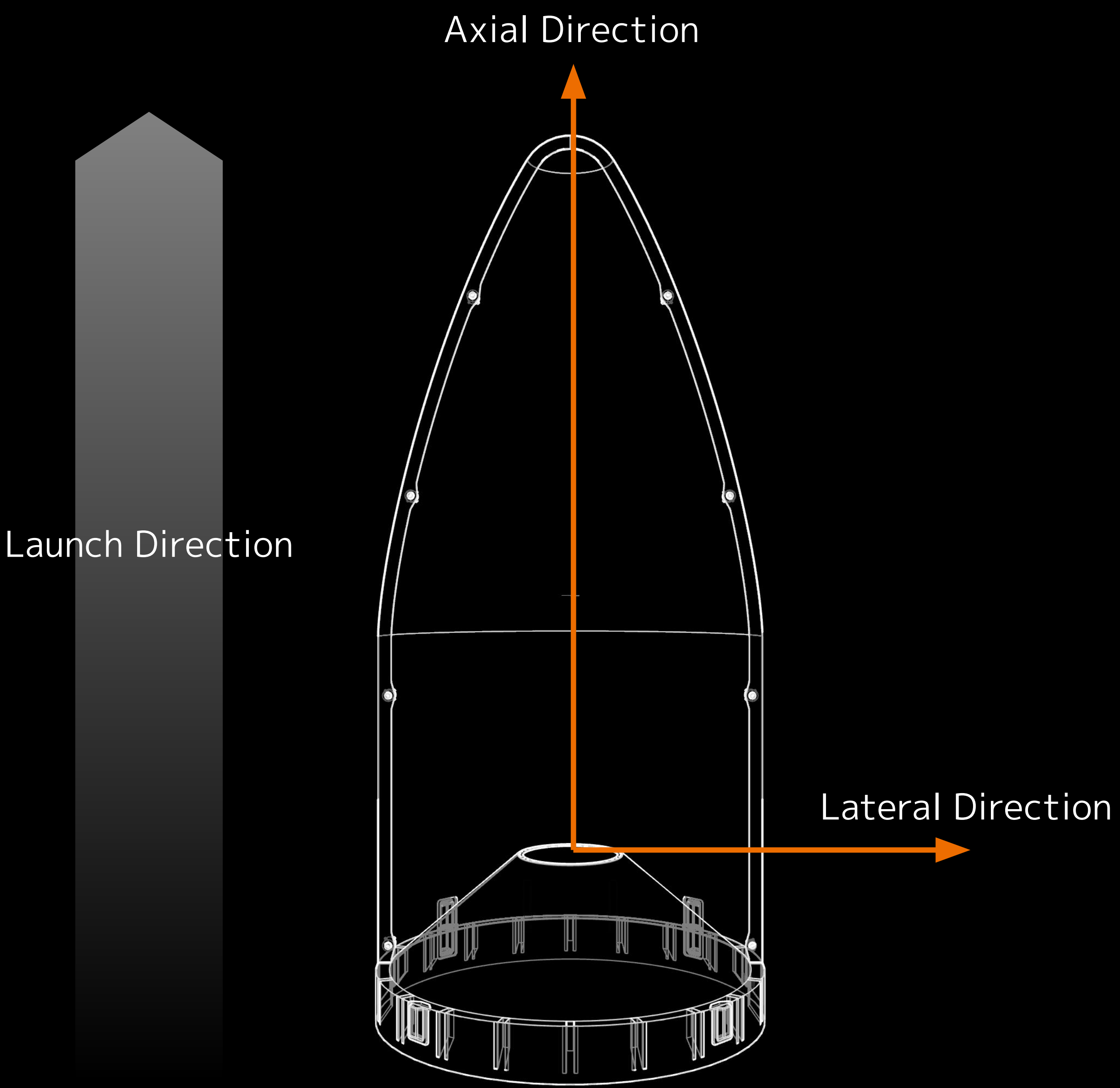
3.1 FAIRING CAPACITY

The payload fairing of ZERO is designed to accommodate a wide range of payload sizes and configurations, offering flexibility for various mission requirements. The accompanying figure illustrates the dimensions and shape of this space. Detailed specifications, including height, diameter, and overall volume, are provided to help you optimize the integration of your payload.



3.2 PAYLOAD COORDINATE FRAME

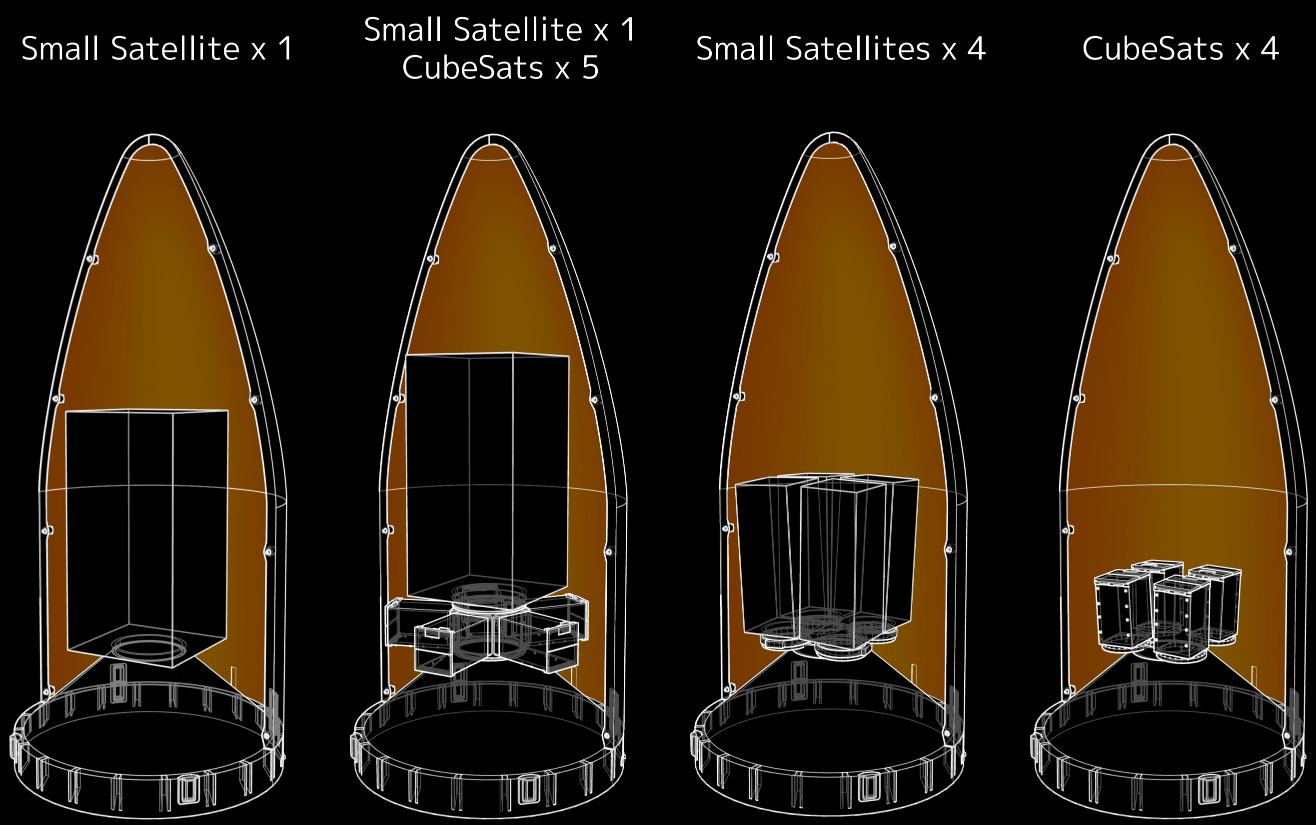
The origin of the Payload Coordinate System is fixed at the center of the mechanical interface between customer-supplied hardware and Interstellar-supplied hardware. This coordinate frame is used for describing the flight environment conditions and mechanical interfaces outlined in this document. The actual payload coordinate frame will be further defined in the mission-specific ICD. For this purpose, assuming a standard circular interface, the direction aligned with the launch is defined as the "Axial Direction," while the orthogonal direction is defined as the "Lateral Direction."



3.3 PAYLOAD CONFIGURATIONS & MECHANICAL INTERFACES

ZERO is capable of supporting various types of payloads, including small satellites and CubeSats. A wide range of separation systems can be accommodated by tailoring the bolt footprint of Interstellar-supplied hardware to match the customer-selected separation system. Payloads can be arranged and fitted in different ways inside the fairing to suit the specific requirements of each flight.

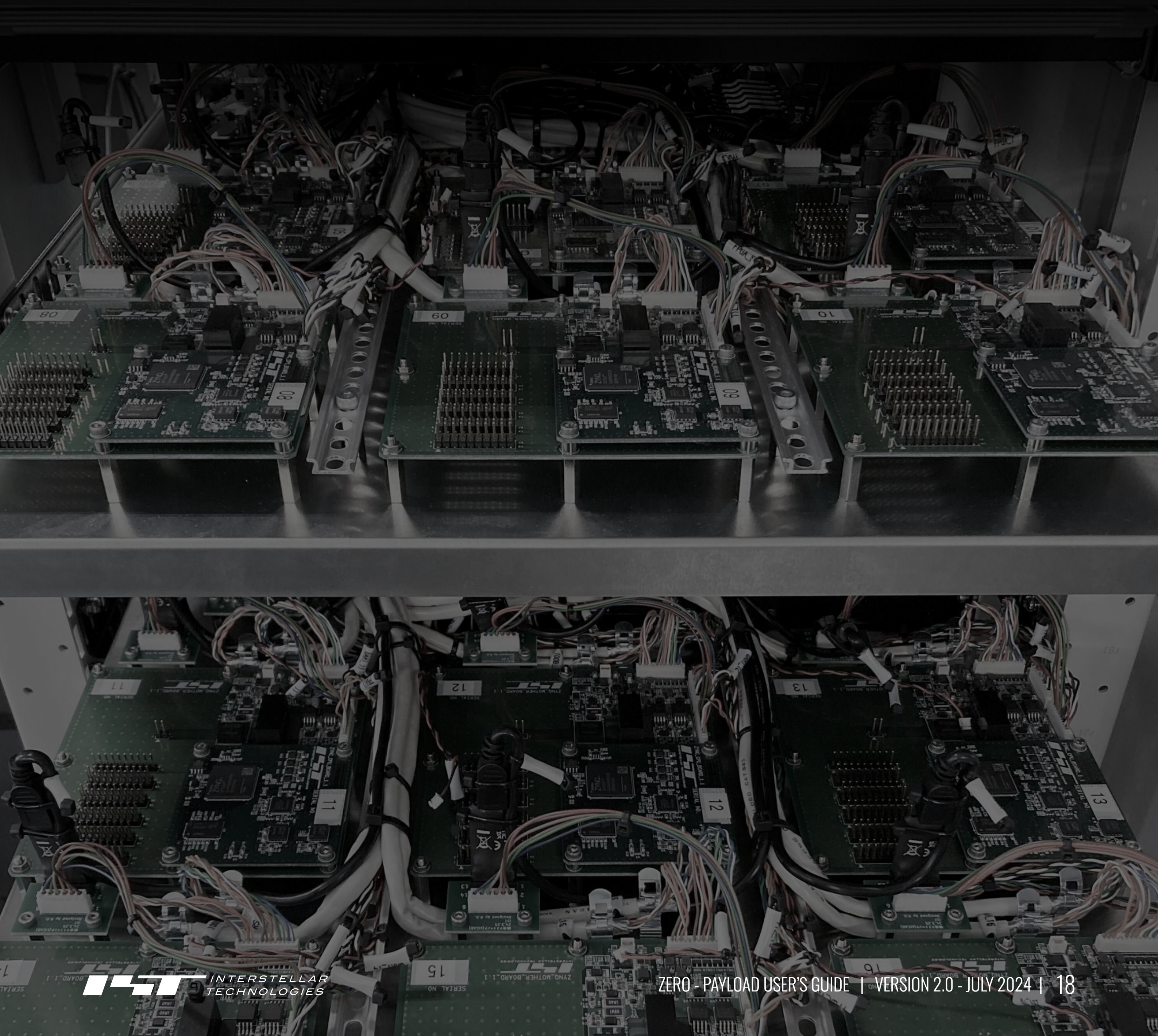
Please contact us if you have any questions or need assistance in selecting a separation system.



3.4 ELECTRICAL INTERFACES

Interstellar provides a flexible electrical interface tailored to accommodate diverse payloads, separation systems, and dispensers. This interface typically includes redundant payload deployment transmission signals and feedback signals to confirm deployment status for standard missions. Specific details regarding the electrical interface will be outlined in the mission-specific Interface Control Document.

Please reach out to us for confirmation of our ability to support your preferred deployer hardware.



04 FLIGHT ENVIRONMENTS

The flight environments outlined below represent the expected maximum predicted environments (MPE) for payloads in a typical mission. The loads and environments provided in this section are for reference only. The actual mission-specific environments will be detailed in the Interface Control Document (ICD) provided to customers.

For any questions about payload environments, please contact our team.

4.1 NATURAL FREQUENCIES & DAMPING

The purpose of defining natural frequencies and damping requirements is to ensure that the payload's elastic natural frequencies do not couple with those of the launch vehicle.

All elastic natural frequencies of the payloads must be above 40 Hz and must have a quality factor (Q) between 10 and 50. These requirements are designed to adequately account for the expected flight environments.

In this document, an elastic natural frequency refers to any frequency response of the payload that involves modal participation, as determined by a fixed-base modal analysis.

Frequencies Requirements (Q=10~Q=50)

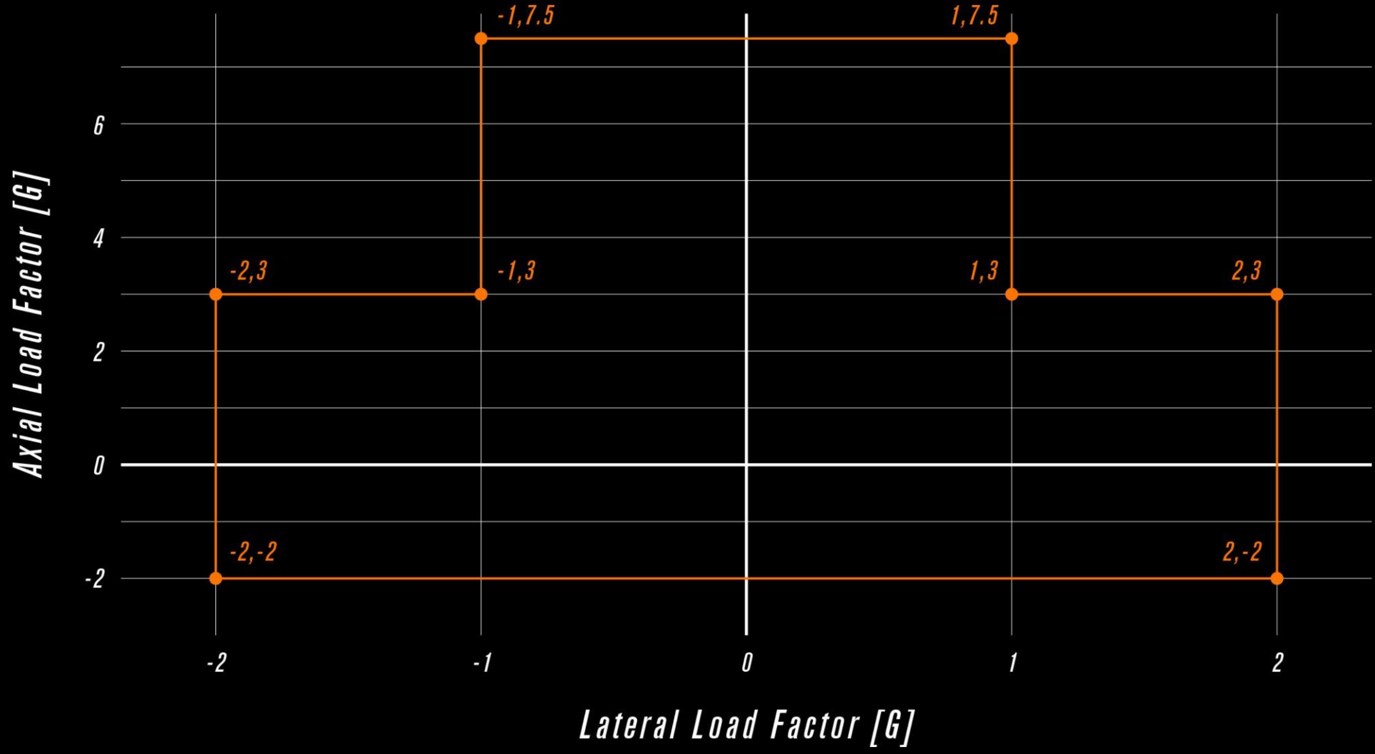
Axis	Axial and Lateral
Frequency	all modes above 40 Hz

4.2 QUASI-STATIC LOAD FACTORS

The payload will experience a range of acceleration loads in both the axial and lateral axes during the flight, as shown in the graph below. This envelope includes static and low-frequency dynamic loads.

Axial acceleration loads arise from thrust, aerodynamic axial forces, separation forces, and similar factors. Lateral acceleration loads result from wind gusts, thrust vector control (TVC) reaction forces, first-stage engine shutdown, and other short-term events.

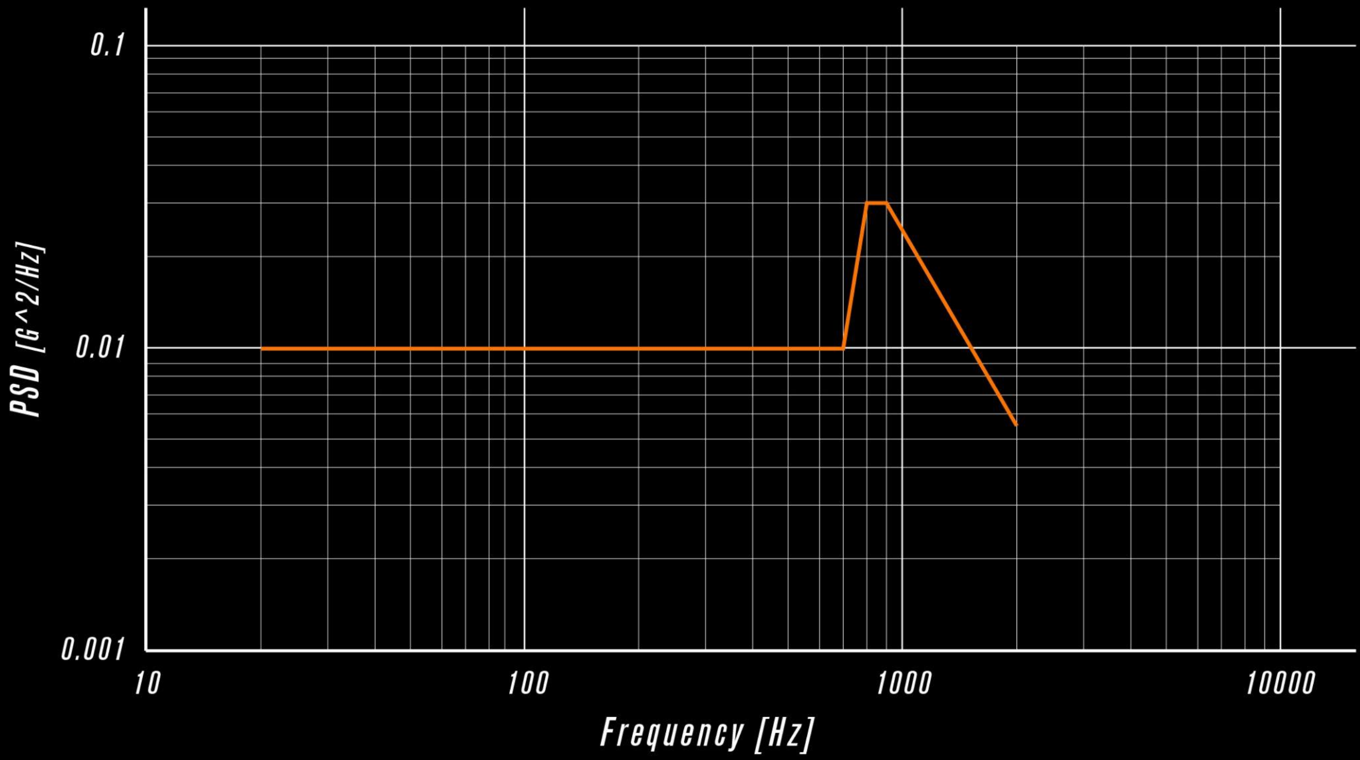
Mission-specific accelerations will be further detailed in the mission-specific Interface Control Document (ICD), determined by the coupled loads analysis.



4.3 RANDOM VIBRATION

The plot below shows the estimated Maximum Predicted Random Vibration Environment for microsatellite-class payloads. This estimate is based on an analysis of vehicle environments and past data and is subject to change as additional flight information and testing become available.

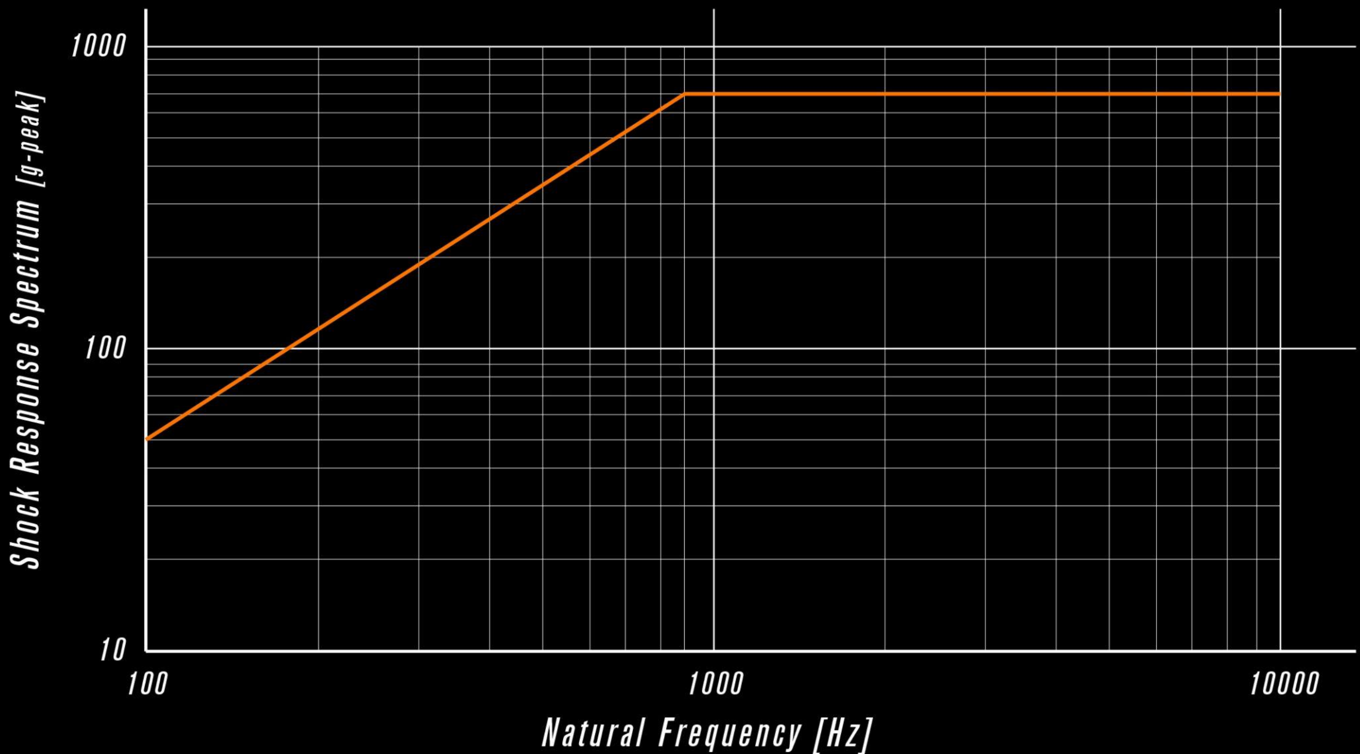
Frequency [Hz]	20	700	800	925	2000	GRMS
PSD [G^2/Hz]	0.01	0.01	0.03	0.03	0.00644	5.23



4.4 SHOCK

The maximum predicted shock response at the payload interface from all sources of launch vehicle shock is shown in the graph and table. This level is defined assuming a quality factor (Q) of 10. The estimate is based on an analysis of vehicle environments and past data and is subject to change as additional flight information and testing become available.

Frequency [Hz]	100	900	10000
Shock Response Spectrum [G]	50	700	700



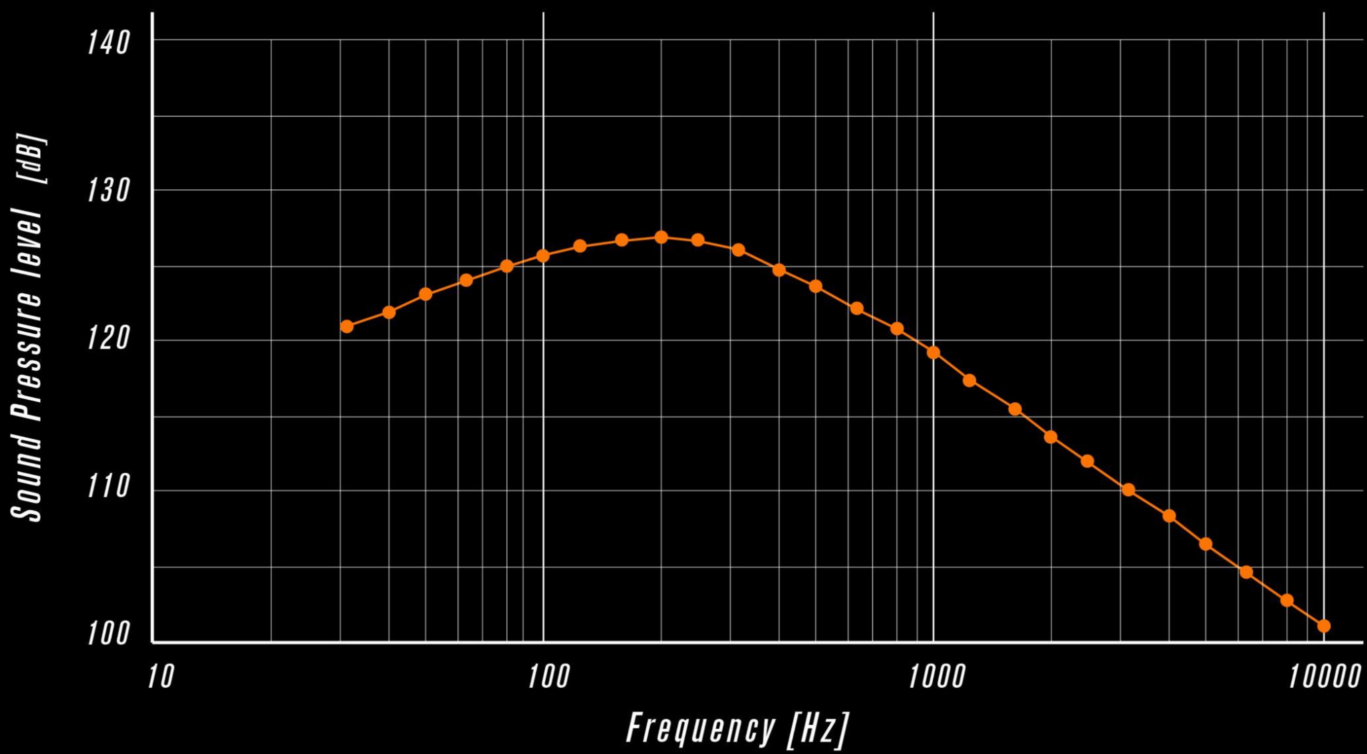
4.5 ACOUSTIC

The vibroacoustic environment inside the fairing is determined as shown in the graph and table below. This environment encompasses the acoustic vibrations generated by the first-stage engine during lift-off, as well as the acoustic vibrations from pressure fluctuations outside the vehicle during atmospheric flight. These conditions will be redefined as more flight data becomes available.

MAXIMUM PREDICTED ACOUSTIC ENVIRONMENT

Frequency [Hz]	31.5	40	50	63	80	100	125	160	200	250	315	400	500
SPL [dB]	121	122	123	124	124.9	125.7	126.3	126.7	126.9	126.6	126	124.8	123.6

FREQUENCY [Hz]	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
SPL [dB]	122.2	120.9	119.3	117.5	115.5	113.6	111.9	110.1	108.4	106.5	104.6	102.8	101.1



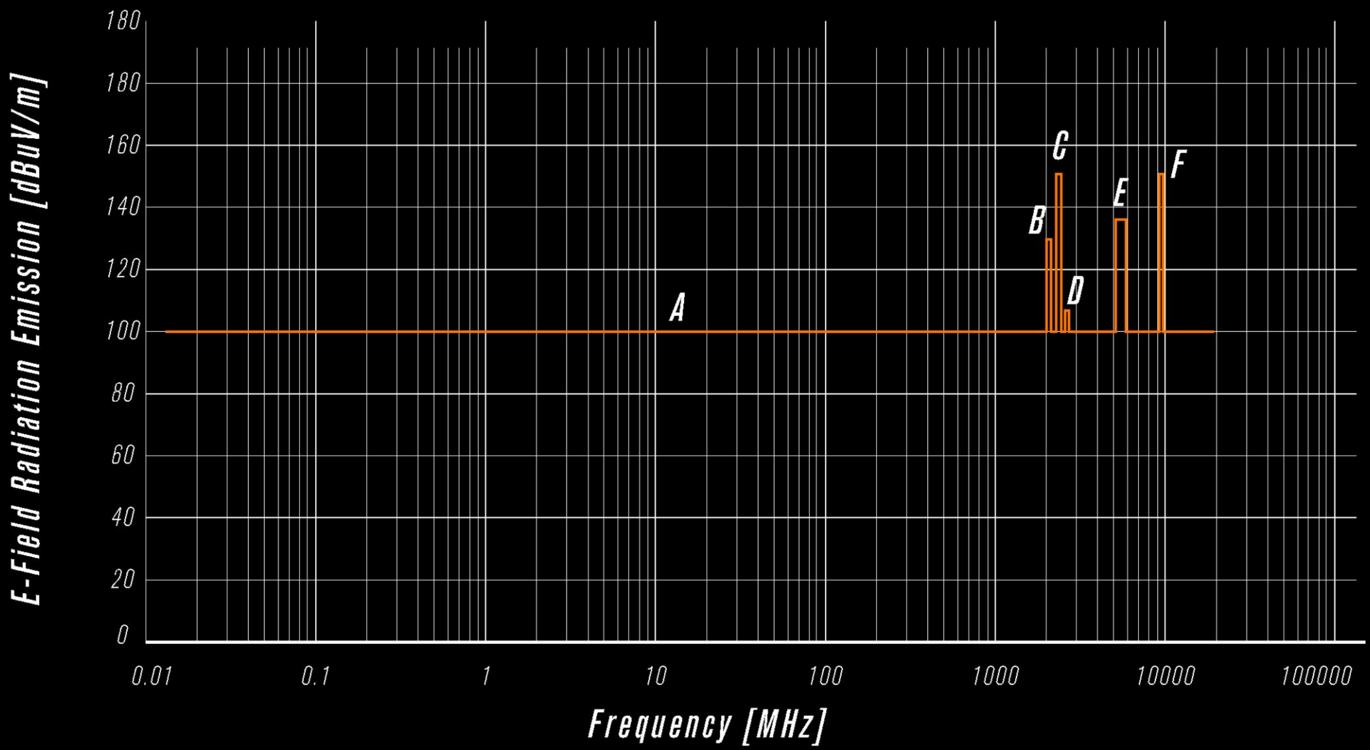
4.6 ELECTROMAGNETIC

ELECTROMAGNETIC EMISSIONS FROM ZERO AND LAUNCH SITE

This section outlines the worst-case radiated emissions from the Launch Vehicle and Launch Site. Payloads can expect to encounter an electric field (E-Field) from these emissions, with levels no higher than those indicated in the graph and table below. The electric field level is measured at the payload interface plane.
Components on payloads that are sensitive to RF environments should be verified for compatibility with the specified radiated environment.

E-Field Radiation Emission vs Frequency

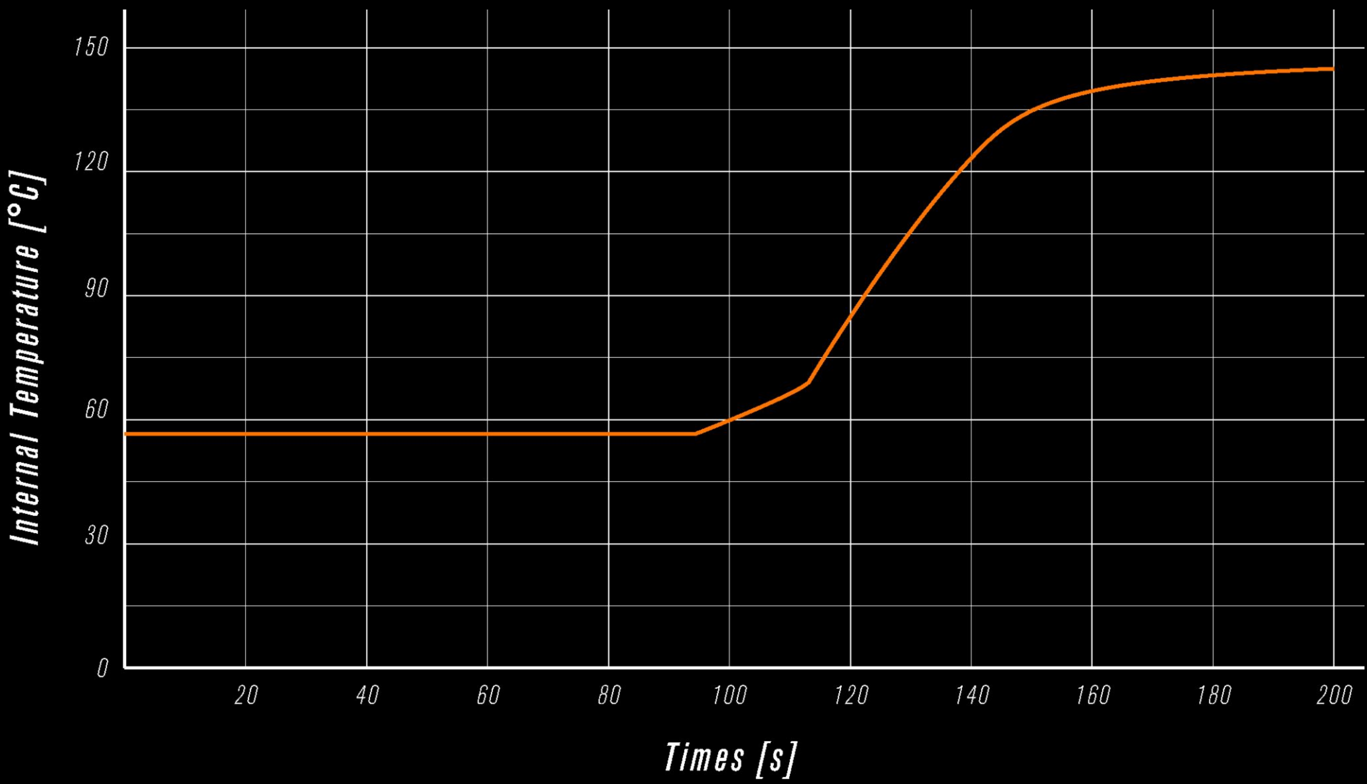
Label	A	B	C	D	E	F
Frequency Range [MHz]	0.014-18000	2025-2110	2200-2300	2401-2495	5230-5390	9410
E-Field Level [dBuV/m]	100	128	150	107	136	150



4.7 FAIRING THERMAL ENVIRONMENT

FAIRING TEMPERATURE AS SEEN FROM PAYLOAD

The temperature profile below shows the maximum fairing spot temperature seen by the payload. The emissivity of the fairing is approximately 0.9.



FREE MOLECULAR HEATING

The Payload experiences a maximum free molecular aero-thermal heating rate of under 1135 W/m² at the point of fairing separation. This heating rapidly diminishes and becomes insignificant within a few minutes.

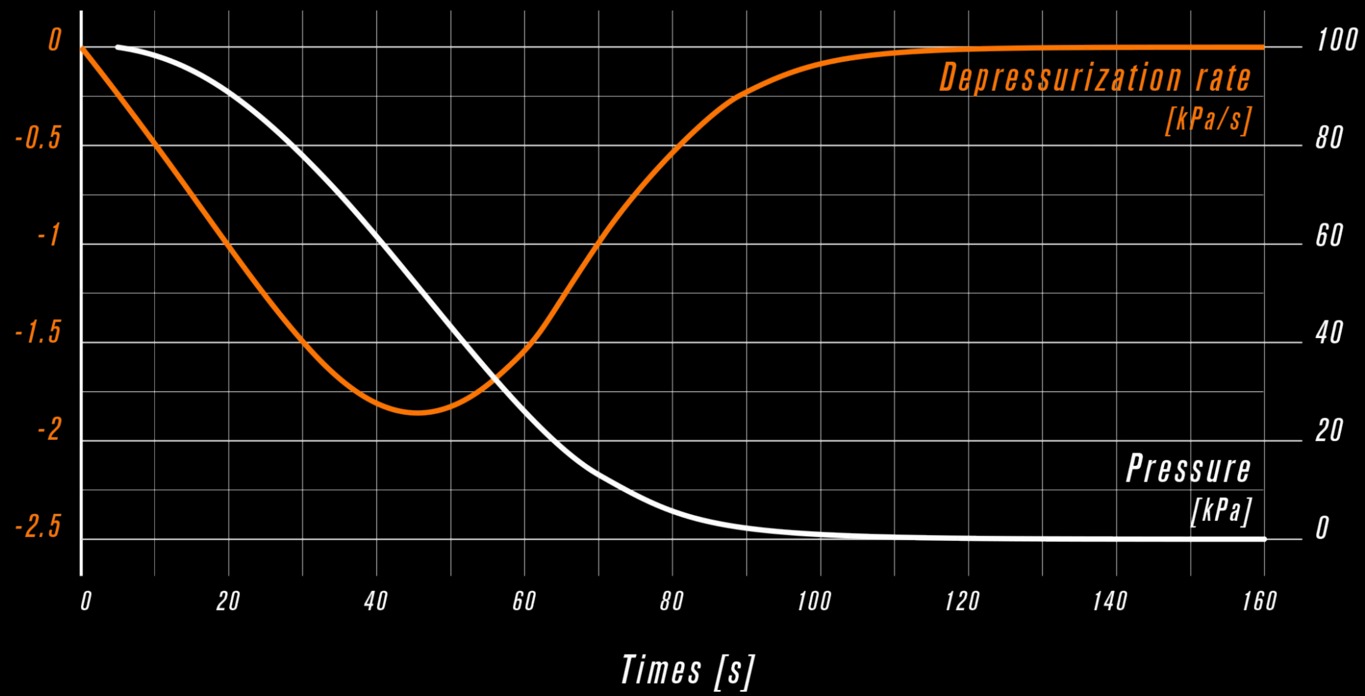
4.8 HUMIDITY

The maximum relative humidity inside the fairing from lift-off until just before fairing separation is 65%. This controlled humidity level ensures the protection and integrity of the payload during the initial phases of the flight. ZERO is designed to maintain optimal environmental conditions, ensuring the successful deployment and operation of the payload.

4.9 VENTING

The graph below shows the pressure and decompression rate during flight for a typical mission. The maximum depressurization rate is 1.9 kPa/s, with brief periods during flight reaching up to 4.5 kPa/s for only 5 seconds.

Please note that these are preliminary values and are subject to refinement with additional calculations and flight data.



05

LAUNCH SITE FACILITIES

Provided by
: SPACE COTAN Co.,Ltd.

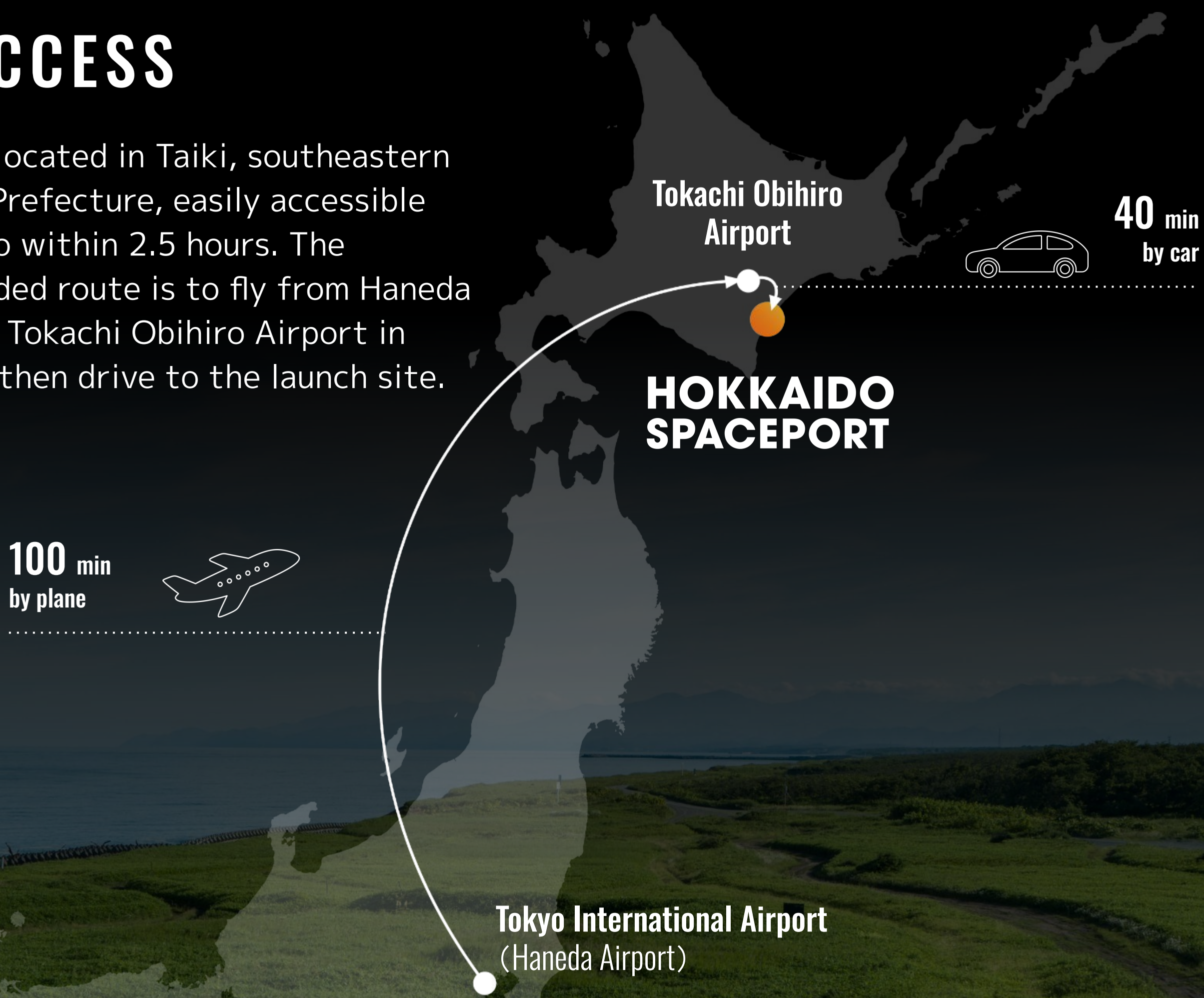
5.1 ABOUT HOKKAIDO SPACEPORT

Hokkaido Spaceport (HOSPO) is the the global commercial spaceport in East Asia, located in Taiki, Hokkaido, Japan.

Situated at HOSPO, Launch Complex-1 (LC-1) serves as the designated launch site for ZERO missions. LC-1 features a Vehicle Assembly Building (VAB) and test facilities, along with an exhaust duct to minimize engine jet noise and vibration impact on satellites. LC-1 is designed to blend seamlessly with the surrounding natural landscape.

5.2 ACCESS

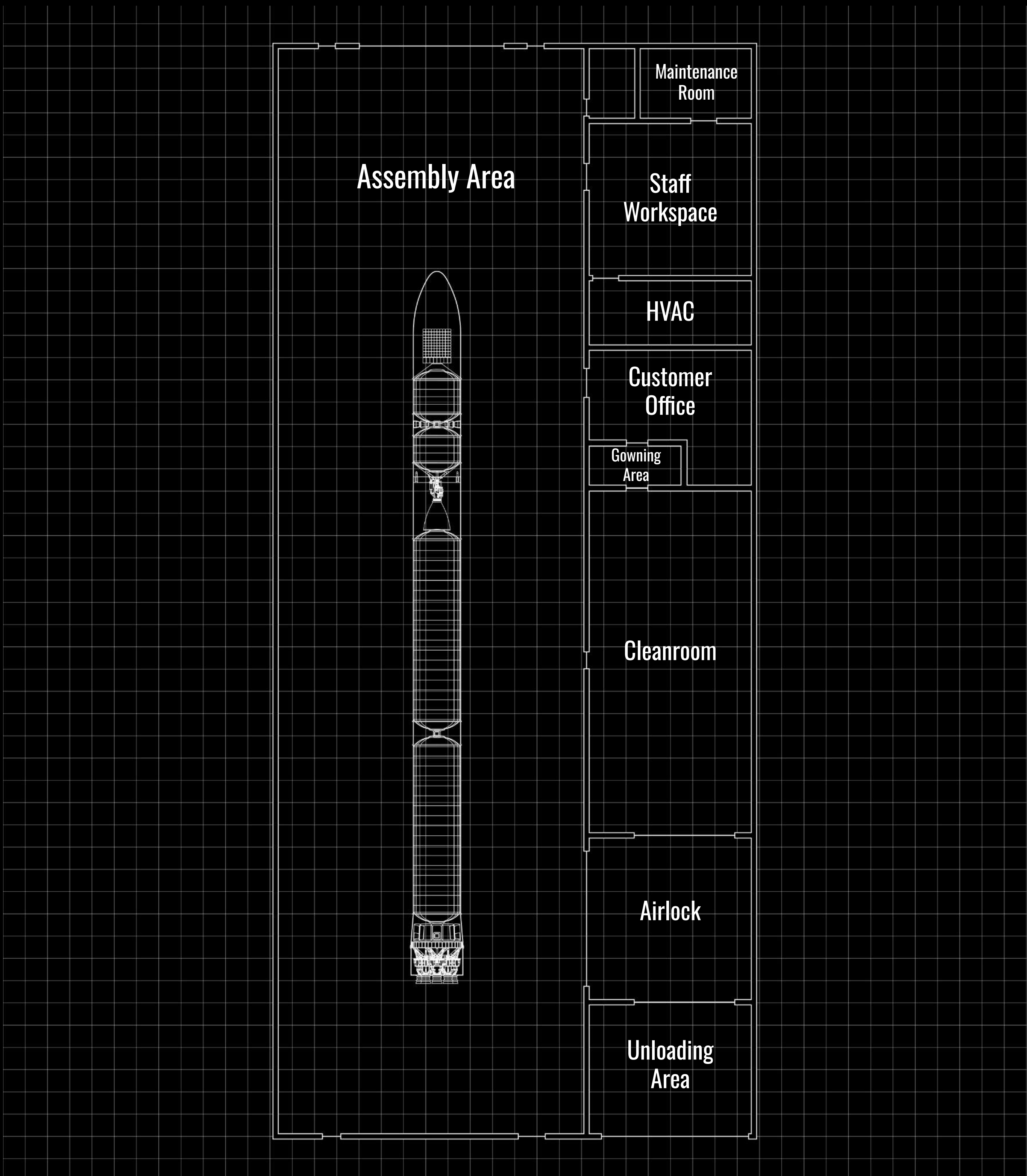
HOSPO is located in Taiki, southeastern Hokkaido Prefecture, easily accessible from Tokyo within 2.5 hours. The recommended route is to fly from Haneda Airport to Tokachi Obihiro Airport in Hokkaido, then drive to the launch site.



Provided by : SPACE COTAN Co.,Ltd.

5.3 PAYLOAD PROCESSING FACILITY

The following illustrates the layout of the Payload Processing Facility at LC-1, featuring the payload integration room, airlock, and dedicated customer office space. Please note that as the facility is currently under construction, the final layout may slightly differ.



5.4 CUSTOMER OFFICE

Interstellar provides an office area within the Payload Processing Facility, strategically positioned adjacent to the payload integration area for convenient access. Although the facility is currently under construction, the aim is to equip the office area with essential amenities including Internet connection, air conditioning, and standard office equipment such as desks, chairs, and phones.

06

OPERATIONS

6.1 AVAILABLE SERVICES & EQUIPMENT

As part of our launch package, Interstellar offers a variety of services and equipment. Some examples of what we can provide are detailed below. Recognizing the uniqueness of each mission, the specific services and equipment will be finalized during the signing of the Launch Services Agreement (LSA). We encourage early discussions during mission planning to ensure that our offerings align with your schedule and budget.

SERVICES

- Dedicated Technical Mission Manager and Customer Support Teams
- Development and Provision of Mission-Specific Interface Control Document (ICD), Including Verification Planning and Deliverables
- Mission Planning and Launch Scheduling
- Customization of Launch Configuration, Mechanical and Electrical Interfaces for Dedicated Missions
- Progress Follow-Up Meetings
- Securing Necessary Launch Licenses from Japanese Authorities
- Guidance and Support for Launch Insurance
- Payload Transportation Assistance
- Interstellar Integration Support Personnel
- Accommodation Assistance for Customer's Launch Team
- Launch Site Access and Commute Support
- Photography Operations
- Confirmation of Payload Separation and Provision of State Vector to Customer

EQUIPMENT

- ISO-8 cleanliness level environment (Class 100K)
- Crane for payload integration operations
- Power provided for electrical ground support equipment (110V AC, 50Hz)
- Isopropyl Alcohol, wipes, gloves, hair nets, gowns, work shoes
- Security guards and video monitoring cameras
- Internet connection and standard office equipment for customer office

For information on additional services not listed above that may be required for your mission, please contact our team.

6.2 PAYLOAD PROCESSING WORKFLOW

This section provides an overview of the payload processing workflow for a typical mission. A dedicated Interstellar integration team will be assigned to the customer, working closely to provide comprehensive support throughout the process.

Payload Delivery to the Launch Complex

The payload will be transported from the customer's facility to our Launch Complex-1 in Hokkaido. Upon arrival, our team will carefully offload and move the payload and ground support equipment to the designated processing area. Typically, the payload arrives at the launch site 30 days prior to launch, though this timeline can be adjusted if necessary.

Payload Final Check-out

Customers will conduct the final checkout of the spacecraft, which involves performing last-minute tests and preparations, such as software loading, powering up, and propellant fueling. Our facilities offer all the necessary support to ensure your payload is fully prepared and ready for integration.

Payload Integration

In this step, the payload will be integrated with the separation system, which will then be attached to the payload attach fitting of the ZERO launch vehicle. This process also includes establishing electrical and data connections to the launch vehicle, enabling communication between the payload and our launch control team.

Fairing Encapsulation

At this stage, the payload, along with the separation system, is integrated with the payload attach fitting. Once the payload is thoroughly checked, it will be encapsulated within ZERO's fairing.

Encapsulated Payload Mate with ZERO Launch Vehicle

The encapsulated payload is then carefully transported to the assembly area for integration with the rest of the launch vehicle. Once integrated, the launch vehicle, with the payload onboard, will be ready to roll out to the launch pad.

6.3 MISSION & LAUNCH TIMELINE

The milestones and payload processing schedule for a typical mission are presented below. If you require an accelerated or extended timeline, Interstellar will work closely with you to develop mission-specific milestones.

To explore options for a customized timeline that aligns with your mission objectives, please contact our team.

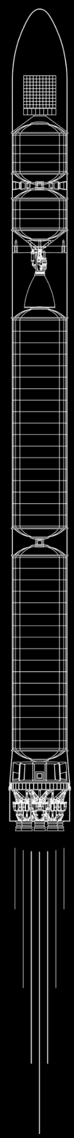
L-12months
Sign Contract & Mission Kick-off

L-6 months
Launch Campaign Planning Kick-off

L-3 months
Finalize ICD and Mission Interfaces

L-30 days
Payload Arrival at Processing Facility

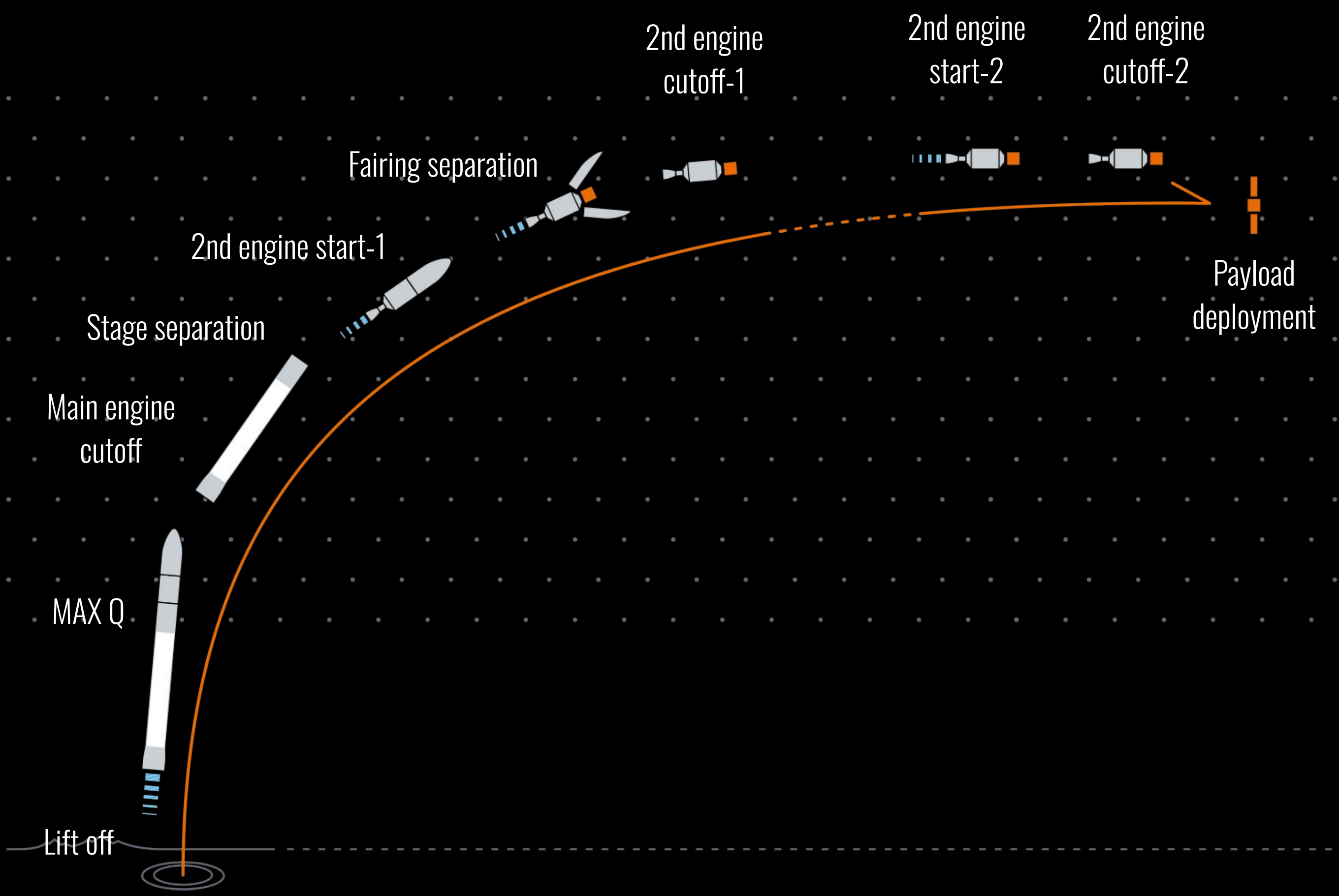
Days	Payload	Launch Vehicle	Launch Complex
L-30	Payload Integration	S1, S2, and Fairing Module Checkouts	Launch Pad and Range Safety Systems Checkouts
L-15	Fairing Encapsulation		
L-13	Encapsulated Fairing Mate with S1 and S2		
L-10	Launch Vehicle and Range Interface Check		RF Checkouts
L-4			
L-3	Final Launch Vehicle Preparation		Final Range Preparation
L-2			
L-1	Roll Out		
L-0	Launch		
L+0	Deliver State Vector to Customer		



LAUNCH

6.4 MISSION PROFILE

The following illustration depicts the standard mission profile and staging sequence for the ZERO rocket. While typical missions follow a similar profile, variations in timing and altitude for key events may occur based on mission-specific requirements.



1	2	3	4	5	6	7	8	9	10
Lift off	MAX Q	Main engine cutoff	Stage separation	2nd engine start-1	Fairing separation	2nd engine cutoff-1	2nd engine start-2	2nd engine cutoff-2	Payload deployment
0 TIME [s]	+ 62	+ 143	+ 148	+ 153	+ 192	+ 429	+ 3148	+ 3149	+ 3200

07 ABOUT OUR COMPANY

7.1 TEAM

Interstellar's development team is made up of highly skilled professionals, each with extensive expertise and dedication. Our engineers include those who have worked on spacecraft development for Japan's government space agency and experts from leading global automobile manufacturers. By merging Japan's industrial technologies, Interstellar is pioneering a new era of space exploration.

7.2 ACHIEVEMENTS

18 ROCKET LAUNCHES

A total of 18 rockets have been manufactured and launched, including three successful space missions. (as of June 2024)

FIRST IN JAPAN

The first rocket developed by a private Japanese company to reach space.

FIRST IN THE WORLD

The first and only private company in the world utilizing bio-methane liquid-fueled engine.

7.3 ADVANTAGES

ON-DEMAND

Your Destination, Your Timeline

Interstellar facilitates on-demand transportation to the desired orbit and altitude, offering a dedicated solution that overcomes the limitations of shared transportation for large satellites. By integrating in-house design, manufacturing, testing, and launch operations, Interstellar significantly reduces the time from contract to launch.

FLEXIBILITY

Tailored Solutions for Your Needs

In-house design and manufacturing capabilities grant flexibility to meet your needs. Interstellar customizes the system to match your requirements and handle sudden changes, ensuring high customer satisfaction.

LOW COST

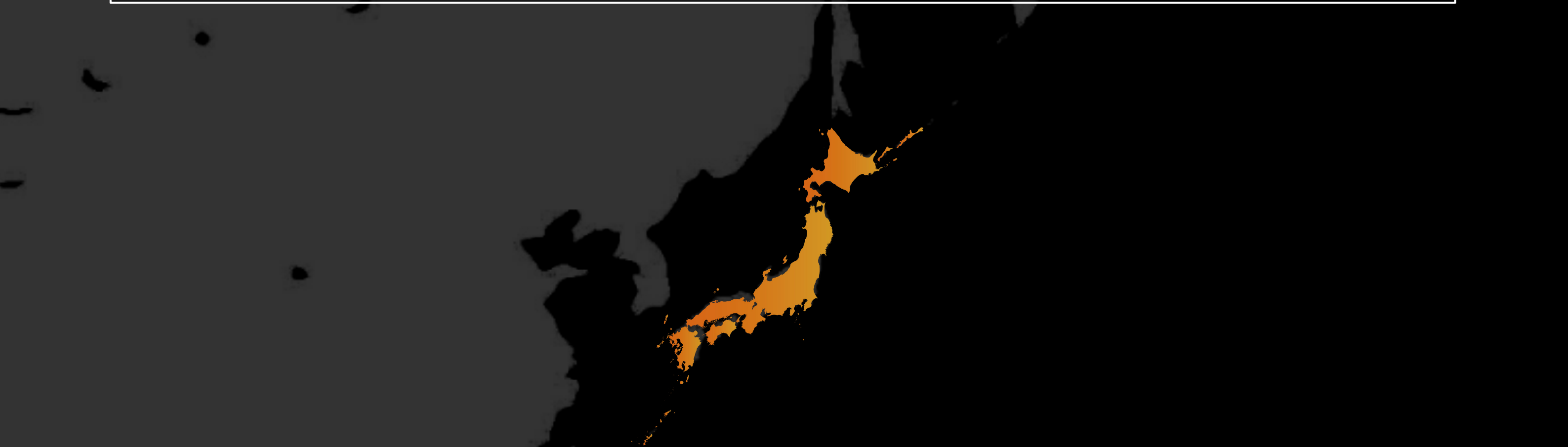
Globally Competitive Launch Costs

Interstellar offers one of the most competitive price points in the microsatellite launch market. Striving to reduce prices through the in-house development of core technologies and the active utilization of cutting-edge technologies such as consumer-grade components and 3D printing.

VERSATILE LAUNCH SITE

Embrace the Allure of the Japanese Spaceport

Hokkaido Spaceport "HOSPO," located in Taiki, Hokkaido, Japan, provides launch capabilities towards the east and south, making it one of the world's most suitable launch sites.



ZERO PAYLOAD USER'S GUIDE

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