INTUITIVE MACHINES

LUNAR ACCESS SERVICES

USER'S GUIDE

V.1.4
NOV 8,2022

Intuitive Machines, LLC
IntuitiveMachines.com

LUNAR ACCESS SERVICES

50 years after Humankind first landed on the Moon, Intuitive Machines is proud to offer Lunar Access Services to Earth's nearest neighbor. Our Lunar Access Services provide a reliable and affordable means for governments to explore, companies to develop, and individuals to place an object in cislunar space or on the lunar surface.

Our landers are based on a decade's worth of engineering development, first as NASA's Project M, then Project Morpheus. Intuitive Machines is staffed by an exceptional team with a deep understanding of spaceflight hardware and operations. By working with one of our Payload Integration Managers, you may focus on your mission objectives while our team works on the details of mission execution.

We've made every effort to take the complexity and cost out of getting to the Moon.

Our entire service, from our lander to rideshare Intuitive Machines' comprehensive processing facility and ground support systems, are designed to make integrating your payload and providing Lunar Access Services as smooth and cost-effective as possible. Our services Include features such as a dedicated launch vehicle, deployment in cislunar space, short transit times to the lunar surface (typically six days), and a precision landing capability to ensure you land when and where you want.

Welcome to the next step in space exploration - the Moon is now within your reach.

PREFACE

This Lunar Access Services User's Guide provides information about Intuitive Machines' capabilities and services. A range of orbit delivery and lander configurations are offered to allow an optimum match to customer requirements. The guide includes essential technical and programmatic data and requirements for preliminary payload design. Interfaces and packaging envelopes are provided to assess first-order compatibility. A brief description of the systems required to support the mission is also given.

Users are encouraged to contact the following representatives from Intuitive Machines to discuss additional details and work on any specific requirements.

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LUNAR ACCESS SERVICES USER'S GUIDE
REVISIONS

Revision Date	Rev No.	Change Description
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1.0

INTRODUCTION

1.0 INTRODUCTION

Intuitive Machines (IM) was founded in 2013 as a think tank company constantly pursuing bettering humanity. In 2018, NASA selected Intuitive Machines as one of its Commercial Lunar Payload Services (CLPS) providers, which helped to form the foundation of our Lunar Access Services. Our team effectively blends diverse thoughts from engineers with decades of spaceflight knowledge to innovative early career professionals. We leverage decades of experience with hardware design and mission operations to provide highly affordable Lunar Access Services. Each customer payload is assigned a Payload Integration Manager (PIM) to guide them through a standard integration effort.

1.1 LUNAR ACCESS SERVICES USER'S GUIDE

The Lunar Access Services User's Guide (LASUG) provides current and future customers with information about our full range of lunar access capabilities and services. We include a range of technical data and requirements to allow customers to evaluate compatibility and perform initial mission concept analysis. Our capabilities and services have the flexibility to accommodate mission-specific requirements that may not be addressed in the LASUG. Customers should reach out to Intuitive Machines to discuss mission-specific requirements.

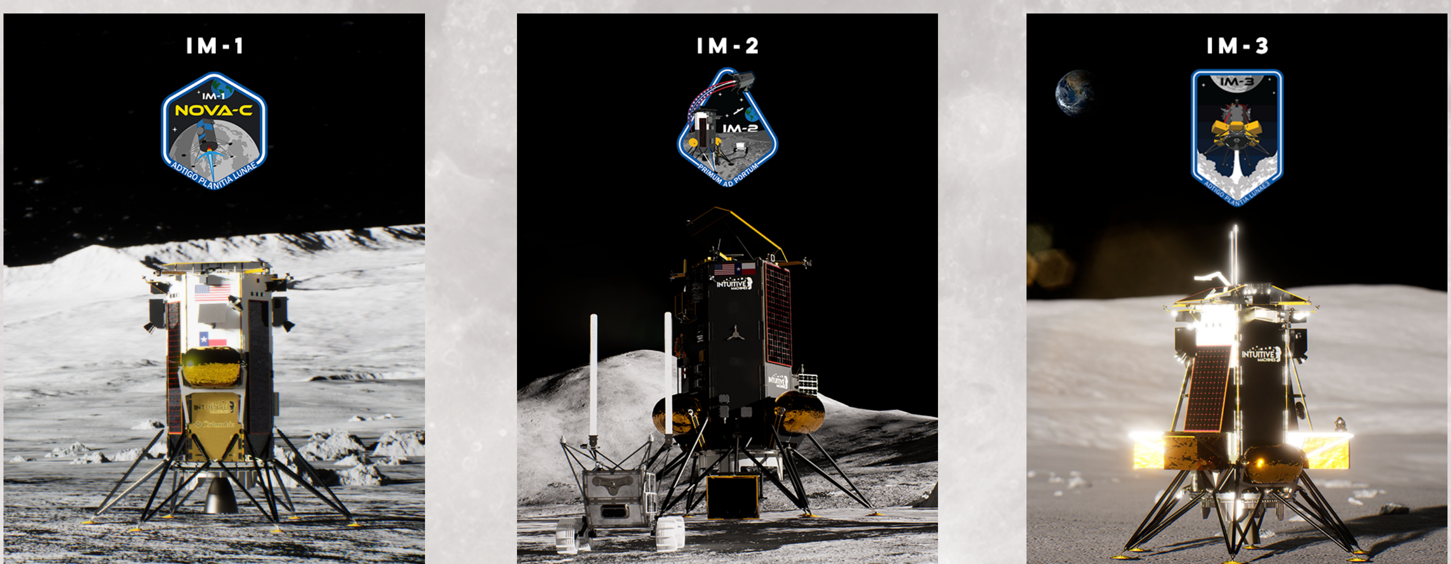

Figure 1. IM Lunar Lander Missions

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1.2 LUNAR ACCESS SERVICES ORGANIZATION AND FUNCTION

The Lunar Access Services User's Guide addresses the full range of services, which includes:

- Launch operations
- Mission Operations
- Mission Integration
- Mission-unique hardware and software design, test, and production
- Payload interface design
- Payload Integration
- Mission management
- Program management
- Launch facilities and support provisions
- Payload processing facilities
- Support at the launch site
- Validation of spacecraft separation and orbit
- Range Safety Interface

1.3 LUNAR ACCESS SERVICES

Intuitive Machines provides multiple options for spacecraft or payload services on each lunar mission.(Figure 1). For Intuitive Machines lander missions, we utilize a launch trajectory (Figure 2) that enables a three-to-six-day lunar transit and one-to-five days in various lunar orbits, depending on phasing for the landing location, before landing on the lunar surface. Due to our mission design, we purchase an entire SpaceX Falcon 9 (F9) rocket, which accommodates our lunar lander mission and the excess capacity to deploy spacecraft or payloads after launch vehicle translunar orbit or any lunar orbit en route to the lunar surface. In addition, Intuitive Machines has systems that can deploy from the lunar lander and provide mobility services on the lunar surface.

Figure 2 - IM Lunar Lander provides lunar access services to lunar orbit and the lunar surface.

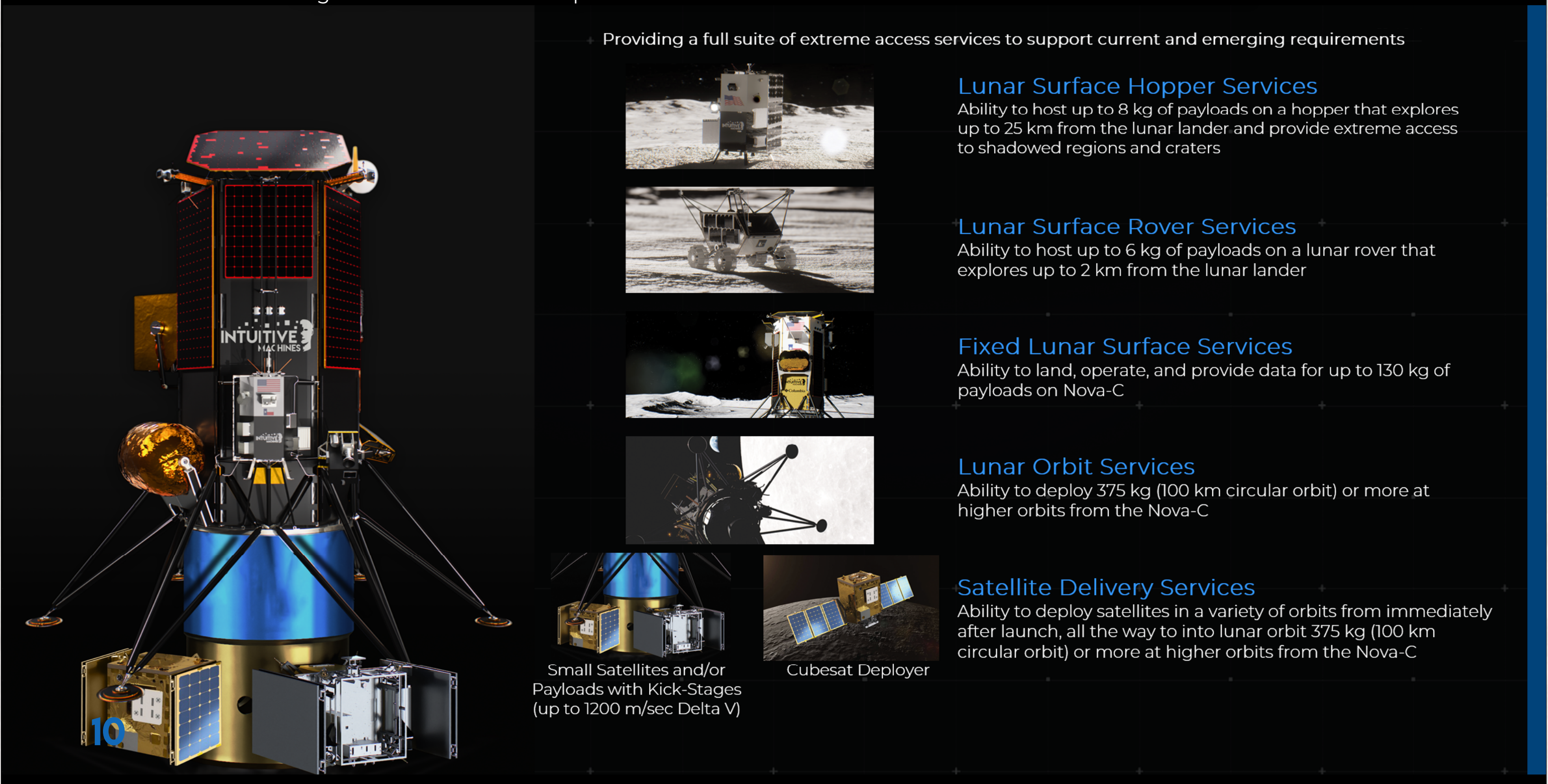

Figure 3 - IM Mission Trajectory

1.3.1 LUNAR TRANSFER ORBIT DELIVERY SERVICES

Intuitive Machines launches into a 185 km by 380,000 km translunar orbit for lunar missions. With the excess capacity, we can launch spacecraft or payloads on an Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) for deployment after the launch vehicle separates from the lunar lander. The spacecraft or payload will be responsible for any orbital maneuvering required post-launch vehicle separation.

1.3.2 LUNAR ORBIT DELIVERY SERVICES

Intuitive Machines can host spacecraft and payloads on the lander and deploy these payloads in a lunar orbit en route to the lunar surface using the lander propulsion for orbital insertion. The deployment orbits can vary from a high lunar orbit to a 100 km circular prior to initiating a lunar landing.

1.3.3 LUNAR SURFACE DELIVERY SERVICES

IM has developed a family of landers to support current and evolving market requirements. The foundation of our landers is the small-class lander, Nova-C, which supports our contracted NASA CLPS missions and commercial customers for landing payloads at equatorial and South Pole landing locations. Utilizing the same systems on the Nova-C lander, IM offers a mid-class lander (Nova-D) that can support larger science payloads, rovers, and NASA's Lunar Terrain Vehicle (LTV). IM's large-class lander (Nova-M) can support future habitats and fission surface power systems.

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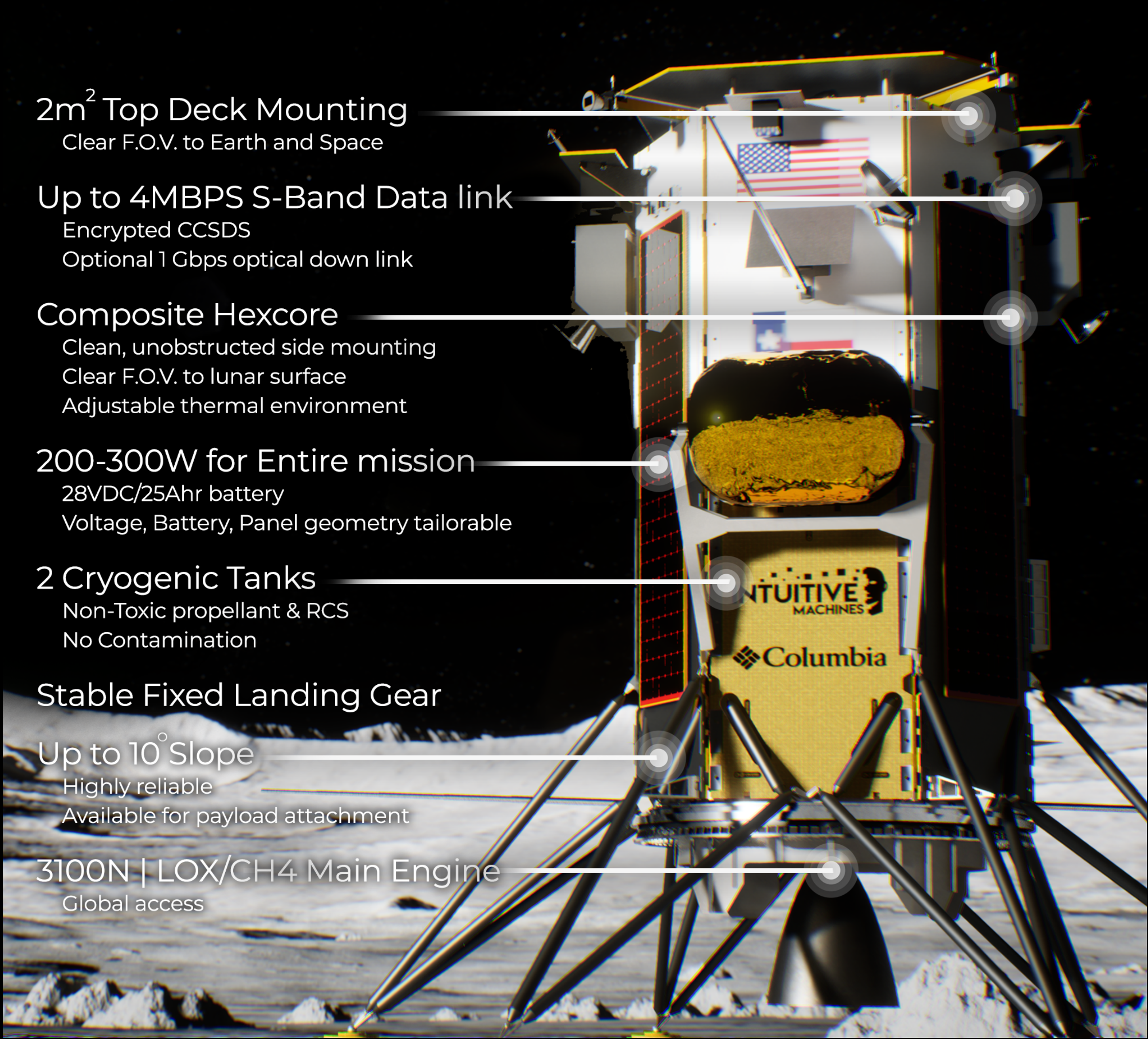
1.3.3.1 NOVA-C

IM has developed a small-class lander, Nova-C, to support contracted CLPS mission requirements for landing payloads at equatorial and South Pole landing locations (Figure 2). Nova-C is the ideal vehicle to deliver lunar science payloads (orbital or landed) and perform engineering demonstrations for the next steps in space exploration. Nova-C provides 130 kg of landed mass payload capability and a 1.57 m wide hexagon shape by 4.0 m height. This offers a wide range of mounting locations in height and azimuth for easy payload integration and tailoring of features such as thermal environment and Field of View (Earth, Lunar, deep space). By stretching the propellant tanks and growing the vehicle by 1 m, we can increase the Nova-C landed mass to 250 kg.

Figure 4 - IM Nova-C Lunar Lander



1.3.4 LUNAR SURFACE MOBILITY SERVICES

The ability to deploy from a lander and explore beyond the initial landing location is important to increase scientific return and discovery. As such, Intuitive Machines has partnered with a rover provider and developed the µNova Hopper to expand the exploration footprint of each mission.

1.3.4.1 ROVER

Intuitive Machines is partnered with Lunar Outpost to deploy the Mobile Autonomous Prospecting Platform (MAPP) rover, which can accommodate up to 5 kg of payloads and traverse multiple kilometers from the landing location. The Intuitive Machines-provided deployment system and Lunar Outpost MAPP rover are manifested on both IM-2, as part of the Nokia LTE/4G demonstration, and IM-3, as part of the Lunar Vertex mission. This capability greatly expands the footprint of a lander mission and increases the potential scientific payload opportunities to explore the lunar surface.

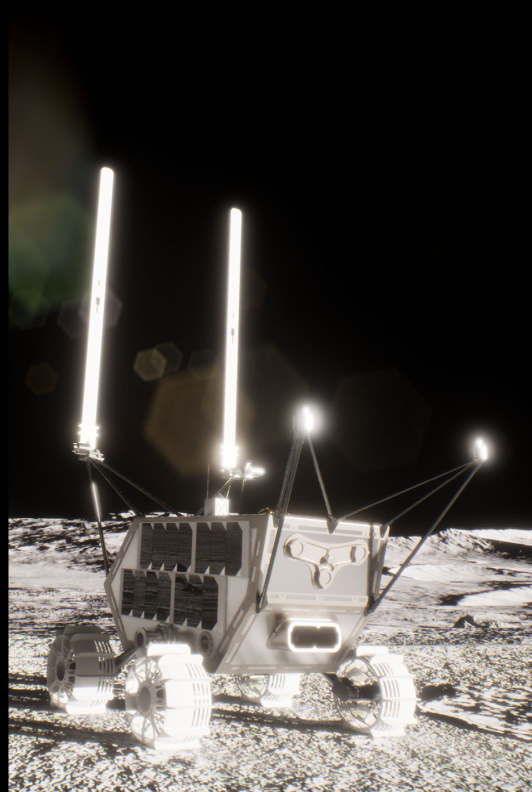
The MAPP Rover boasts 6630 cm^3 internal payload space. This payload area allows for indirect access to the lunar surface through the MAPP base plate and/or lower front panel, if desired by the payload provider. Access to the external environment can be utilized by cameras, deployable payloads, or any payload that requires a direct line of sight to the lunar environment. For payloads that do not require access to the lunar surface, MAPP's panels can remain sealed from the rover's exterior. Lunar Outpost will also work with payload providers to accommodate externally mounted payloads.

The MAPP is equipped with many payload communication interfaces, including UART, SPI, GPIO, I2C, RS-422, and more. The MAPP rover offers numerous payload power channels, including standard 3.3VDC, 5VDC, and 12VDC, with custom voltages also available. Lunar Outpost can provide integration into the thermal control subsystem of MAPP with services such as heater integration, temperature monitoring, and heat dissipation. For larger payloads, Lunar Outpost is developing the Heavy-Lift MAPP (HL-MAPP).

The HL-MAPP uses high-TRL flight-heritage subsystems to accommodate up to 200 kg of payload and 125W of peak payload power. HL-MAPP will be able to operate independently of a lunar lander with optional direct-to-Earth communications allowing for extended mission durations. With a maximum drive speed of 40 cm/s, HL-MAPP can traverse tens of kilometers throughout its mission. Figure 5. LA-117. Lunar Outpost Heavy-Lift MAPP (HL-MAPP)

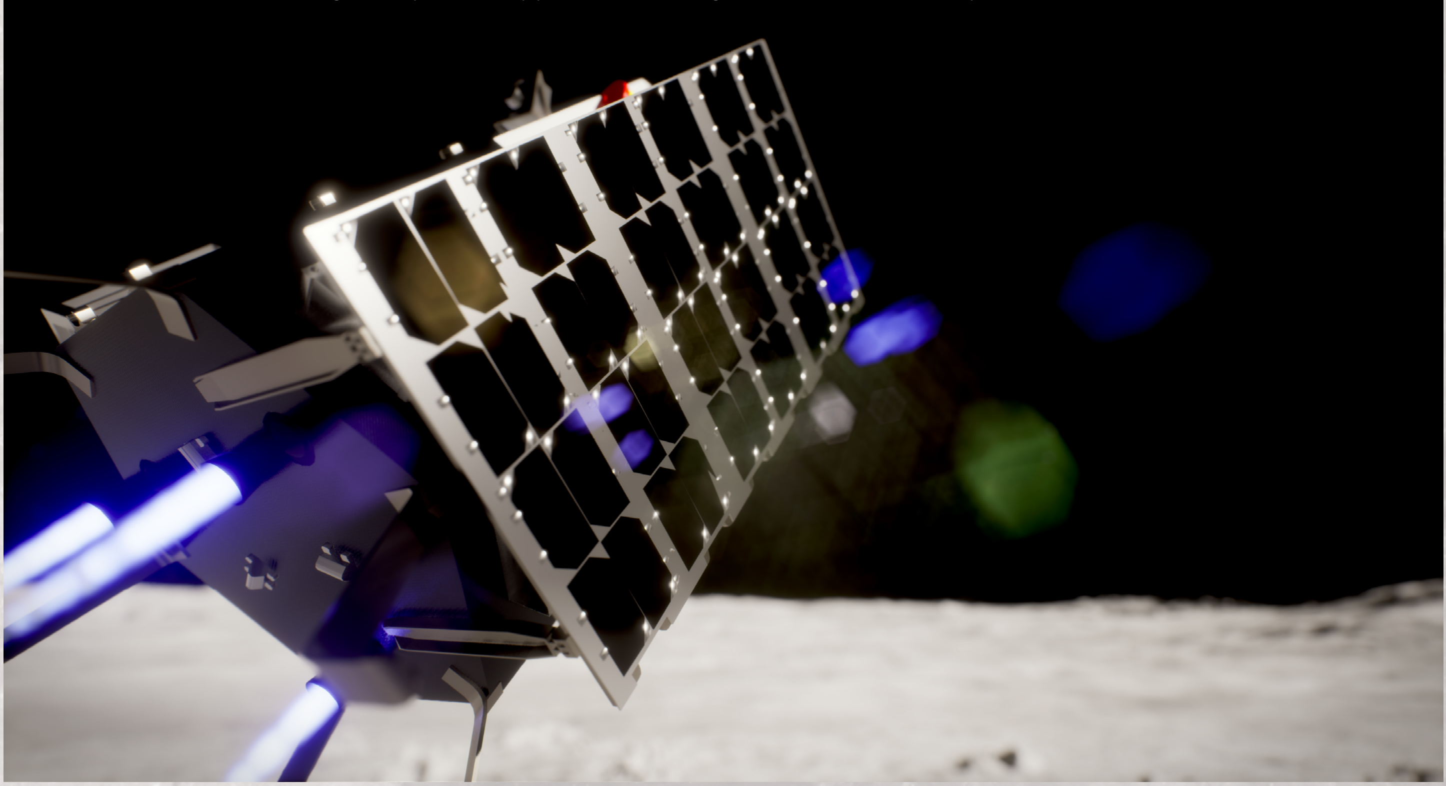
For more information on lunar mobility services, visit the Lunar Outpost website (https://lunaroutpost.com) or contact info@lunaroutpost.com.

Figure 5 - Lunar Outpost MAPP Rover



1.3.4.2 MICRO NOVA- HOPPER

Figure 6. µNova Hopper extends range to 25 km and can hop into PSRs



Given the lack of atmosphere on the lunar surface, a traditional propeller-driven drone is not feasible. As such, under a NASA Space Technology Mission Directorate's (STMD) Tipping Point contract, IM developed the µNova Hopper, which is a propulsive drone that will land, deploy, and hop on our IM-2 mission. The µNova Hopper can accommodate up to 1 kg of scientific payloads and expand the exploration footprint for up to 25 km from the initial landing location. µNova Hopper is designed to hop into and out of permanently shadowed regions (PSRs), providing a first look into undiscovered regions that may provide the critical science needed to sustain human presence on the Moon. IM has also designed a scaled-up µNova LX Hopper that can accommodate up to 8 kg of payloads and hop up to 25 km from the initial landing location.

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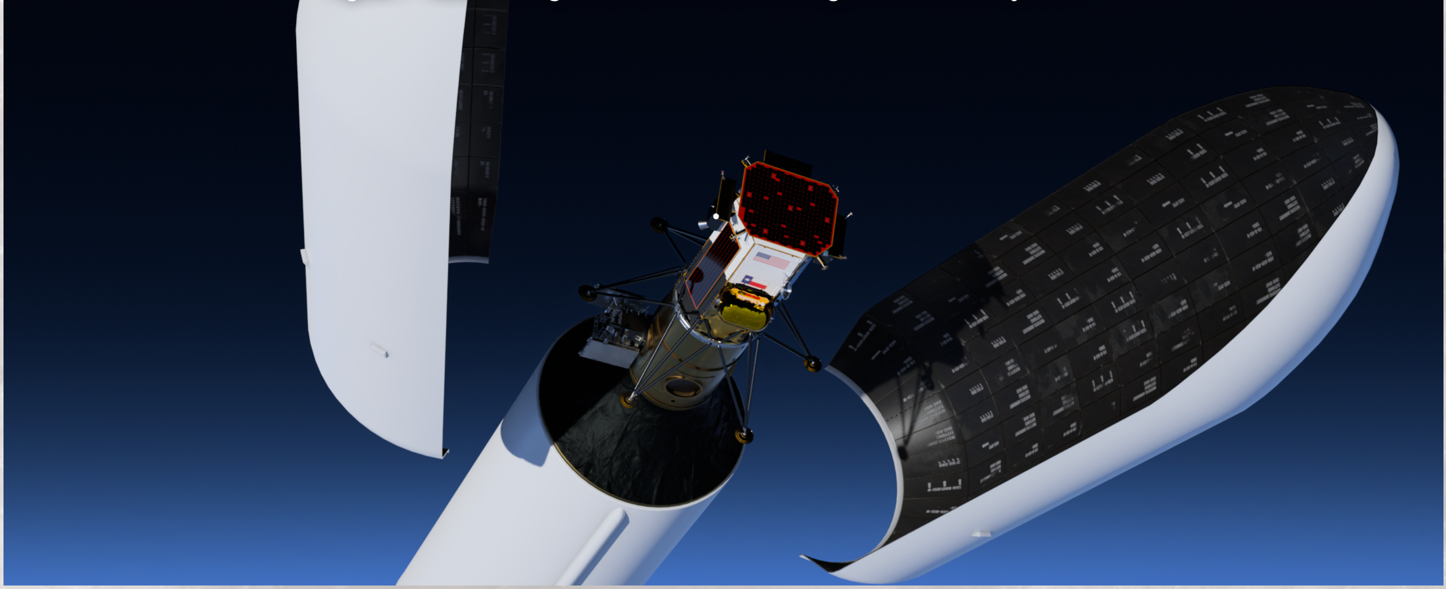
2.0

PAYLOAD DELIVERY CAPABILITY

2.1 LUNAR TRANSFER ORBIT DELIVERY SERVICES

Figure 7 - Nova-C Integrated Stack with ESPA Ring for Rideshare Payloads



IM can accommodate up to 1000 kg of payload for all Nova-C missions attached to a 4 x 24” port ESPA ring. Payloads must comply with the mass and center of gravity limitations defined in the SpaceX Rideshare Users Guide, Figure 2-1 (SpaceX - Rideshare). Payloads must target a minimum separation velocity of 0.3 m/s and a maximum separation velocity of 1.0 m/s.

2.2 LUNAR ORBIT DELIVERY SERVICES

For all lunar lander missions, Intuitive Machines can utilize the propulsion capabilities of the lander to deploy payloads in lunar orbit. As part of the standard mission profile, the lander will capture into a 2,000 km circular lunar orbit and then reduce the attitude to a 100 km circular orbit before final descent and landing. The range of maximum performance capability for each lander to a set of lunar orbits is provided in Table 1.

Deployed Orbit	Nova-C	Nova-D	Nova-M
100-km circular	390-750 kg	1,500-7,500 kg	15,000-30,000 kg
200-km circular	650-1,250 kg	2,500-12,500 kg	25,000-50,000 kg
2,000-km circular	715-1,375 kg	2,750-13,750 kg	27,500-55,000 kg

Table 1. Lunar Orbit Delivery Capability

The lunar landers provide an accurate and stable platform for delivering lunar orbital payloads with an attitude accuracy of ±0.1° and a rate of <0.1°/sec. Net accuracy for separation conditions is determined by the sum of the Nova-C accuracy and the accuracy of the deployment mechanism provided with the payload.

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2.3 LUNAR SURFACE DELIVERY SERVICES

IM has optimized performance for each lander configuration based on market demand while considering available launch vehicle performance. The range of maximum payload capability for dedicated Design Reference Missions (DRMs) for each lander configuration is provided in Table 2 below.

Landing Location	Nova-C	Nova-D	Nova-M*
Equatorial	130-250 kg	500-2500 kg	5,000-10,000 kg
South Pole	130-250 kg	500-2500 kg	5,000-10,000 kg
North Pole	130-250 kg	500-2500 kg	5,000-10,000 kg

Table 2. Lunar Surface Delivery Capability

The landers utilize an advanced navigation system that fuses laser range finder data with visual cues to provide unprecedented accuracy in payload delivery, landing within a <50 m radius. In addition to landing site positional accuracy, Nova-C provides an azimuth clocking angle accuracy of better than 5°. Lander tilt is controlled by landing site selection. The landers also have both active and passive design features that minimize the impact of surface roughness and slope on mission success. They incorporate both a laser range finder and a visual cueing system to measure and avoid unsafe slopes and large boulders that could destabilize the vehicle upon landing. They incorporate a novel hexapod landing system that maximizes stability. The lateral struts are placed above the landing plane to minimize interference with the terrain.

2.4 LUNAR SURFACE MOBILITY SERVICES

IM provides mobility services that accommodate multiple mission requirements. Maximum range and payload capability for each of the mobility systems are provided in Table 3, below.

	MAPP Rover	µNova Hopper	µNova-LX Hopper
Range (Max Distance from Lander)	2.5 km	25 km	25 km
Payload Mass	5 kg	1 kg	8 kg

Table 3. Lunar Surface Mobility Capability

3.0

ENVIRONMENTS

3.0 ENVIRONMENTS

This section provides a baseline set of environments for use in payload design and mission planning. Payload-specific environments will be developed and agreed to as part of the payload integration process and documented in each payload's Payload Integration Plan (PIP).For rideshare payloads, environments can be found in SpaceX's Rideshare Users Guide (SpaceX - Rideshare).

Unless otherwise specified here, payloads should expect to experience the relevant natural environments defined in NASA/TM—2016–218229: Natural Environments Definition for Design (NEDD). Mission-induced environments generally follow the guidance of the General Environmental Verification Standard (GEVS, GSFC-STD-7000) and MIL-STD-1540.

All environments in this guide are meant to be conservative and to help identify early signs of potential integration issues. Environment margins may be reduced as the mission and payload designs mature, and uncertainty is reduced. The final set of environments is included in each payload's PIP.

3.1 LOADS

The payloads shall use the appropriate Factors Of Safety (FOS) listed in Table 4 for design and selection of hardware. These FOS apply to verification of all loads environments.

Item	Sub Component	Load Case	Factor of Safety		Proof Factor
			Ultimate	Yield	
Electronic Crates		All	2.0	1.5	N/A
Line and Fittings	<1.5-inch diameter	Internal Pressure	4.0 x MDP	N/A	1.5 x MDP
Line and Fittings	>1.5-inch diameter	Internal Pressure	2.0 x MDP	N/A	1.5 x MDP
Actuating Cylinders, Valves, Filters, Switches, Line-Installed Alignment Bellows, Heat Pipes		Internal Pressure	2.5 x MDP	N/A	1.5 x MDP
Reservoirs / Pressure Vessels		Internal Pressure	2.0 x MDP	N/A	1.5 x MDP
Flex Hoses	All diameters	Internal Pressure	4.0 x MDP	N/A	2.0 x MDP[1]
Support Structure (metallic)		All	2.0	1.25	N/A
1. In a system with fluid lines and flex hoses, the individual flex hoses are proof tested to 2.0 x MDP and the assembly level tested to 1.5 x MDP					

Table 4. Structure Factors of Safety

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The payloads shall be designed to the launch loads listed in Table 5. These loads represent the highest static g load environment from all anticipated launch vehicles.

Loads	Nx g	Ny g	Nz g	Rad/sec2 Rx	Rad/Sec2 Ry	Rad/Sec2 Rz	Note
Launch	±10.0	±10.0	±10.0	N/A	N/A	N/A	1

Notes:

1. The reference frame for the Launch Load is as follows:

X: The longitudinal axis of the vehicle (e.g., centerline of the launch vehicle's long axis)

Y: Y axis is perpendicular to the X-axis

Z: Z axis is perpendicular to the X and Y axes and completes the right-handed coordinate system

Table 5. Static Acceleration Launch Loads

3.2 RANDOM VIBRATION

The payload vibration environment will be determined through a Coupled Loads Analysis, driving the launch vehicle vibration environment through the Nova-C lander and into the attached payload. Smaller payloads generally have higher accelerations, although their lower mass results in a lower total load. As such, a detailed vibration environment will be developed for each payload in coordination with the payload provider as details of the payload and the mounting interface are refined. As a starting point, payloads are encouraged to design to the conservative acceptance vibration environment provided in Table 2.4-3 of GSFC-STD-7000A, depicted in Figure 7 below.

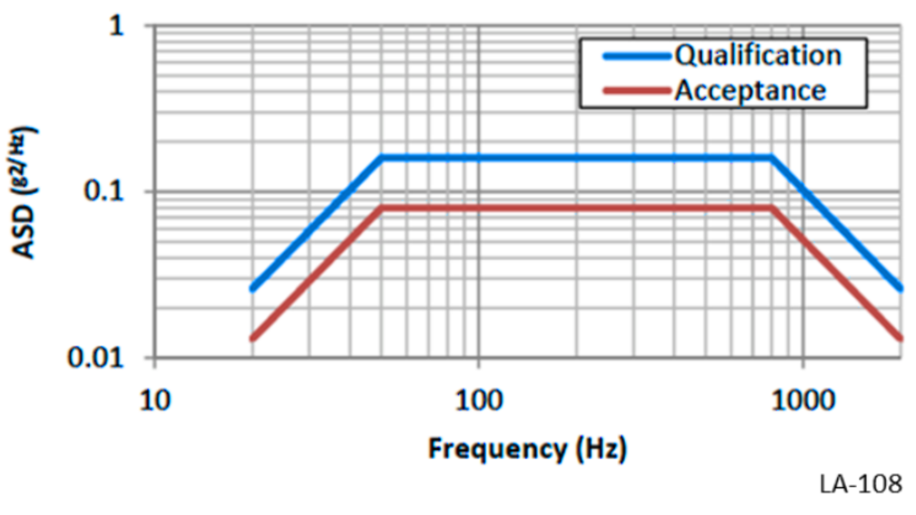

Figure 8. Initial Payload Random Vibration Environment

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3.3 ACOUSTIC

The acoustic environment provided in Table 6 is meant to envelop a range of potential launch vehicles and will be refined and documented in each payload's PIP as integration details are finalized.

Octave Center Frequency (Hz)	Max Predicted Acoustic Environment (dB)
25	115
31.5	125
63	130
125	132
250	130
500	125
1000	120
2000	115
4000	110

Table 6. Acoustic Environment

3.4 SHOCK

The shock environment is typically a function of the spacecraft adapter and separation system selected for the mission and then the attachment mechanism for a specific payload to the Nova C chassis. Actual shock environments experienced by the payload at the top of the mission-unique payload adapter will be determined following the selection of a specific payload adapter and separation system. Table 7 provides a typical payload adapter-induced shock at the payload interface. The actual flight shock levels at specific payload mounting locations will be mission unique.

Frequency (Hz)	Shock Response Spectrum (g)
100	50
1,000	1,000
10,000	1,000

Table 7. Lander Generic Payload Shock Load Environment

3.5 PRESSURE AND HUMIDITY

Payload processing is performed near sea level in a climate-controlled, clean room environment (~21° C, ~50% RH). However, processing at the launch center will expose the payload to a wider range of relative humidity. The payload must also be able to withstand the rapid depressurization of launch and the in-space environment. The atmospheric conditions the payload must consider are provided in Table 8.1.6-1. It should be noted that payloads in proximity to the Reaction Control System (RCS) jets may experience brief pressure pulses during the in-space portion of the mission. Any plume-induced pressure effect will be captured and documented in the PIP.

Mission Phase	Pressure (psia)	Relative Humidity (%)
Ground handling processing	13.5 - 15.2	10 - 95%
Air Transport	10.5	10 – 95%
Launch Site Processing thru Launch	-0.9 psia/sec	50 ± 5%
In-Space	~0.0	~0.0

Table 8. Atmospheric Pressure and Humidity Environment

3.6 TEMPERATURE AND THERMAL CONTROL

3.6.1 AMBIENT TEMPERATURE ENVIRONMENT

Table 9 provides the standard temperature ranges payloads should expect during processing and the mission. The exact thermal environments for each payload are dependent on mission parameters and placement on the lander and will be documented in the PIP. Note that the temperatures in Table 9 are the range of predicted environmental temperatures. See Section 3.6.3 for options on thermal control.

Mission Phase	Temperature (°C)	Comment
Ground handling processing	+15 to +25	Generally climate controlled
Transport	+5 to +30	Generally climate controlled
Launch Processing	20 ± 3	Climate controlled
In-Space	-100 to +100	Top deck faces Sun, with oscillation, varies depending on orbital position
Lunar Surface	-100 to +150	Varies with latitude, azimuth on the vehicle, and time-of-day

Table 9. Temperature Environment

3.6.2 PLUME HEATING

Payloads placed near the bottom of the lander may experience plume-induced radiative heating from the main engine (some burns exceed five minutes in duration). Payloads that must be located near the lower portion of the lander should inquire with IM regarding the amount of plume heating they may encounter and shielding options.

3.6.3 THERMAL

Landers provide numerous options for payload thermal control. In general, payloads are expected to be mounted externally on a thermally isolating interface panel to minimize thermal interaction between the lander and the payload. Each payload is provided a temperature sensor channel and a heater to maintain the payload above its minimum survival and operating temperatures. Heaters are controlled with software setpoints and may be adjusted during the mission. Payloads may utilize MLI blankets as required to reduce the significant temperature swings associated with the thermal vacuum. Finally, using a heat pipe or radiator may be considered but must be coordinated as a non-standard service. The final approach will be assessed with an integrated thermal analysis and/or thermal vacuum testing. Payload providers must provide a thermal model of their payload, which Intuitive Machines will incorporate into an integrated thermal analysis to refine the thermal environment.

3.7 ELECTRO-MAGNETIC INTERFERENCE (EMI)

The landers have been designed to provide a low-EMI environment to provide a quiet platform for sensitive instruments. Intuitive Machines plans to perform an integrated EMI test of each final lander configuration to identify and resolve any potential EMI concerns.

3.8 CONTAMINATION

The landers and all payloads must be manufactured from low-outgassing materials (see section 4.2.1). In addition to those precautions to preserve a clean environment for payloads, landers utilize a green propellant (LOX/CH_4) system and pressurized nitrogen for their reaction control system. The lander's RCS system uses low thrust (~1lbf) cold-gas helium to further reduce the risk to payloads.

3.9 IONIZING RADIATION

IM has chosen a rapid transit trajectory to the Moon, minimizing exposure to the ionizing radiation environment. After launch, the lander only makes one pass through the VanAllen radiation belts. Exposure during lunar transit and lunar surface operations is expected to be less than 0.5 rad/day. There are also chances of heavy ionizing radiation that can cause memory corruption and latch-up in computers; these instances can be mitigated by commanding a payload power cycle from the ground.

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4.0

MISSION INTEGRATION

4.1 MISSION MANAGEMENT AND INTEGRATION

Intuitive Machines employs a multi-faceted approach for end-to-end payload integration services (Figure 9) using established processes exercised on prior missions with experienced engineers and integration technicians. Upon contract signing, we assign a payload integration manager (PIM) and initiate the development of the payload integration plan (PIP), which documents specific locations, power profiles, environmental considerations, operational timelines, and communication profiles for the payload. We conduct a Mission Design Review (MDR) three months after the contract signing to review the draft operations plan and timeline, payload-specific environments, and test plan, which are captured in the initial PIP. Intuitive Machines then conducts a Mission Integration Review (MIR) five months after contract signing that baselines the operations plan and timeline, payload-specific environments, and test plan, which are captured and approved by both parties in the final PIP. Payloads integrated onto the lander or mobility systems are provided to the Intuitive Machines facility (or our rover partner's facility) six months before launch for integration. For rideshare payloads, they are provided to the SpaceX processing facility one month before launch for integration with the ESPA per SpaceX rideshare users guide (SpaceX - Rideshare). Intuitive Machines performs a mechanical and electrical interface test in our Flatsat Facility to ensure that each payload does not harm other payloads before final integration on the lander or mobility system. Intuitive Machines finalizes flight certification, mission analysis, and the operations plan at launch minus three months. Launch site integration begins a launch minus two months with late access and the late load of payloads, pre-mission operations rehearsals, and final encapsulation.

Figure 9. Standard Payload End-to-End Integration Services

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4.2 PAYLOAD RESPONSIBILITIES

Payloads deployed from the ESPA ring of the SpaceX rocket must adhere to the payload requirements set forth in the SpaceX Rideshare Users Guide (SpaceX - Rideshare). For all other payloads, the following section defines payload requirements.

4.2.1 OFFGASSING

All payloads must be constructed of vacuum-stable materials to avoid contaminating nearby sensitive equipment. Payload providers must provide a vacuum stability testing report (ASTM E595 or equivalent) and/or a materials certification memo. All payload materials shall have a Total Mass Loss of ≤ 1.0 % and a Collected Volatile Condensable Material value of ≤ 0.1 %. On-compliant materials may be considered via the submittal of a non-standard materials approval request.

4.2.2 CLEANLINESS

All payloads are expected to meet, at a minimum, Class 100,000 / ISO 8 standards for processing and be compatible with all standard cleaning procedures for those environments. Payload-specific cleanliness requirements, such as a payload contamination control purge, may be requested as a payload-specific service in the payload-specific integration plan.

4.2.3 DESIGN AND MANUFACTURING STANDARDS

All payload hard goods shall be free from burrs, sharp edges, and exposed threads on bolts. Soft goods shall be sewn and manufactured to applicable standards for spaceflight. All soldering, crimping, and wire harnesses shall be performed to applicable standards for spaceflight.

4.2.4 LIMITATION ON DEBRIS

Payloads shall not shed components or materials, including thermal blankets, conformal coatings, paint, or solder beads, at any point in the mission. Mechanisms for release or operation shall not create additional space debris.

4.3 RANGE AND SYSTEM SAFETY

Payloads shall comply with all aspects of AFSPCMAN 91-710 and provide inputs to support the Missile Systems Prelaunch Safety Packages (MSPSP).

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5.0

PAYLOAD INTERFACES

5.1 LUNAR TRANSFER ORBIT DELIVERY SERVICES

The baseline configuration for the rideshare interface is an ESPA ring with four x 24-inch diameter mechanical interfaces, as noted in SpaceX's Rideshare Users Guide (SpaceX - Rideshare). In the nut-plate configuration, the payload will mechanically interface to the Launch Vehicle hardware via thirty-six 0.25-inch diameter 28 threads-per-inch fasteners. In the thru-hole configuration, the payload will mechanically interface to the Launch Vehicle hardware via thirty-six 0.272" diameter thru-holes. The maximum fastener grip length for use on the thru-hole configuration is -16 (1 inch).

The Launch Vehicle provides electrical connectivity between the payload and Customer provided EGSE before Launch. During Launch, the Launch Vehicle provides in-flight separation device initiation and separation. Other Payload commands or interleaved telemetry access is not provided as a standard service. The Launch Vehicle provides an electrical bulkhead located next to each mechanical interface where a payload is mounted. This bulkhead exposes all the channels the payload will use for the mission. The bulkhead consists of several MIL-STD-1560 connectors, which will be specified as part of the Payload-specific ICD. The number of channels provided by the Launch Vehicle is in Table 10.

Channel Type	24-in Dispenser Ring
Primary Deployment	8 channels
Secondary Deployment	8 channels
Breakwire (payload-side loop)	16 channels
Umbilical Group	1 channel group

Table 10. Standard Electrical Interfaces for Rideshare Payloads

5.2 LOW LUNAR ORBIT DELIVERY SERVICES

On the IM landers, we can accommodate either a clamp band interference for a single payload or a deployment system for a CubeSat or multiple CubeSats. IM will work with the payload provider if a different mounting approach is required. Mounting location is subject to other payload considerations and the overall vehicle mission design. The lander will provide an electrical umbilical at the payload interface that provides primary and secondary deployment, a break wire, and an umbilical group consistent with a typical ESPA class payload noted in Section 5.1 above.

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5.3 LUNAR SURFACE DELIVERY SERVICES

5.3.1 PAYLOAD SIZE, MASS, AND CENTER OF GRAVITY LIMITS

Individual payloads with < 600 cm2 of mounting area, < 20 kg of mass, and with a Center of Gravity < 10 cm radially from the surface of the barrel structure can be accommodated nearly anywhere on the exterior of the structure or on the top deck. Payloads in excess of these limits may be accommodated case-by-case after a more detailed assessment.

5.3.2 NOVA-C PAYLOAD ENVELOP

The Nova-C lander nominally supports 130 kg of payload anywhere on the exterior of the hexagonal core (~10 m^2) or the top deck (~2 m^2). Additional mounting locations are available on the RCS struts and landing gear, depending on the size and complexity of the payload.

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5.3.3 MOUNTING INTERFACE

The hexagonal faces and top deck of the landers are constructed from one-half-inch thick composite panels. Payloads are mounted directly to the exterior wall via IM-provided threaded inserts. These inserts are typically 10-28 or 10-32 (other sizes are available) and are positioned for each payload's custom footprint on a mutually-agreed-to mechanical ICD.

5.3.4 THERMAL ISOLATION

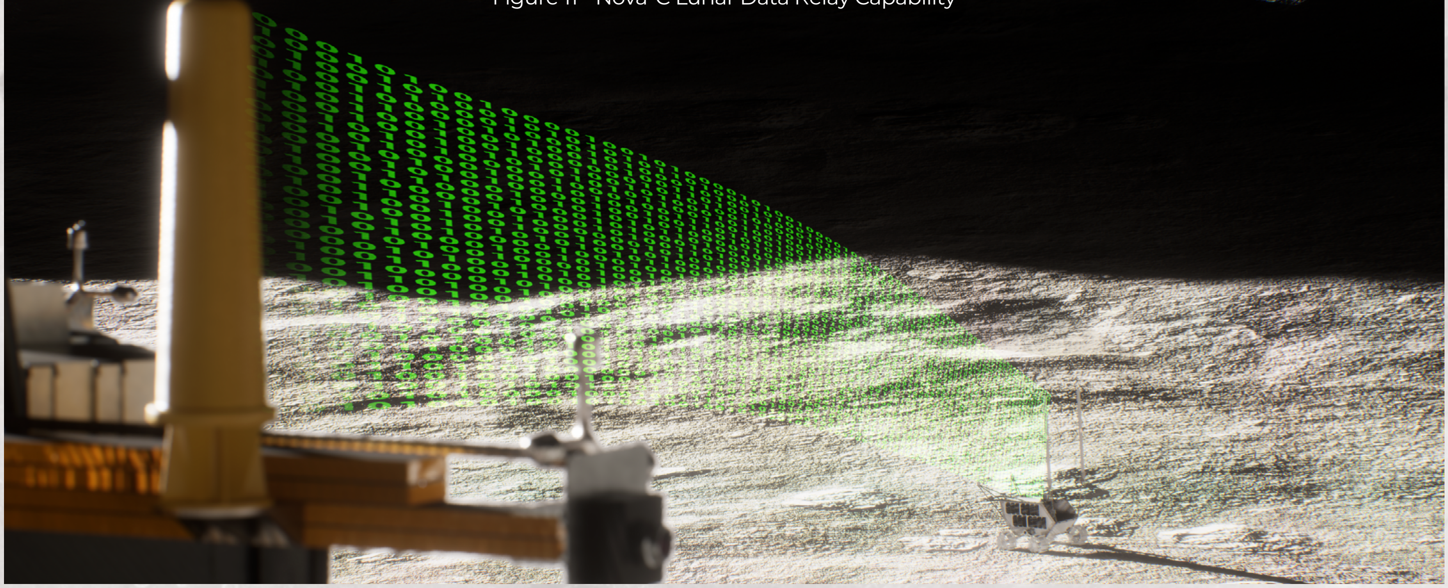
Payloads are generally expected to be thermally isolated from the lander structure. This is usually accomplished using one-half-inch diameter by one-quarter-inch thick G10 fiberglass washers and MLI blankets. The thermal interface is tailored for each payload, with the largest effect being which face of the hex the payload is installed on.

5.3.5 POWER

Landers provide power connections tailored to meet individual payloads. Power is nominally unregulated 28 VDC (26 – 34 VDC); however, regulated power at 5, 12, and 28 VDC is available. For Nova-C, it continuously generates in excess of 400W during transit and on the lunar surface and nominally provides 200 W of power for all payloads during transit and 200W to all payloads during lunar surface operations. Payload power is limited during transient events (launch, orbital maneuvers, descent, and landing). Power connector types, voltage, and power profiles are defined in the specific PIP. Missions and payloads requiring higher power levels can be accommodated by tailoring the mission or lander configuration (solar panel size and/or orientation, supplemental batteries, etc.).

5.4 DATA-NOVA-C

Figure 11 - Nova-C Lunar Data Relay Capability



Landers provide data connections tailored to meet individual payloads. Data protocols are per RS-422 or Ethernet. Our lander utilizes encrypted Consultative Committee for Space Data Systems (CCSDS) encoding for secure command and telemetry. Connector types and data formats are defined in the specific Payload Integration Plan. Data rates are discussed in Section 6.0.

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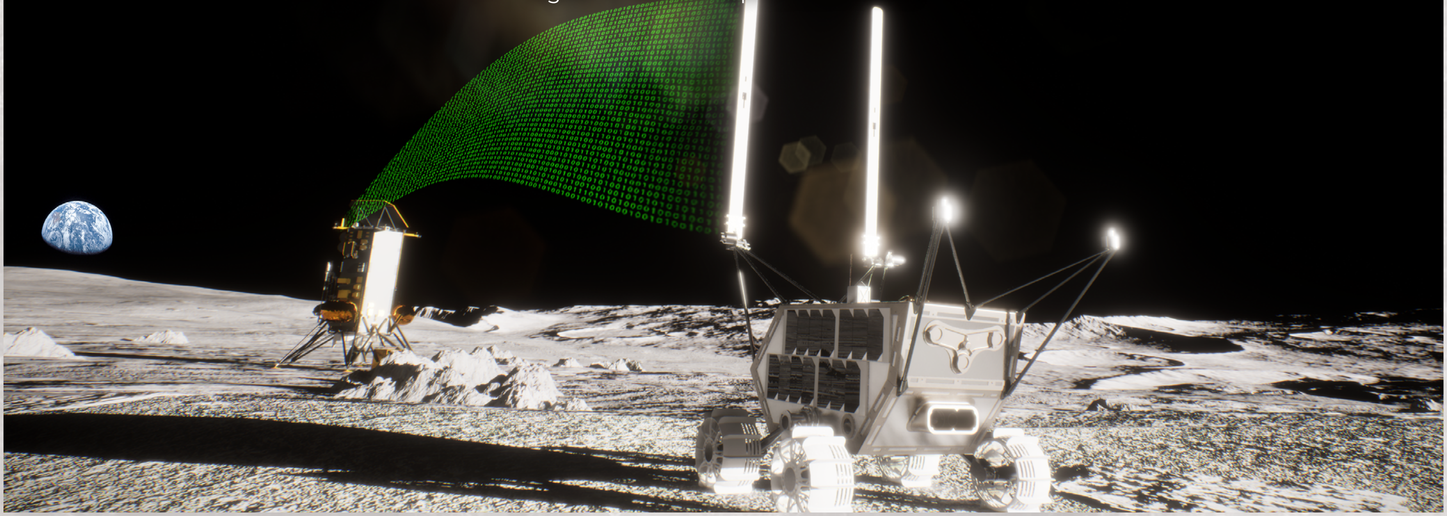
5.4.1 ROVER

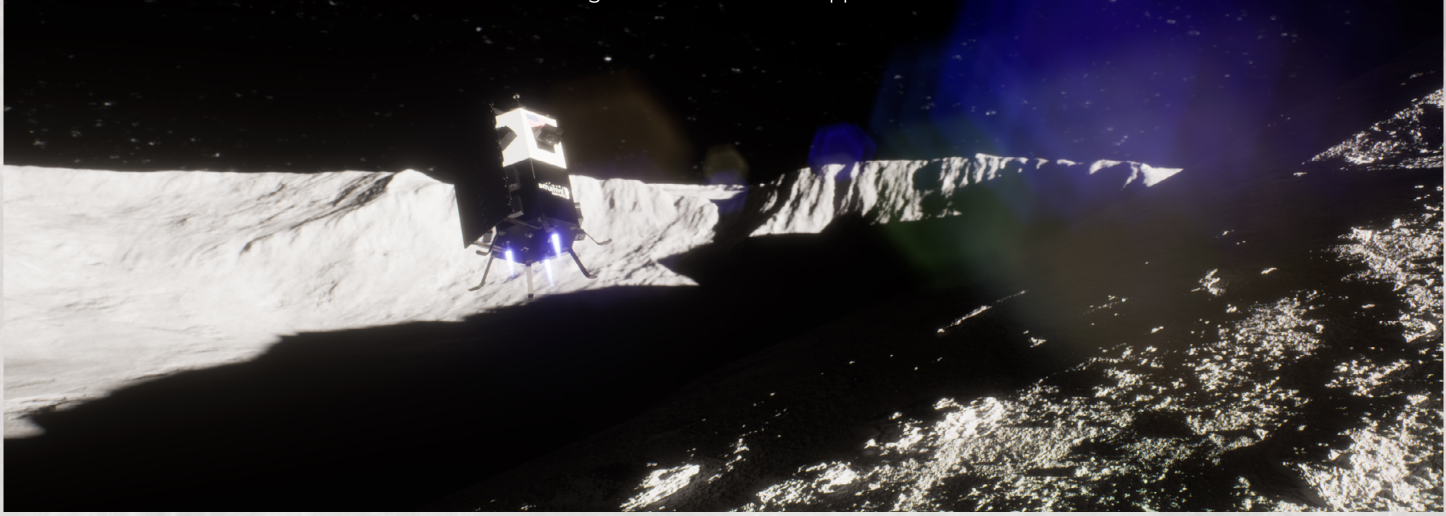
Figure 12 - Lunar Outpost MAPP Rover



The MAPP rover provides RS422, Universal Asynchronous Receiver Transmitter (UART), Controller Area Netowrk (CAN), and high-speed data interface options. Specific payload interface information can be obtained by contacting Lunar Outpost via Reserve Payload Space (lunaroutpost.com).

5.4.2 MICRO-NOVA HOPPER

Figure 13 - Micro-Nova Hopper



μNova Hoppers provide data connections tailored to meet individual payloads. Data protocols are per RS-422 or Ethernet. Our μNova Hopper utilizes encrypted Consultative Committee for Space Data Systems (CCSDS) encoding for secure command and telemetry. Connector types and data formats are defined in the specific Payload Integration Plan. Data is transmitted from the μNova Hopper to the lander and then relayed to Earth. Data rates are discussed in Section 6.0.

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6.0

PAYLOAD DATA SERVICES

6.1 LUNAR TRANSFER ORBIT DELIVERY SERVICES

Customers can contract with IM to provide data services for their satellite after separation from the launch vehicle utilizing our Lunar Data Network (LDN), which comprises lunar data relay satellites, a globally dispersed set of ground stations, and a control center that provides delivery of secure, encrypted data. Additional details regarding our LDN services can be found in IM's Lunar Data Services Users Guide.

6.2 LOW LUNAR ORBIT DELIVERY SERVICES

Customers can contract with IM to provide data services for their satellite after separating from the launch vehicle utilizing our LDN that delivers secure, encrypted data to Earth. Additional details regarding our LDN services can be found in IM's Lunar Data Services Users Guide.

6.3 LUNAR SURFACE DELIVERY SERVICES

For lander missions, IM provides a wired communication bus utilizing RS-422 protocols and an S-Band command and telemetry link with a total baseline capacity of 250 kbps once on the lunar surface. Ethernet ports are also available. Command and telemetry (~2 kbps total shared amongst all payloads) is available during lunar transit for payload wake-up, commissioning, and health and status. Telemetry is transmitted and received utilizing CCSDS protocols through a commercial network providing 24/7 coverage throughout the mission duration. IM provides secure, encrypted data relay services with up to 4 Mbps downlink from the lunar lander to Earth, utilizing our LDN for the standard mission duration.

6.4 LUNAR SURFACE MOBILITY SERVICES

IM provides secure, encrypted data relay services from the mobile platform through the lunar lander and to Earth, utilizing our LDN for the standard mission duration. For missions extending beyond the first lunar day, customers can contract with IM to provide data services utilizing our LDN that delivers secure, encrypted data direct from the lunar mobility system to Earth. Additional details regarding our LDN services can be found in IM's Lunar Data Services Users Guide.

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7.0 PAYLOAD PROCESSING AND LAUNCH OPERATIONS

7.1 PAYLOAD PROCESSING AND TRANSPORT

For all rideshare payloads, the customer is responsible for transportation to the launch site facility for payload processing. All lander and lander payload transportation and payload processing is performed in climate-controlled processing facilities maintained near ambient temperature (~20°C, ~50% RH) and can be refined as required for payload special handling conditions.

7.2 LANDER INSTRUMENTATION

The lander incorporates a broad range of instrumentation, including attitude determination, voltage and current, and a suite of temperature sensors. These environmental measurements are time-synchronized and made available to all payloads for correlation with their own instrumentation.

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8.0 MISSION OPERATIONS

8.0 MISSION OPERATIONS

Figure 14 - Nova Control at IM Headquarters in Houston, Texas.

For all lander missions, IM provides mission operations to support the launch, transit, and surface operations. IM conducts all mission operations through Nova Control (NC) based at IM's headquarters in Houston, Texas. IM provides payload customers access to its FlatSat Facility and NC for early payload interface verification, mission training, and mission operations. IM provides voice network connections between the NC voice network used to coordinate mission operations and the voice nets at the customer's payload operations centers. IM provides standardized REST API and WebSocket interfaces for the remote payload control centers to receive streaming telemetry and submit commands to and from NC. During flight operations, IM accommodates up to two payload team members in a NC adjacent room. After landing, lander subsystem staffing in the NC main control room (Figure 12) may be reduced, freeing space for payload operations team members for surface operations.

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