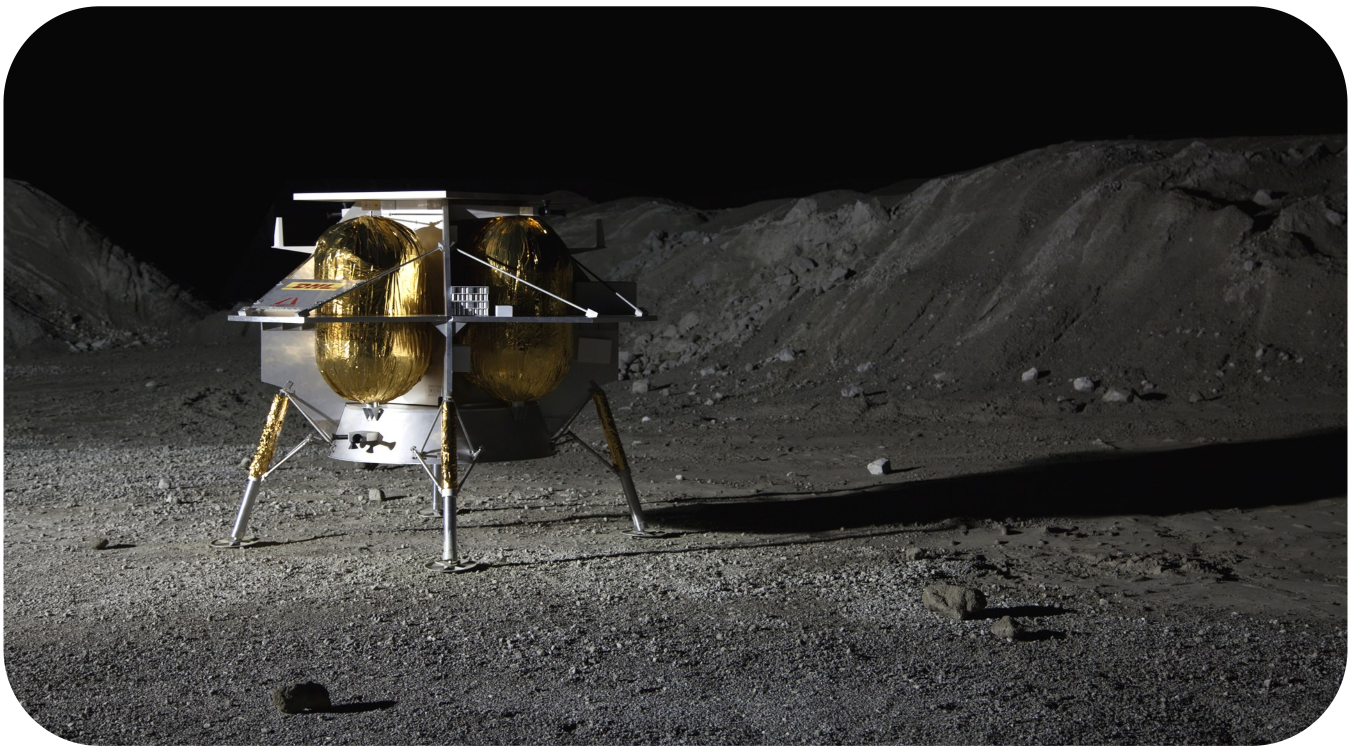

PEREGRINE LUNAR LANDER

PAYLOAD USER'S GUIDE

Version 3.0 October 2018

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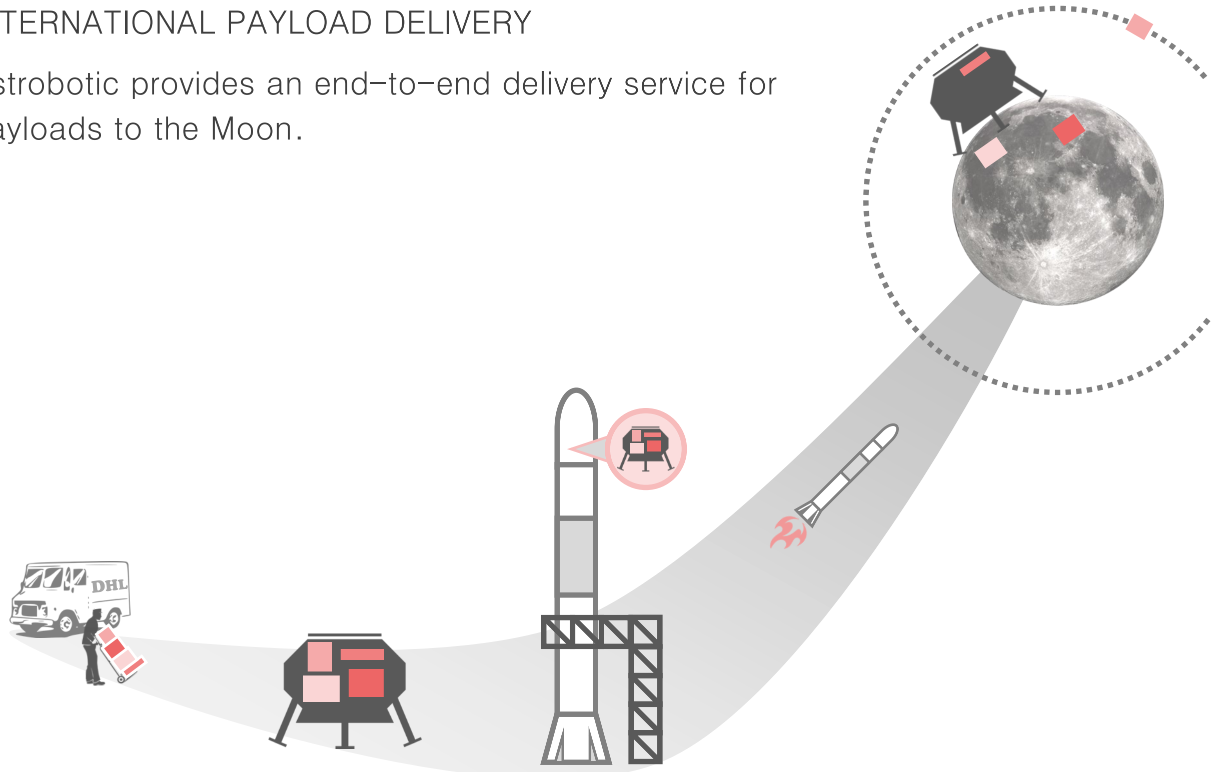
ABOUT US

INTERNATIONAL PAYLOAD DELIVERY

Astrobotic provides an end–to–end delivery service for payloads to the Moon.



- On each delivery mission to the Moon, payloads are integrated onto a single Peregrine Lunar Lander and then launched on a commercially procured launch vehicle.
- The lander safely delivers payloads to lunar orbit and the lunar surface.
- Upon landing, Peregrine transitions to a local utility supporting payload operations with power and communications.

Astrobotic provides comprehensive support to the payload customer from contract signature to End–Of–Mission (EOM). The Payload Customer Service Program equips the customer with the latest information on the mission and facilitates technical exchanges with Astrobotic engineers to ensure payload compatibility with the Peregrine Lunar Lander and overall mission success.

ASTROBOTIC LUNAR DELIVERY

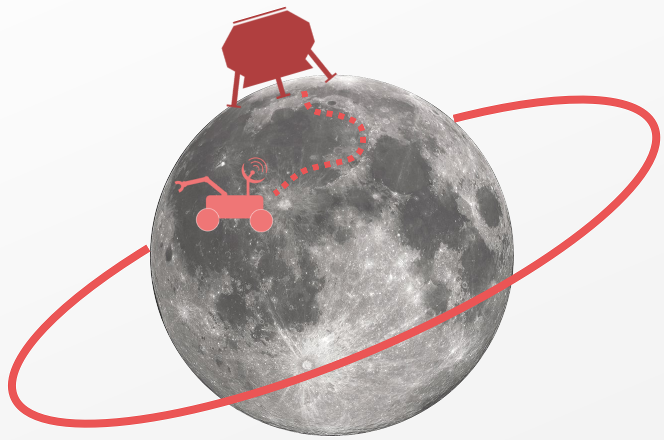
COMPANIES, GOVERNMENTS, UNIVERSITIES, NON-PROFITS, AND INDIVIDUALS can send payloads to the Moon at an industry-defining price of $1.2M per kilogram of payload to the lunar surface.

Standard payload delivery options include deployment in lunar orbit prior to descent and to the lunar surface where payloads may remain attached to the lander, deploy from the lander for an independent mission, or hitch a ride on an Astrobotic lunar rover.

LUNAR ORBIT
$ 300,000 / kg

LUNAR SURFACE
$ 1,200,000 / kg

DELIVERY ON ROVER
$ 2,000,000 / kg



For every kilogram of payload, Peregrine provides:

0.5 Watt POWER

10 kbps BANDWIDTH

Additional power and bandwidth is available upon request.
Please contact Astrobotic to learn more.

Payloads onboard the Mission One (M1) manifest can expect an increased
20 kbps per kilogram of payload.

NOTE: Payloads less than 1 kg may be subject to integration fees.

NOTE: DHL MoonBox offers an affordable alternative to send small items to the Moon. Prices start at $460. Check it out on Astrobotic's website.

MISSION ONE AT A GLANCE

Astrobotic's flagship Mission One stands to
DOUBLE THE NUMBER OF NATIONS THAT HAVE LANDED ON THE MOON.

M1 delivers a manifest of international payloads to lunar orbit and the lunar surface. The following specifications provide an overview of Astrobotic's inaugural mission to the Moon.

Lunar Surface Payload Delivery Capacity: **35 kg**

Peregrine supports 35 kg of non-NASA payload to the lunar surface for M1. Additional capacity can be supported to lunar orbit.

Lunar Surface Delivery Location: **Lacus Mortis, 44°N 25°E**

Lacus Mortis is in the North-Eastern quadrant of the near-side of the Moon. The selected landing site is a relatively flat plateau in this region.

Lunar Orbit Delivery Location: **100 km × 750 km**

Orbital payload deployment is nominally performed in this stable orbit. Delivery to a 100 km × 8700 km lunar orbit may be available upon request.

Mission Duration: **≤ 2 Months**

This is the upper limit mission duration from launch to EOM, which includes the cruise to the Moon. The mission duration varies depending on the resulting trajectory for the launch date selected by the launch vehicle primary payload.

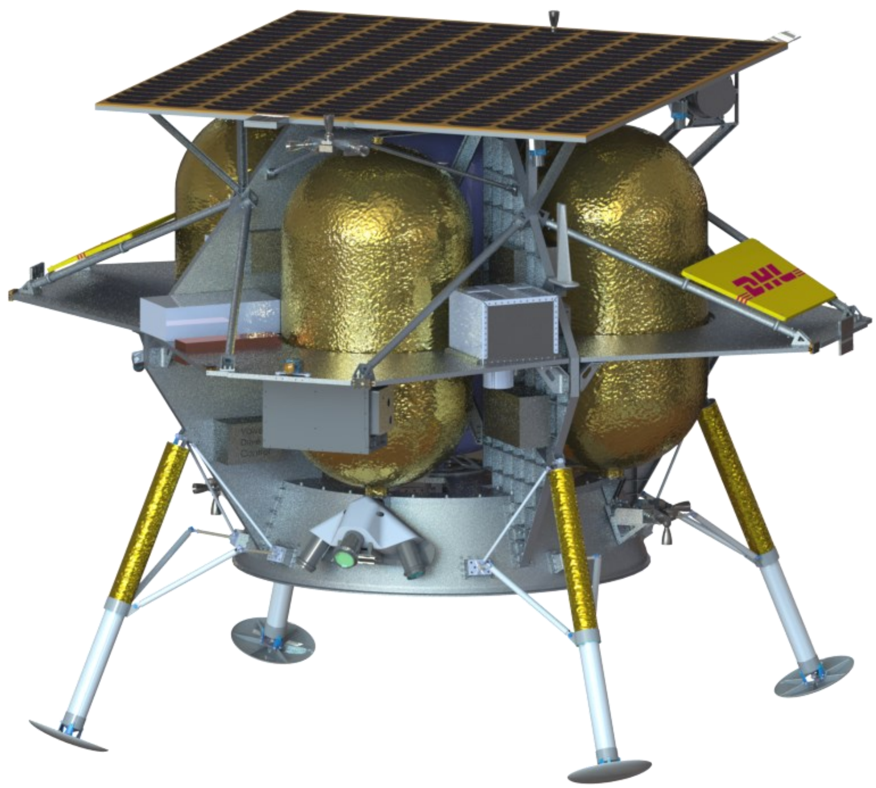
Surface Operations Duration: **192 Hours**

Peregrine provides utilities to surface payloads for 8 Earth days, or 192 hours, before beginning shut-down procedures. The lander is not expected to survive lunar night.

THE LANDER AT A GLANCE

THE PEREGRINE LUNAR LANDER DELIVERS PAYLOADS TO THE MOON
for Astrobotic's historic first mission.

This is the M1 configuration and specifications of the Peregrine Lunar Lander.



Lander Height: 1.9 m

Lander Diameter: 2.5 m

Lander Wet Mass: 1,283 kg

This is the total mass of the lander including propellant and payloads.

Lunar CATALYST Program Partner

Official Logistics Provider

Technical Design Partner

Launch Partner

Propulsion System Partner

Premium Communications Partner

PEREGRINE SUPPLIERS

Propulsion System Integrator

Landing Leg Supplier

Engine Supplier

Propellant Tank Supplier

Flight Processor Supplier

Battery Supplier

PAYLOAD EXPERIENCE

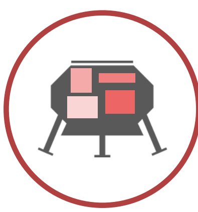
1 SERVICES AGREEMENT

Following contract signature, the payload customer is connected with their payload manager to begin development of a schedule and an Interface Control Document.

2 TECHNICAL SUPPORT

Astrobotic supports the payload customer by participating in payload design cycle reviews and facilitating payload testing with simulated spacecraft interfaces.

3 INTEGRATION



The payload is sent to the Astrobotic integration facility using DHL Logistics. Astrobotic accepts the payload and integrates it onto the Peregrine Lunar Lander.

4 MISSION

The integrated lander is launched and commences its mission. The Astrobotic Mission Control Center connects the customer to their payload during the flight to the Moon and on the lunar surface.

ASTROBOTIC IS HERE TO SUPPORT THE SUCCESS OF YOUR PAYLOAD MISSION.

The standard payload interfaces and services are defined to enable nominal payload missions. This Payload User's Guide (PUG) provides an overview of these standard interfaces and services.

Astrobotic is able to accommodate payloads with needs outside of the standard interfaces and services at additional cost. Please contact Astrobotic to discuss any nonstandard requests such as custom interfaces, accommodation of large or unusual geometries, specific trajectory or landing site requirements, payload design consulting services, etc.

The Payload Customer Service Program is a standard service for all payload customers to provide the tools necessary to design a payload that successfully interfaces with the Peregrine Lunar Lander. The following features are included as part of the program.

- Availability for general and technical inquiries
- Quarterly presentation of Astrobotic business and mission updates
- Monthly technical exchanges with Astrobotic mission engineers
- Access to library of Astrobotic payload design references and standards
- Technical feedback through payload milestone design reviews
- Facilitation of lander–payload interface compatibility testing

NOTE: Access to materials within the Astrobotic library is not always restricted to signed customers. Please contact Astrobotic for more information on obtaining the latest version of any document referenced within the PUG.

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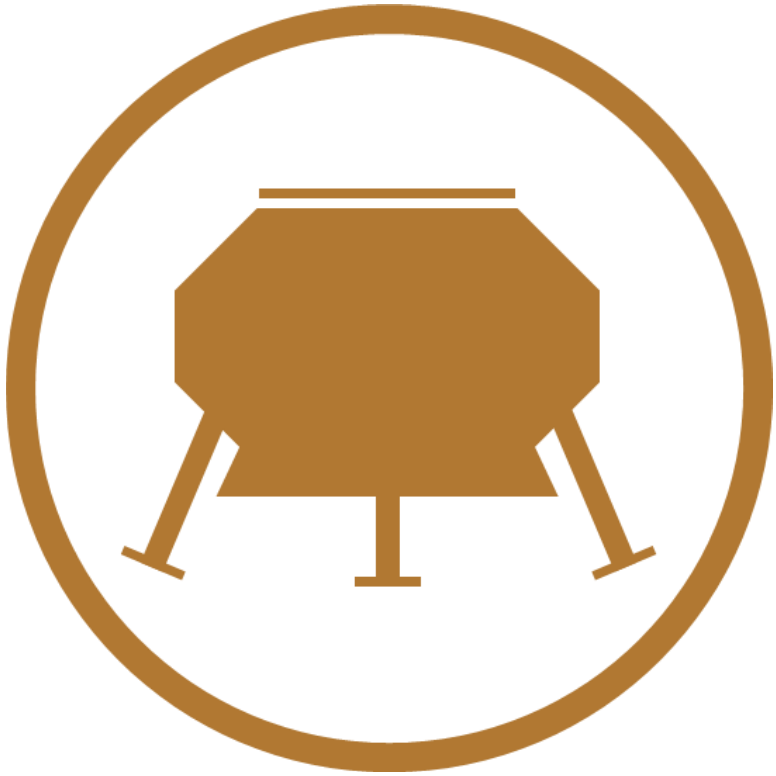
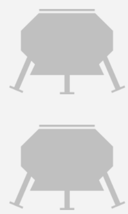
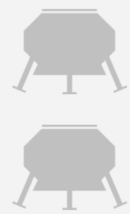


PEREGRINE

PEREGRINE MISSIONS

PEREGRINE IS A LUNAR LANDER PRODUCT LINE
that delivers payloads for Astrobotic's first five missions.

Following Mission One (M1), Astrobotic anticipates a flight rate of about one mission per year.

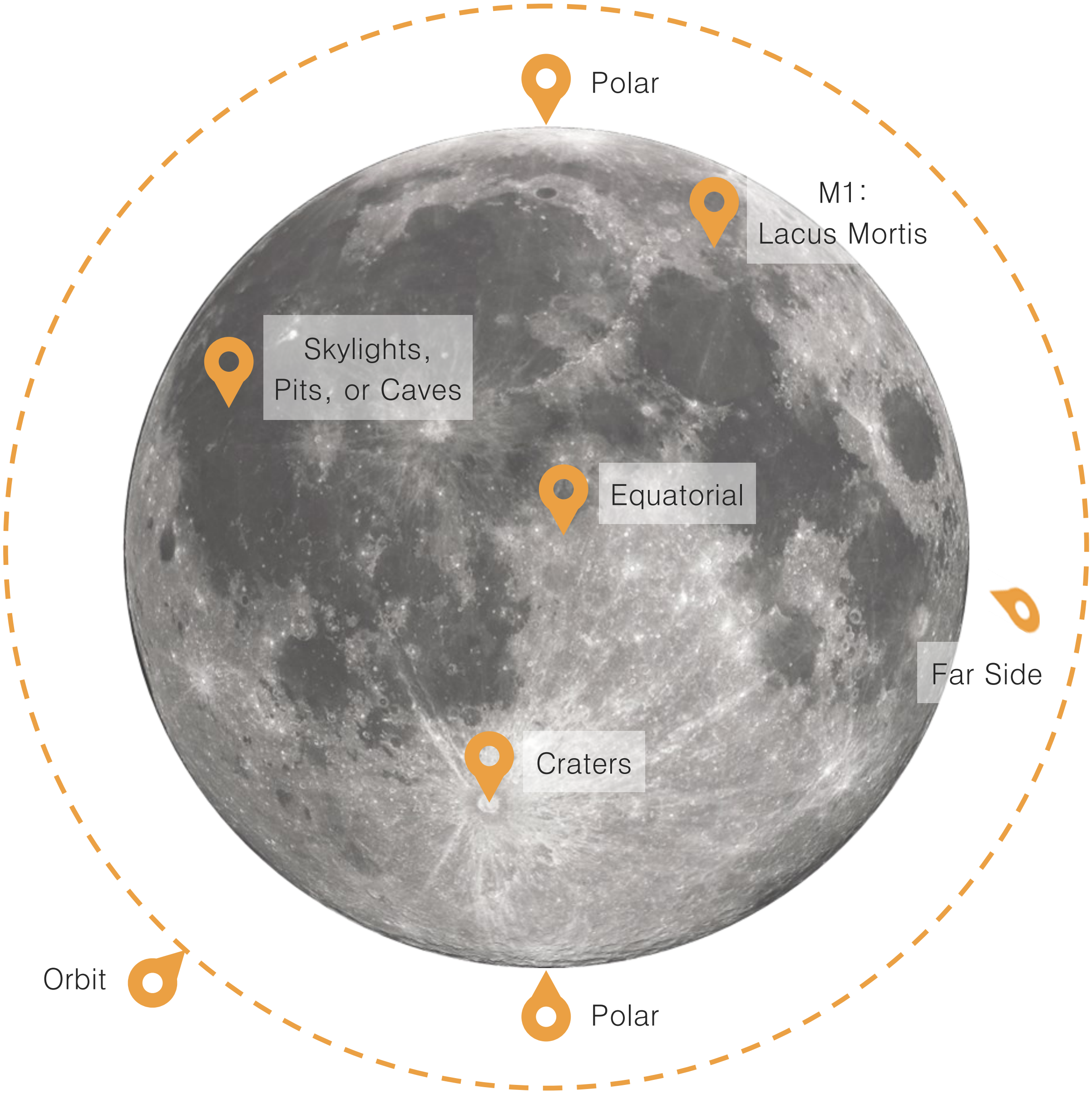
MISSION	1	2	3	4	5
NUMBER OF LANDERS					
NOMINAL SURFACE CAPACITY	35 kg	175 kg	265 kg	530 kg	530 kg
LAUNCH CONFIG	Secondary Payload	Secondary Payload	Secondary Payload	Primary Payload	Primary Payload

The launch orbit is determined by the launch vehicle's primary payload. Peregrine can accept primary trajectories to Low Earth Orbit (LEO), Sun-Synchronous Orbit (SSO), and Geosynchronous Transfer Orbit (GTO). As the primary launch vehicle payload on Missions Four and Five, Peregrine selects a direct launch into a Trans-Lunar Injection (TLI).

NOTE: The nominal surface capacity is the lunar surface delivery capability of the mission. For M1, this includes 35 kg of non-NASA payload. For Missions Four and Five, this is the combined payload capacity of both landers. Peregrine can support increased payload capacity for lunar orbit delivery.

PEREGRINE DELIVERY LOCATIONS

THE PEREGRINE LUNAR LANDER SAFELY DELIVERS PAYLOADS
to lunar orbit and the lunar surface on every mission.

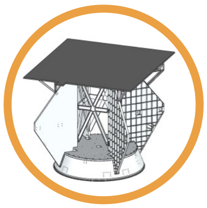


The Peregrine Lunar Lander product line is capable of supporting payload missions to locations of interest from the lunar equator to the poles. Future missions incorporate technology to enable precision landing at sites of interest, operations on the far side, and lunar night survivability.

PEREGRINE BUS SYSTEMS

A CORE SET OF SYSTEMS, KNOWN AS THE BUS,
defines the Peregrine product line.

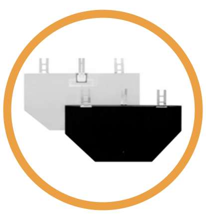
The spacecraft bus design enables safe payload delivery to lunar orbit and the lunar surface. The bus systems of the Peregrine Lunar Lander, listed below, remain consistent throughout the product line missions providing confidence in flight-proven design for future missions.



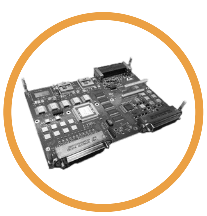
STRUCTURE

PROPULSION

GUIDANCE, NAVIGATION, AND CONTROL



POWER

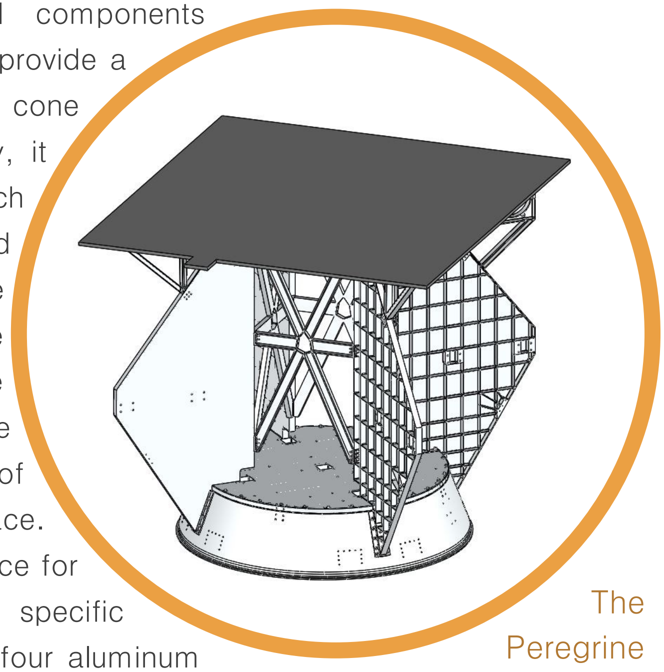


AVIONICS

COMMUNICATIONS

THE PEREGRINE LUNAR LANDER'S STRUCTURE
is stout, stiff, and simple for survivability during launch and landing.

The bus structure is mainly manufactured out of lightweight aluminum alloy. Several components feature ortho-grid designs in order to provide a strong and sturdy framework. The cone houses the main engines. Additionally, it serves as the adapter to the launch vehicle where a releasable clamp band mates Peregrine to the launch vehicle and enables separation prior to the cruise to the Moon. For future missions, the entire structure is scalable to accommodate up to 265 kg of payload for delivery to the lunar surface. The standard physical mounting interface for the payloads is optimized for the specific mission profile. Mission One features four aluminum payload mounting decks. For missions to the lunar surface, four landing legs, designed to absorb shock and stabilize the craft on touchdown, are fastened to the bus structure.

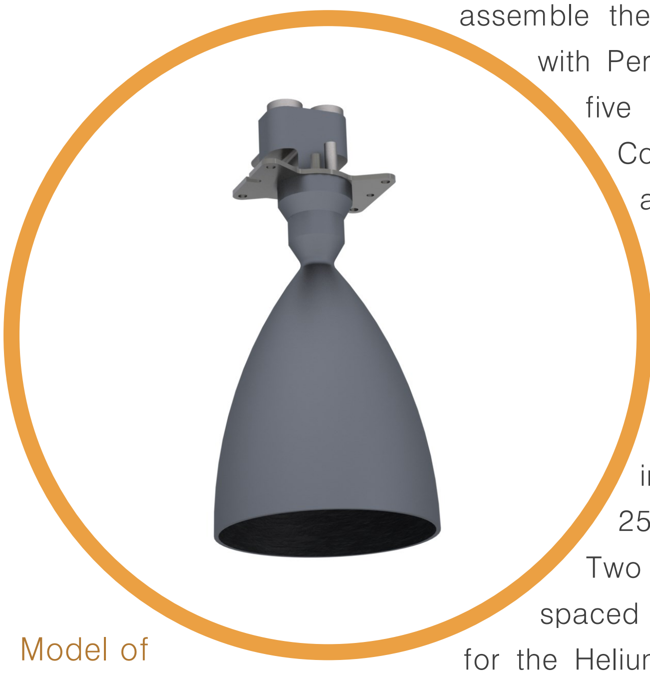


The Peregrine Lunar Lander bus structure

Maximum Lunar Delivery Capacity:	265 kg
Main Structure Material:	Aluminum
Launch Vehicle Adapter Diameter:	1194 mm

PROPULSION

THE PEREGRINE LUNAR LANDER USES A PROPULSION SYSTEM
featuring next generation space engine technology to power payloads to the Moon.



Model of one of five main engines

Astrobotic is utilizing a propulsion system integrator to assemble the propulsion system and incorporate it with Peregrine's structure. The system features five main engines and twelve Attitude and Control System (ACS) engines powered by a hypergolic bipropellant, which does not require ignition as the fuel and oxidizer combust on contact. A proven hydrazine derivative, Mono-Methyl-Hydrazine (MMH), serves as the fuel. The oxidizer is a solution of nitric oxide in dinitrogen tetroxide/nitrogen dioxide, 25% Mixed Oxides of Nitrogen (MON-25). Two tanks each of the fuel and oxidizer are spaced evenly about the craft with a fifth tank for the Helium pressurant in the center. Peregrine's main engines, located within the cone, are used for all major maneuvers. The ACS thrusters, grouped in clusters of three and placed about the lander to ensure control with six degrees of freedom, maintain spacecraft orientation throughout the mission.

Individual Main Engine Thrust:	667 N
Individual ACS Engine Thrust:	45 N
Fuel & Oxidizer:	MMH & MON-25

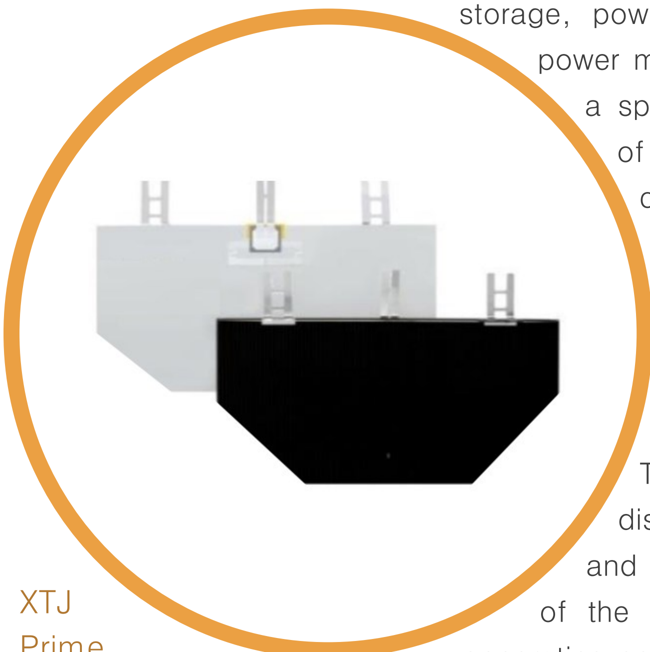
PEREGRINE'S GUIDANCE, NAVIGATION, AND CONTROL (GNC) SYSTEM orients the spacecraft throughout the mission to facilitate operations.

GNC processes the inputs from an array of sensors, correcting for idiosyncrasies, and uses them to revise the internal estimate of the lander's position, attitude, and velocity during flight. Commands to maneuver the spacecraft are updated based on this estimate of the craft's state. Earth-based ranging informs position and velocity state estimates for orbital and trajectory correction maneuvers. Input from the star tracker, sun sensors, as well as rate gyros and accelerometers within an inertial measurement unit aid the Attitude Determination and Control System (ADCS) in maintaining a sun-pointing orientation, with the solar panel facing the Sun, during nominal cruise operations. During powered descent and landing, a Doppler LiDAR provides velocity information that guides the spacecraft to a safe landing at the target site within the touchdown constraints outlined below.

Berlin Space Technologies star tracker

Powered Descent Duration:	600 s
Maximum Horizontal Landing Velocity:	0.5 m/s
Maximum Vertical Landing Velocity:	2.0 m/s

PEREGRINE IS DESIGNED TO BE A POWER POSITIVE SYSTEM, generating more power than it consumes during nominal mission operations.



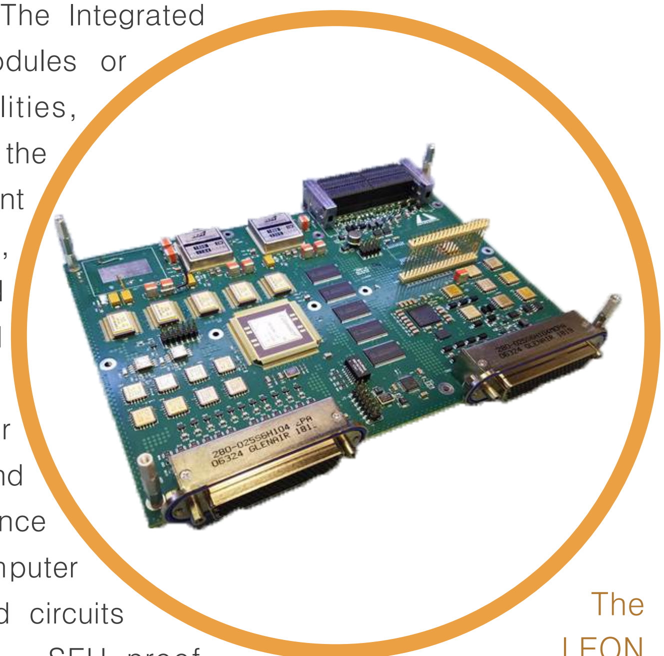
XTJ Prime solar cell

The spacecraft power system is responsible for power storage, power generation, power distribution, and power management. Peregrine stores energy in a space-grade lithium-ion battery. A panel of GaInP/GaAs/Ge triple junction solar cells with heritage in orbital and deep space missions generates the spacecraft's power. The battery feeds into a 28 V power rail from which unregulated and regulated power is distributed to all lander subsystems. The battery is utilized during quick discharge activities, such as engine burns and attitude maneuvers, and during phases of the mission where the solar panel is not generating power, such as in lunar shadow. The solar panel is nominally pointed towards the Sun to enable power generation and is utilized to provide battery charge and maintain surface operations.

Bus Voltage:	28 Vdc
Battery Composition:	Lithium-Ion
Solar Cell Composition:	GaInP/GaAs/Ge

THE PEREGRINE LUNAR LANDER'S AVIONICS
perform all command and data handling for the spacecraft.

The avionics system manages the various inputs and outputs of the lander's subsystems. The Integrated Avionics Unit (IAU) houses nine modules or boards with distinct functionalities, encompassing the major aspects of the avionics system like power management and the flight computer. Other aspects, such as GNC flight sensor drivers and propulsion control units, are enclosed separately near the relevant subsystem hardware. Peregrine's flight computer serves as the spacecraft's brain and consists of a 32-bit high-performance dual-core microprocessor. The computer employs radiation-hardened integrated circuits as well as fault-tolerant and SEU-proof characteristics. The payload controller is also housed within the IAU and manages the individual payloads as well as their contractual services. The payload controller features Error Detection And Correction (EDAC), upset monitoring, and software robustness.

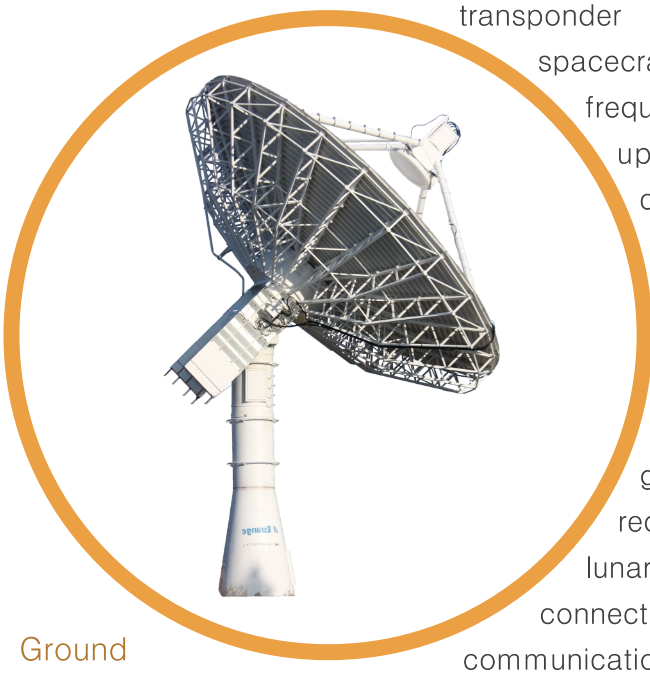


The LEON flight computer board

Flight CPU Design:	LEON 3 FT
Payload CPU Design:	Xilinx FPGA
Payload CPU Safety Features:	EDAC, Software Robustness

COMMUNICATIONS

PEREGRINE SERVES AS THE PRIMARY COMMUNICATIONS NODE relaying data between the payload customer and their payloads on the Moon.



Ground station dish antenna

The lander houses a high-powered and flight-qualified transponder to communicate with Earth. The spacecraft-Earth connection uses different frequencies within the X-Band range for uplink as well as downlink space communications. The selection of several ground stations maintains 100% coverage around Earth. The lander utilizes multiple low gain antennas for optimal coverage during flight operations and then switches to a high gain antenna with more precise pointing requirements following touchdown on the lunar surface. The spacecraft-payload connection is provided via Serial RS-422 wired communication throughout the mission. Following landing, a 2.4 GHz IEEE 802.11n compliant Wi-Fi modem enables wireless communication between the lander and deployed payloads on the lunar surface.

Payload Wired Protocol:	Serial RS-422
Payload Wireless Protocol:	802.11n Wi-Fi
Payload Wireless Frequency:	2.4 GHz

ADDITIONAL SUBSYSTEMS

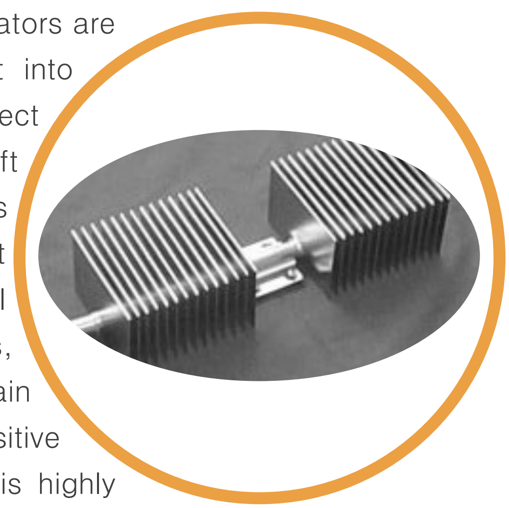
ADDITIONAL SUBSYSTEMS SUPPORT THE PEREGRINE LUNAR LANDER BUS throughout the varied mission profiles.

FLIGHT SOFTWARE

Flight software is a supporting subsystem enabling and monitoring the required operations of the bus systems. The lander's flight software is built on NASA's core flight software and tested in the NASA TRICK/JEOD simulation suite. Astrobotic utilizes a standard agile approach to build, test, and implement software.

THERMAL CONTROL

The spacecraft is designed to implement mainly passive methods to regulate its thermal environment. Radiators are used to amass excess heat and radiate it out into space. Passive heat pipes are employed to direct excess heat to colder regions of the spacecraft where it is needed. Layers and coatings, such as Multi-Layer Insulation or MLI, are used to protect components from undesired external thermal effects. Some active thermal control methods, heating or cooling, may be implemented to maintain particularly stringent thermal conditions of sensitive critical components. The overall thermal design is highly mission specific as the spacecraft may be either hot- or cold-biased depending on the extreme thermal case of each mission profile. For M1, the lander is a cold-biased system designed to survive the thermal environment of solar noon on the lunar surface.

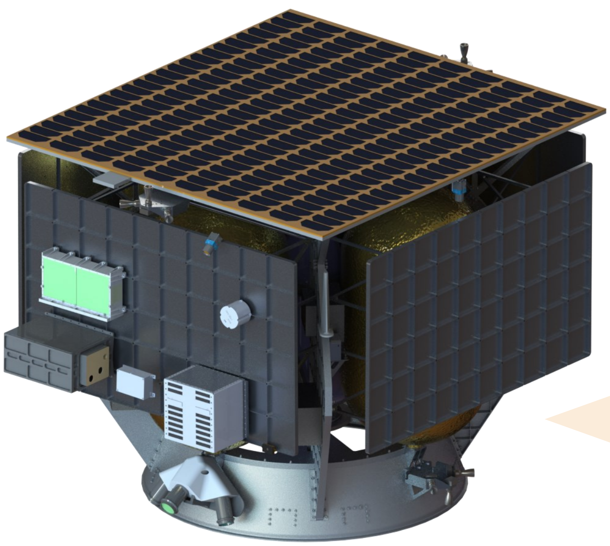


Advanced Cooling Technologies heat pipe assembly

PEREGRINE CONFIGURATIONS

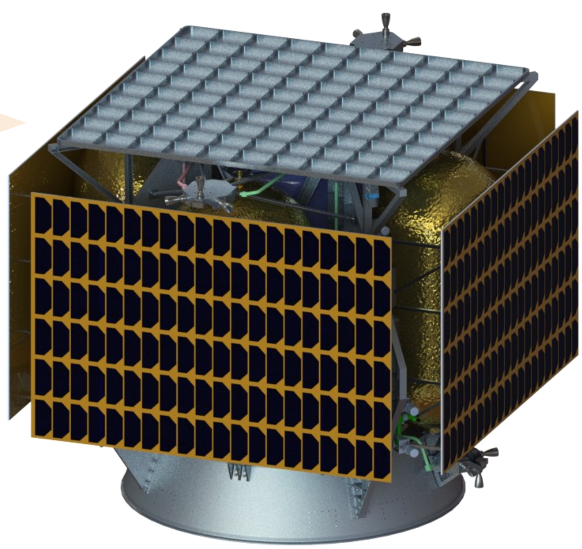
THE PEREGRINE LUNAR LANDER IS AN ADAPTABLE SPACECRAFT designed to meet the varied mission needs of the payload market.

The spacecraft bus can be arranged and augmented to adapt to the various possible payload delivery locations in lunar orbit and on the lunar surface as well as the needs of various payload types.



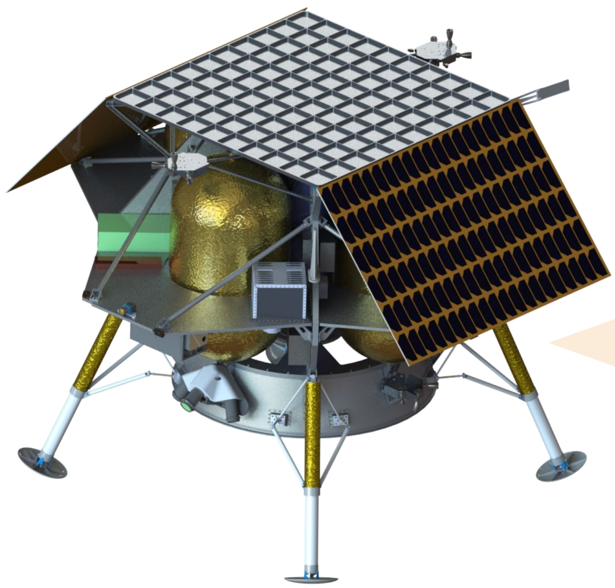
For Peregrine missions designed solely to deploy payloads in lunar orbit, the landing legs are removed. The orbital configuration shown here features vertical mounting panels instead of the classic horizontal mounting decks.

The orbital delivery configuration shown above can easily be reconfigured to accommodate a top-mounted small satellite. This "orbital tug" configuration is shown with solar panels on the spacecraft sides.



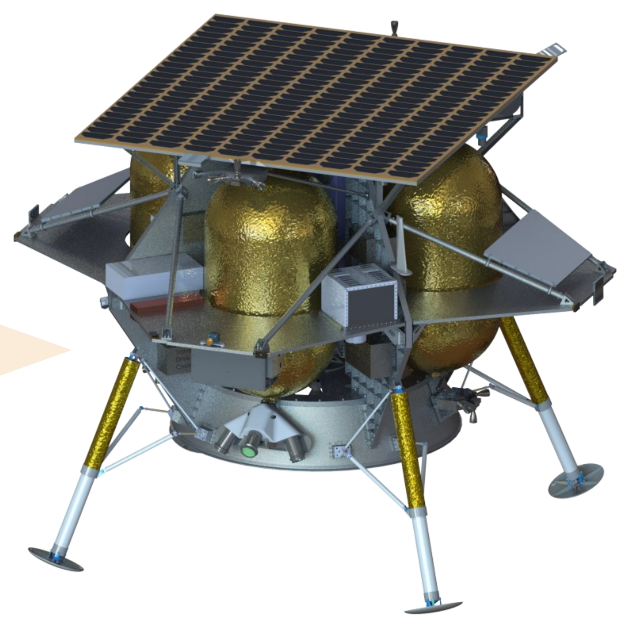
PEREGRINE CONFIGURATIONS

Peregrine's flexible payload mounting accommodates a variety of payload types for science, exploration, marketing, resources, and commemoration.



Missions to the polar regions of the lunar surface feature side-mounted solar panels to produce sufficient power at higher latitudes to support spacecraft and payload needs. The ortho-grid panel at the top can be used to accommodate a large top-mounted payload and can be outfitted with ramps to support egress of a large rover.

This configuration features horizontal payload decks for simplified mounting, sturdy legs for landing, and a top-mounted solar panel for equatorial or near-equatorial missions. This is the Peregrine Lunar Lander configuration set to fly Mission One.



Other alterations to the spacecraft bus, such as additional sensors for precision landing or a satellite communications relay for far-side operations, may be necessary depending on the specific mission but are not illustrated in the representative models above.

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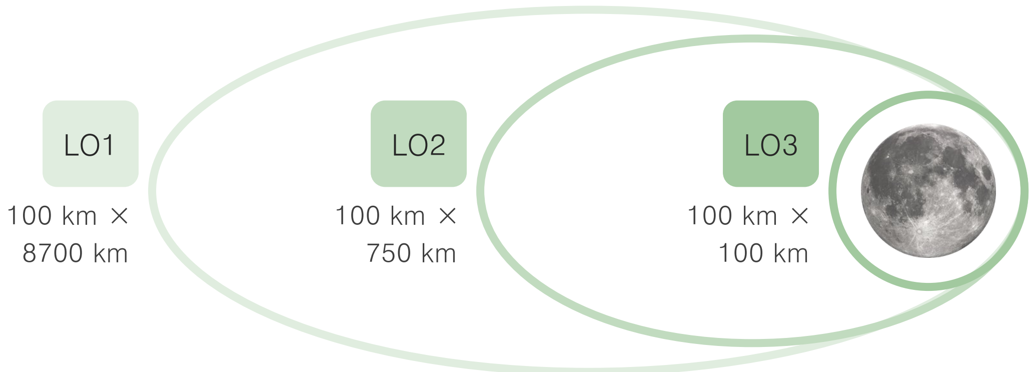
MISSION ONE

The Peregrine Lunar Lander supports
LUNAR ORBIT DELIVERY FOR MISSION ONE (M1).



Peregrine holds in three distinct Lunar Orbits (LOs), only one of which is unavailable for payload deployment. The periapsis is consistent at 100 km while the apoapsis decreases through Lunar Orbit Insertion (LOI) maneuvers from 8700 km to a circular 100 km. The orbital inclination remains between 56° and 57° as determined by the launch.

Lunar Orbit 1

The initial LOI is into a highly elliptical orbit. Peregrine nominally spends 12 hours in LO1. Nonstandard payload deployment may be available in this orbit upon request.

Lunar Orbit 2

The next LOI is into a stable elliptical orbit. According to the baseline trajectory, Peregrine spends 48 hours in LO2; the actual duration depends on the launch date and subsequent trajectory as well as the orbital deployment schedule. All payload deployments are nominally planned for this orbit.

Lunar Orbit 3

The final LOI is into a circular orbit. Peregrine nominally spends 72 hours in LO3 for descent preparations. Payload deployment is not supported in this orbit.

M1 LUNAR SURFACE DELIVERY

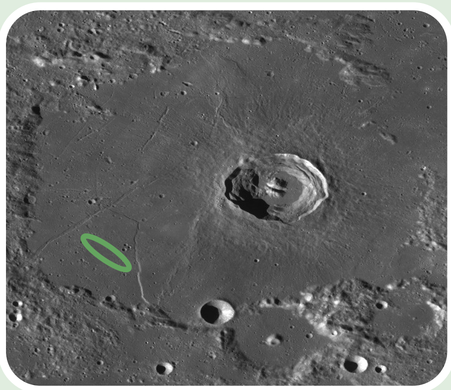
The Peregrine Lunar Lander supports
LUNAR SURFACE DELIVERY FOR MISSION ONE.

The target landing site for Mission One is Lacus Mortis, a basaltic plain in the northeastern region of the nearside of the Moon.

Target Landing Site: 43.914° N, 25.148° E

Landing Ellipse Dimensions: 24 km × 6 km

The landing ellipse represents the requirement on maximum expected variation in actual touchdown location from the target landing site. These values represent the major and minor axes, respectively.




Graphical representation of landing ellipse for reference only.

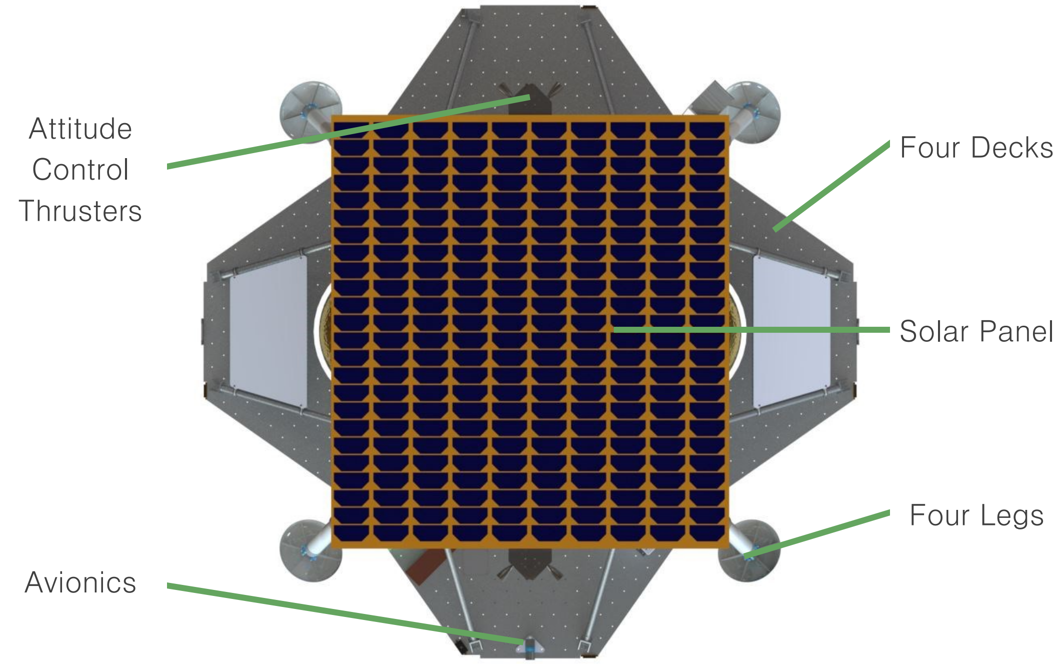
Effective Slopes: ≤ 12°

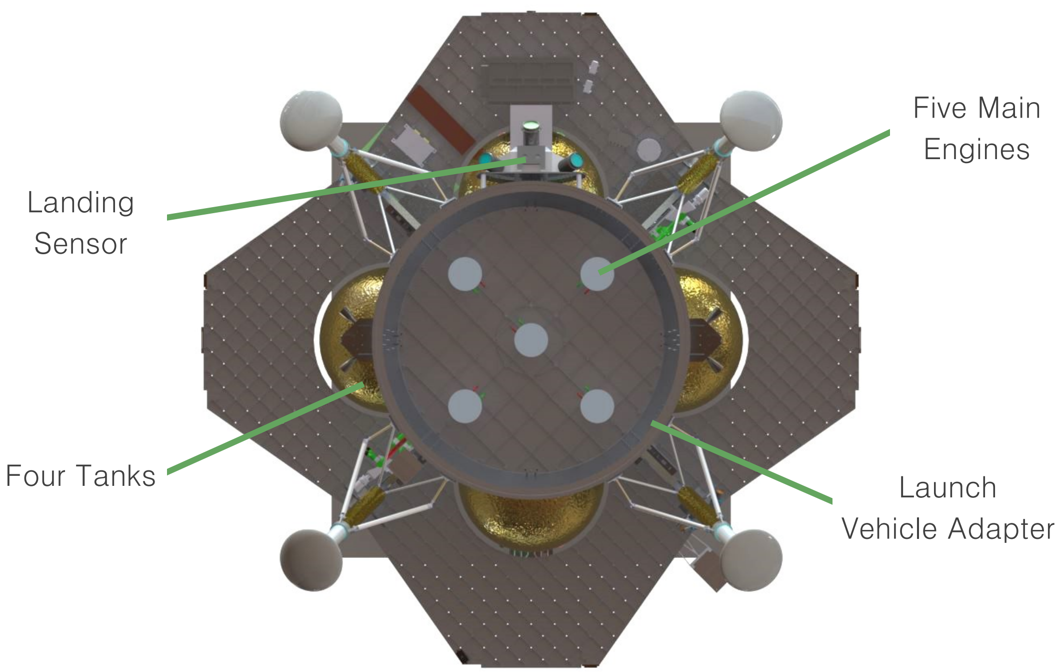
The effective slope takes into account natural slopes in the topography and the presence of rocks. The greatest expected rock height is 0.35 m.

Local Landing Time: 55–110 Hours After Sunrise

A lunar day, from local sunrise to sunset on the Moon, is equivalent to 354 Earth hours, or approximately 14 Earth days.

MISSION ONE DEMONSTRATES PEREGRINE'S PAYLOAD DELIVERY CAPABILITY to lunar orbit and lunar surface.





This configuration of Peregrine is set to fly M1; it stands 1.9 m tall and 2.5 m in diameter. The lander launches as a secondary payload onboard a ULA Atlas V launch vehicle, enabling a low-cost mission to the Moon.

M1 MISSION PROFILE

THE ASTROBOTIC MISSION ONE PROFILE ENCOMPASSES FIVE DISTINCT PHASES.

Payload Integration with Peregrine

5–9 Months	PRE-LAUNCH PHASE	Includes preparation activities

Launch Vehicle Lift-Off

1–3 Hours	LAUNCH PHASE	Includes transit from Earth's surface to Low Earth Orbit (LEO)

Peregrine Separation from Launch Vehicle

3–33 Days	CRUISE PHASE	Includes all Trans-Lunar Injection (TLI) maneuvers from LEO to LOI1

Peregrine Insertion into Lunar Orbit

4–25 Days	LUNAR ORBIT PHASE	Includes all LOI maneuvers, orbital payload deployments, and descent to the lunar surface

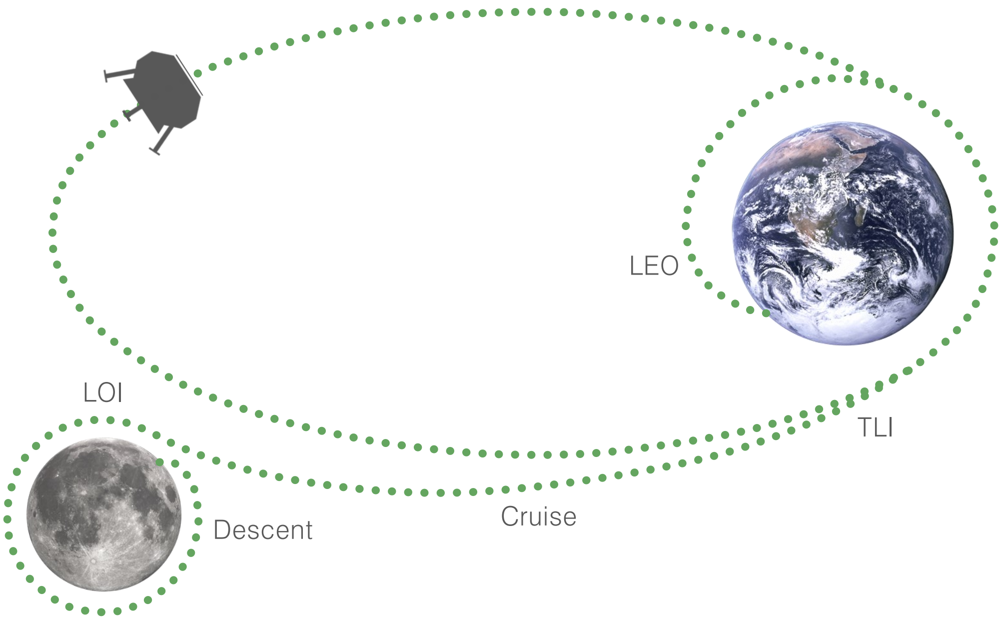
Peregrine Touchdown on the Lunar Surface

8 Days	SURFACE PHASE	Includes surface activities such as surface payload deployments

Onset of Lunar Night

Following launch, the total mission duration does not exceed 2 months. The duration of the individual mission phases depends on the launch date, selected by the launch vehicle's primary payload, and the corresponding trajectory of the Peregrine Lunar Lander.

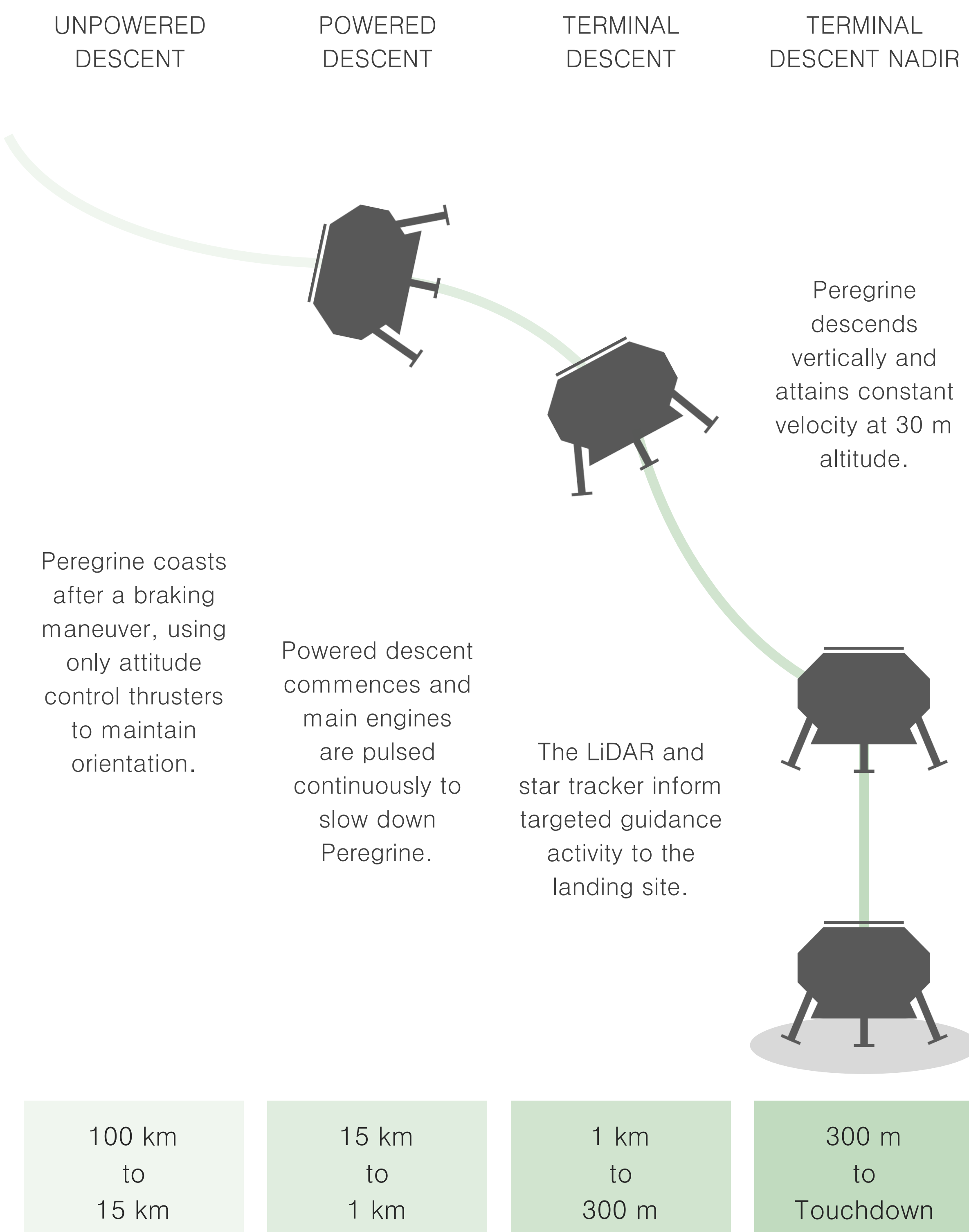
M1 TRAJECTORY



- Launch to LEO aboard the Atlas V
- Earth–departure burn from the Centaur booster
- Separation from the launch vehicle
- Perigee raise maneuver
- TLI maneuver
- Cruise through cislunar space
- LOI maneuver
- Lunar orbit hold
- Autonomous descent operations
- Landing at Lacus Mortis
- Surface operations

M1 ORBIT & DESCENT

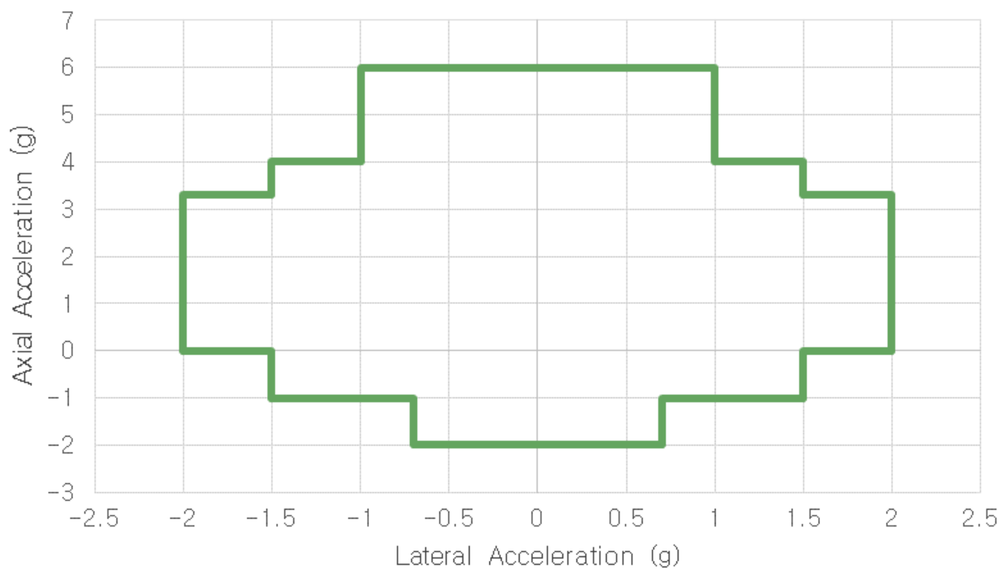
DESCENT IS INITIATED BY AN ORBIT-LOWERING MAIN ENGINE BURN.



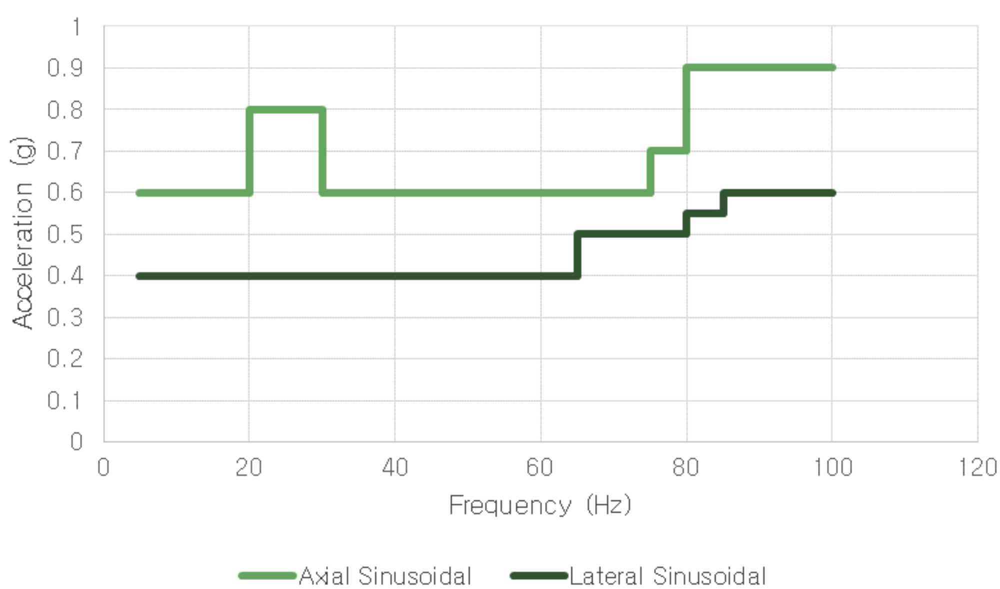
The Peregrine Lunar Lander encounters
the greatest mechanical environments during launch.

The following environments are based on the ULA Atlas V as the selected launch vehicle for M1. Please contact Astrobotic for the latest version of the relevant ULA Atlas V User's Guide document.

This is the maximum range of axial and lateral accelerations. A positive axial value indicates a compressive net center of gravity acceleration whereas a negative value indicates tension.

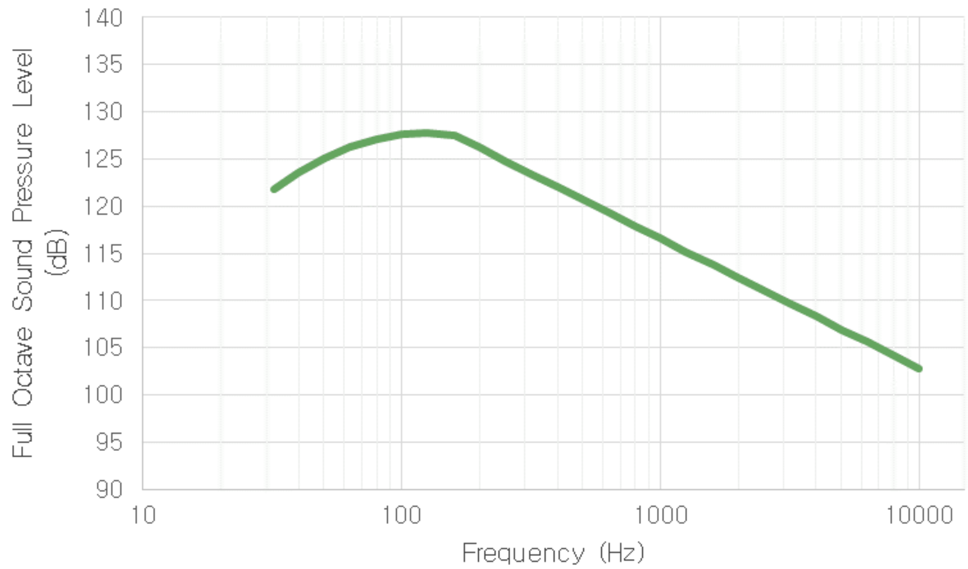


This is the maximum range of axial and lateral sine environments.



The highest acoustic levels occur at lift-off and during transonic flight, when the launch vehicle transitions to speeds greater than the speed of sound.

This is the maximum predicted acoustic environment.



Peregrine encounters shock events during launch and injection originating from the launch vehicle fairing release and separation from the launch vehicle.

These are the maximum shock levels for the clamp band release, not accounting for variation during flight.

Frequency (Hz)	100	1,500	10,000
Shock Response Spectrum (g)	100	2,800	2,800

NOTE: These environments are experienced by the lander; the corresponding mechanical environments of the payload depend on mounting location and are a function of the structural dynamic properties of both the lander and the payload. Astrobotic works with each customer to develop payload-specific environments for relevant system testing prior to payload integration.

THERMAL ENVIRONMENT

The Peregrine Lunar Lander encounters
the following approximate thermal environments during Mission One.

Pre-Launch: 0°C to 27°C

The integration and launch facilities are climate-controlled to provide this specific temperature range.

Launch: 0°C to 27°C

The thermal environment does not change significantly for the lander during launch due to the short duration of launch and the large thermal mass of the launch vehicle.

Cruise: -60°C to 100°C

The thermal environment is significantly colder for objects in shadow and much hotter for objects in direct sunlight.

Lunar Orbit: -120°C to 100°C

The thermal environment is significantly colder for objects in shadow and much hotter for objects in direct sunlight.

Surface: -30°C to 80°C

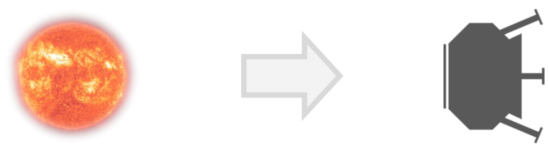
The thermal environment is significantly colder for objects in shadow and much hotter for objects in direct sunlight. This range is relevant for the nominal lunar surface operations duration and does not include lunar night.

NOTE: The corresponding thermal environments of the payload depend on mounting location and the incident sunlight at that location throughout the mission. Astrobotic works with each customer to develop payload-specific environments for relevant system testing prior to payload integration.

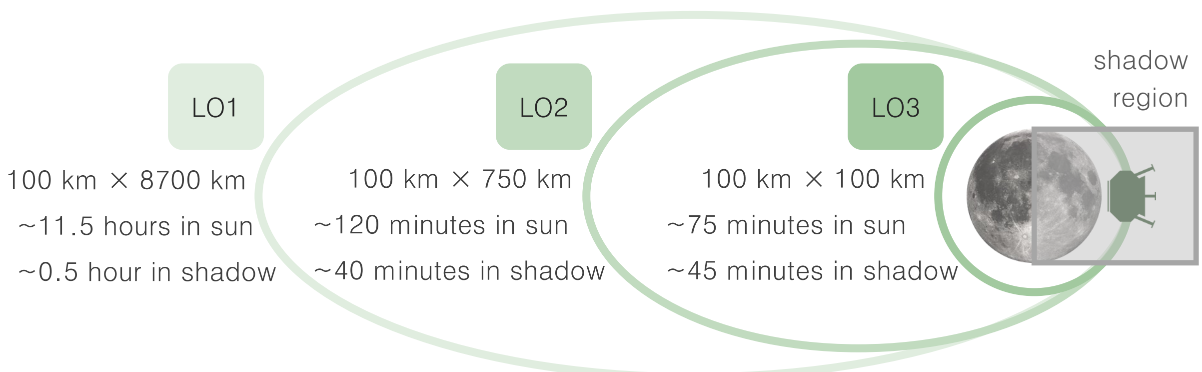
THERMAL ENVIRONMENT

Throughout flight, the Peregrine Lunar Lander
is nominally oriented with the solar panel facing the Sun.

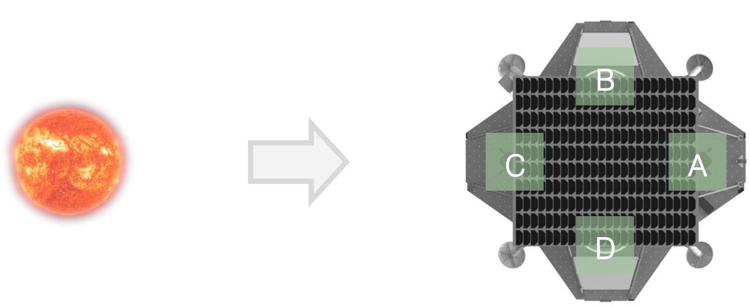
The lander's top-side receives the most incident solar radiation, and resulting heat, during the Cruise and Lunar Orbit phases. By contrast, the underside of the decks are in near-perpetual shadow and at the lower extremes of the expected temperatures for those phases.



The most extreme thermal environments occur during the Lunar Orbit phase when the spacecraft cycles through cold and hot as it passes through the Moon's shadow, shown in the representative diagram below. Peregrine nominally spends a total of 12 hours in LO1 and 72 hours in LO3. The duration in LO2 is dependent on the trajectory and orbital deployment concept of operations, but is currently baselined at 48 hours.



On the Lunar Surface, Peregrine is nominally oriented such that the avionics deck, Deck A, is in shadow at solar noon.



The movement of the Sun throughout the lunar day and the reflection of light from the lunar surface creates thermal environments highly specific to the payload's mounting location.

PRESSURE & HUMIDITY

The Peregrine Lunar Lander encounters
the following approximate pressure environments during Mission One.

Pre-Launch: **101.3 kPa**

This value represents the average atmospheric pressure at sea level; the actual value depends on the respective locations of the integration and launch facilities.

Launch: **−6.2 kPa/s**

The pressure drop in the launch vehicle fairing is expected to surpass −2.5 kPa/s only briefly during transonic flight as the launch vehicle exceeds the speed of sound. These values are based on the Atlas V as the selected launch vehicle for M1.

Remaining Mission: **6.7×10^{-5} kPa**

This value represents the vacuum of the space environment.

The Peregrine Lunar Lander encounters the following approximate humidity environments during Mission One:

Pre-Launch: **35% to 90%**

The integration and launch facilities are climate-controlled to the lower end of this range. The higher humidity values may occur during transportation and depend on the local climate of the facilities' locations.

Remaining Mission: **0%**

This value represents the vacuum of the space environment.

PARTICLE & CONTAMINANT

The Peregrine Lunar Lander encounters the following approximate particle and contaminant environments during Mission One.

Pre-Launch

Planetary Protection regulations govern the Pre-Launch particle and contaminant environment. Assembly and maintenance of the lander and payloads must occur in a 100k or ISO Class 8 cleanroom. The integration and launch facilities provide suitable cleanrooms for Pre-Launch activities. The payload customer must ensure compliance with Planetary Protection protocols prior to integration with the lander. Please contact Astrobotic for the latest version of the relevant Planetary Protection Provisions for Robotic Extraterrestrial Missions (NPR-8020.12D) document.

Cruise, Lunar Orbit, and Surface

The firing of main and thruster engines expels a minute amount of propellant. Following touchdown on the lunar surface, the propulsion system is made safe by venting excess helium pressurant, which may carry trace amounts of fuel and oxidizer. These propellant residuals are unlikely to affect payloads; however, payload customers may design for shielding of sensitive components if so desired.

Lunar Orbit and Surface

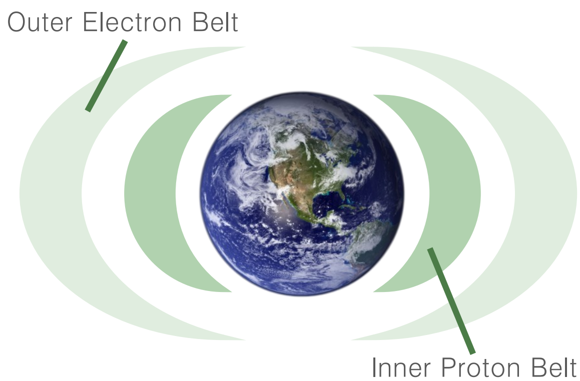
During the landing procedure, Peregrine displaces an unknown amount of lunar regolith, which may take several hours or days to fully settle. Lunar regolith is sharp and may cause damage to sensitive components. Lunar regolith is also electrostatically charged, which may cause it to cling to payload surfaces. The payload customer is responsible for identifying at-risk payload systems and implementing mitigation strategies such as shielding or deployable dust covers if necessary.

RADIATION ENVIRONMENT

The Peregrine Lunar Lander encounters
the following approximate ionizing radiation environments during Mission One.

Near-Earth: 20 rads/day

The near-Earth environment is defined by the trapped radiation within the Van Allen belts. This ionizing dosage is based on expected electron as well as heavy ion and proton radiation per Earth day in the near-Earth environment.



Interplanetary: 1 rad/day

The interplanetary environment is defined as outside of the shielding effects of Earth's magnetic field. This ionizing dosage is based on expected electron radiation per Earth day in the interplanetary environment.

Peregrine may experience 3 to 15 days in the near-Earth environment, during the Launch and Cruise phases, and 14 to 38 days in the interplanetary environment, from Cruise phase onwards. The final trajectory depends on the launch date selected by the launch vehicle's primary payload.

The total ionizing dosage for M1 is not expected to exceed 1 krad. The lander is designed to mitigate destructive events within its own electronics caused by nominal radiation for a period of eight months.

NOTE: These values do not take into account the potential for a solar particle event.

ELECTROMAGNETIC ENVIRONMENT

The Peregrine Lunar Lander encounters
Electro-Magnetic Interference (EMI) during Mission One.

The spacecraft and all payloads must be designed for compliance with MIL-STD-461D for conducted emissions. The table below shows the appropriate testing to perform based on payload type. Please contact Astrobotic for additional information or the latest version of the relevant Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility (MIL-STD-461D) document.

EMI CATEGORY	Conducted Emissions	Conducted Susceptibility	Radiated Emissions	Radiated Susceptibility
REQUIREMENT	CE102	CS101 CS114 CS115 CS116	RE102	RS103
APPLICABILITY	Active Payloads	Active Payloads	Payloads with Radio Devices Onboard	Active Payloads

These tests characterize the interference, susceptibility, and compatibility of the lander and payloads to ensure appropriate electrical interfacing that does not induce significant interference, noise, or performance degradation into the integrated system. Additionally, these tests inform compliance with other external standards and regulations such as Range Safety. Please contact Astrobotic for the latest version of the relevant Range Safety User Requirements Manual Volume 3 Launch Vehicles, Payloads, and Ground Support Systems Requirements (AFSCMAN91-710V3) document.

INTERFACES OVERVIEW

The Peregrine Lunar Lander provides payloads with
STANDARD INTERFACES AND SERVICES TO SUPPORT THEIR MISSIONS.

Astrobotic recognizes four payload types. A payload may be either passive or active as well as either static or deployable; this results in the four distinct payload types detailed below. The standard payload interfaces, services, and operations are informed by the payload type.

	Static	Deployable
Passive	Static Passive • remains attached to lander • does not perform mission tasks Example: memorabilia	Deployable Passive • detaches from lander • does not perform mission tasks Example: surface time capsule
Active	Static Active • remains attached to lander • performs mission tasks Example: telescope	Deployable Active • detaches from lander • performs mission tasks Example: rover

To support the varied needs of these payload types, the Peregrine Lunar Lander provides power and data service interfaces including continuous power as well as power signals and both wired and wireless communication. Additionally, the lander provides physical interfaces such as mechanical mounting to the lander and electrical connectors, which support general payload needs and facilitate the provision of the power and data services.

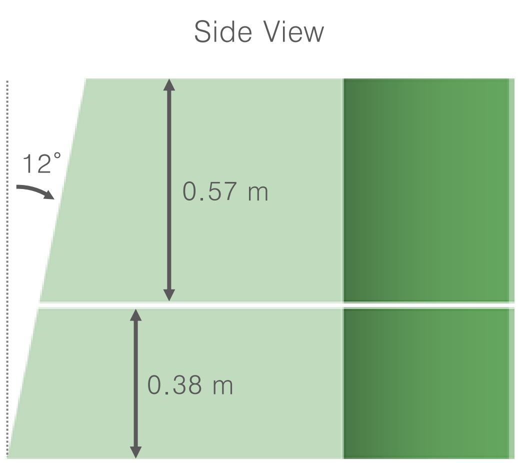
The following pages outline the standard physical, service, and ground segment interfaces for payloads on Mission One. Astrobotic is able to accommodate nonstandard interfaces upon request. Please contact Astrobotic for additional information or the latest version of the Interface Definition Document (IDD), which provides a comprehensive description of the standard interfaces.

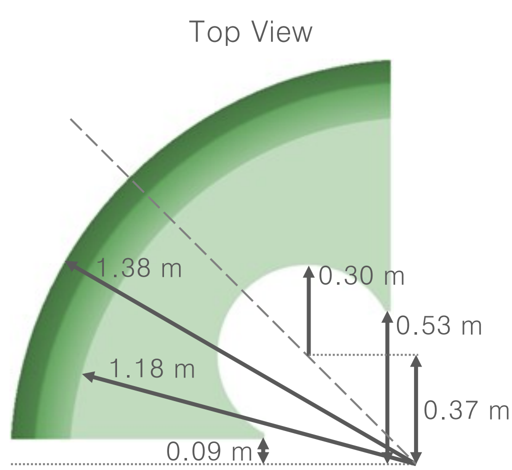
STANDARD PAYLOAD MOUNTING

PEREGRINE ACCOMMODATES A WIDE RANGE OF PAYLOAD TYPES
including lunar satellites, rovers, instruments, and artifacts.

Four orthogrid aluminum decks serve as the standard payload mounting structure on M1; one of these decks is reserved for spacecraft avionics. Alternate mounting locations, such as on the vertical shear panels separating the payload mounting decks, are available as a non-standard service; please contact Astrobotic for additional information.

The volume about the payload mounting decks designated for safe and simple accommodation of payloads, known as the payload envelope, is shown to the left. The envelope ensures safe stowage during flight and sufficient ground clearance upon landing for payloads. The stowed payload must be fully within the defined payload envelope dimensions illustrated below. Payload accommodation outside of the payload envelope is possible. Please contact Astrobotic for additional information.

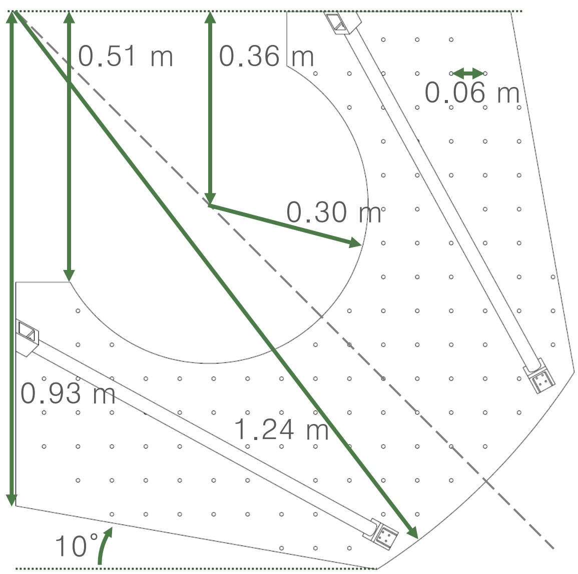




Depending on the landing conditions, the ground clearance from the bottom of the payload envelope ranges between 0.40 m and 0.80 m.

Payload operations outside of the envelope are permitted during the Surface phase. Such operations must be discussed and scheduled with Astrobotic. Egress procedures may also be performed during the Lunar Orbit phase as discussed and scheduled with Astrobotic.

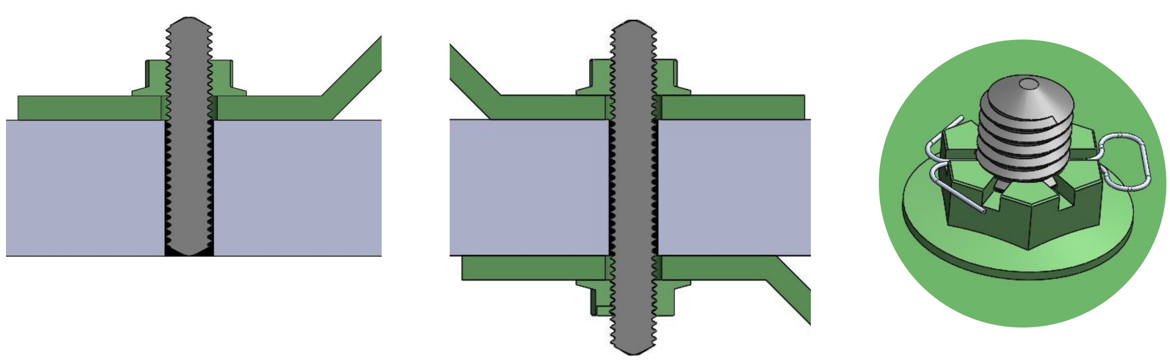
THE ALUMINUM DECK FEATURES A STANDARD BOLT PATTERN
for simplified payload mounting.



Each deck offers approximately 0.5 m^2 of mounting area per side. The same bolt pattern is provided on both sides of every deck. The bolt holes are sized for standard M5 bolts and are spaced 63.5 mm apart, from center to center. Please contact Astrobotic for more detailed drawings and dimensions of the standard payload mounting deck.

Astrobotic assigns specific bolt holes to every payload based on their size and mounting location requirements. Astrobotic provides a suitable number of bolts to each payload as determined by the payload size and allotted number of bolt holes. The customer is responsible for providing the appropriate dual-locking mechanism for each bolt.

The appropriate method for attaching a payload to its assigned bolt holes is illustrated in the diagram below. The lander deck and Astrobotic-supplied pins are shown in grey whereas customer-supplied components are shown in green.

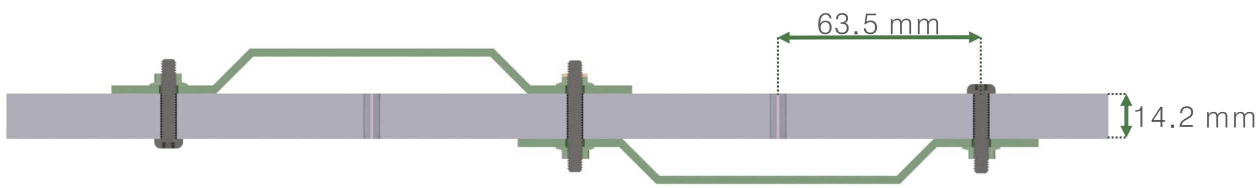


In the image to the left, one payload attaches to the provided bolt from one side of the deck. In the center image, two payloads utilize the same bolt from opposite sides of the deck. The image to the right shows a sample dual-locking mechanism, a nut and pin.

ADAPTER PLATE

ASTROBOTIC RECOMMENDS THE USE OF AN ADAPTER PLATE
within the payload unit to mount to the deck bolt pattern.

Payload placement on the lander is an iterative and cooperative process between Astrobotic and the payload customer. The final assignment of bolt holes to each payload occurs once the manifest is filled. The use of an adapter plate allows the payload design to progress independently of the assignment of bolt holes. The diagram below illustrates two payload adapter plates on opposite sides of the payload mounting deck; the payload customer is responsible for the adapter plate components in green.



Additionally, the adapter plate can be utilized to dampen loads as experienced by the payload. It can also simplify the provision of the required thermal characteristics as well as the implementation of the required grounding, bonding, and isolation techniques at the payload mounting interface to the lander.

THERMAL

The payload must implement a thermally isolating connection to the spacecraft. This allows the payload to more effectively regulate its own thermal environment using passive methods, such as radiators and coatings, or active methods, such as internal heaters.

GROUNDING, BONDING, AND ISOLATION

The Peregrine Lunar Lander operates with one common ground. Payloads must conform to this approach by employing proper grounding, bonding, and isolation schemes within their own payload design and by providing contact points for the payload structural and conductive elements as well as internal electrical circuit common ground, which Astrobotic connects to the spacecraft chassis for grounding.

ELECTRICAL CONNECTORS

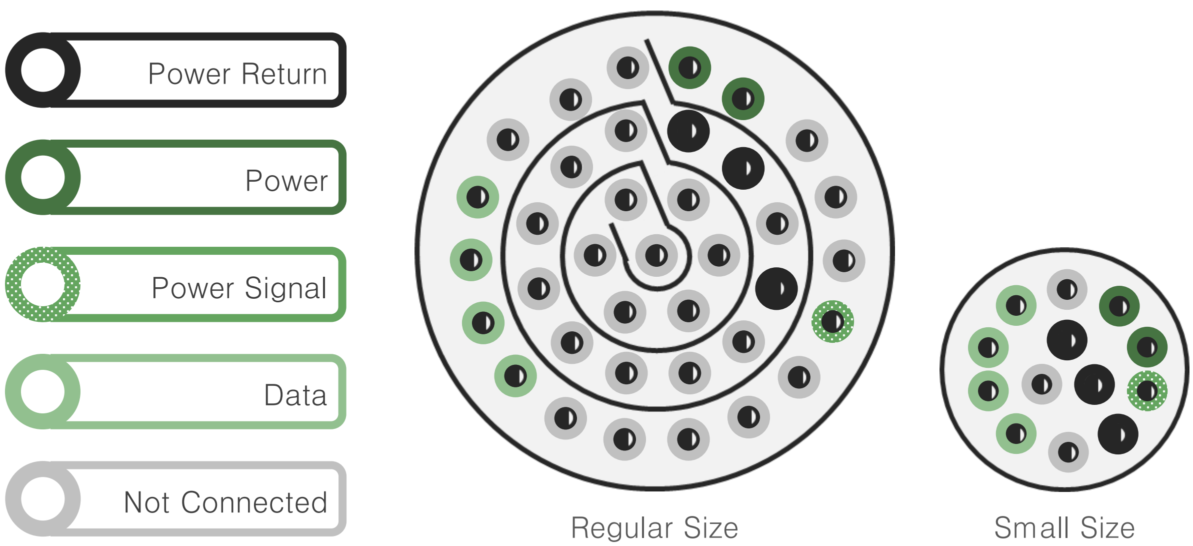
Peregrine provides power and bandwidth services
VIA A SINGLE ELECTRICAL CONNECTOR.

The Standard Electrical Connector (SEC) is a Glenair SuperNine connector of the MIL-DTL-38999 Series III type.

- Static payloads employ a straight plug screw type connector.
- Deployable payloads employ a zero separation force connector.

Please contact Astrobotic for the specific SEC part number for your payload type.

Both the static and deployable connector types are available in a regular and small size, each with a standard pin configuration providing the same contacts as illustrated below.



NOTE: Access to premium laser communication services requires a supplementary optional High-Speed Data Connector (HSDC) for static payloads. Deployable payloads access premium laser communication services through the wireless interface. Please contact Astrobotic for additional information.

RELEASE MECHANISMS

PAYLOADS MAY DEPLOY FROM THE PEREGRINE LUNAR LANDER
in lunar orbit or on the lunar surface.

Deployable payloads require a release mechanism to detach from the lander. Astrobotic does not mandate the implementation of a specific device model. The customer is responsible for the selection, procurement, testing, and integration of the release mechanism they deem most suitable for their payload design in accordance with the Astrobotic guidelines and requirements.

Due to the mission-critical nature of orbital payload deployments prior to landing, Astrobotic requires the use of a proven release mechanism design for lunar orbit deployable payloads such as the following.

- CubeSat payloads use standard CubeSat dispenser models suitable for their size.
- Small satellites use a Mark II Motorized LightBand (MLB) suitable for their size.

For lunar surface deployable payloads, Astrobotic recommends the use of hold-down and release mechanism style devices, but the customer may select the device most suited to the payload design provided that it meets the following requirements.

- Is non-pyrotechnic
- Creates minimal debris
- Imparts no shocks greater than 300 g's on the lander upon actuation
- Is housed within the payload unit

Peregrine provides power services and power release signal services to the SEC interface. The payload customer is responsible for integrating the release mechanism into their payload design such that it correctly interfaces with these provided services and employs the appropriate arm and fire techniques to satisfy Range Safety requirements. Please contact Astrobotic for the latest version of the relevant Range Safety document.

POWER SERVICES

PEREGRINE SUPPORTS PAYLOAD OPERATIONS WITH POWER SERVICES.

M1 Nominal Power Services:
0.5 W per kilogram of payload

M1 Power (Release) Signal Services:
30 W peak power signal for approximately 60 seconds

Peregrine provides nominal power services throughout all phases of the mission except Launch. The power (release) signal services are available only during the Lunar Orbit phase for orbital deployment payloads and during the Surface phase for surface deployment payloads. No power services are provided during spacecraft maneuvers or emergency procedures.

Additional features of the power services interface include the following.

- Regulated and switched 28 ± 5% Vdc power line
- 2.5 W per kilogram of payload peak power available upon request during the Surface phase

Power services are provided through the SEC. Therefore, power services are available only while the payload is attached to the lander. Deployable payloads take full control of their own power generation and consumption following release from the lander.

For additional power needs, please contact Astrobotic.

NOTE: Requested peak power services are scheduled by Astrobotic. Average payload power consumption must remain at the nominal allowance.

DATA SERVICES

PEREGRINE SUPPORTS PAYLOAD OPERATIONS WITH DATA SERVICES.

Wired and Wireless Data Services at

M1 Limited Data Rates:
less than 10 bps per payload

M1 Nominal Data Rates:
20 kbps per kilogram of payload

M1 High-Speed Data Rates:
according to purchase agreement

Peregrine provides wired data services at limited data rates to support "heartbeat" payload data throughout all phases of the mission except Launch. Wireless data services as well as access to nominal and purchased high-speed data rates are available only during the Surface phase. For M1, the nominal data rate is increased to 20 kbps per kilogram from the standard 10 kbps per kilogram. No data services are provided during loss of contact to Earth, spacecraft maneuvers, or emergency procedures.

Additional features of the data services interface include the following.

- Serial RS-422 wired communication using HDLC
- Ethernet high-speed data wired communication using TCP/IP
- 2.4 GHz 802.11n Wi-Fi radio wireless communication using TCP/IP

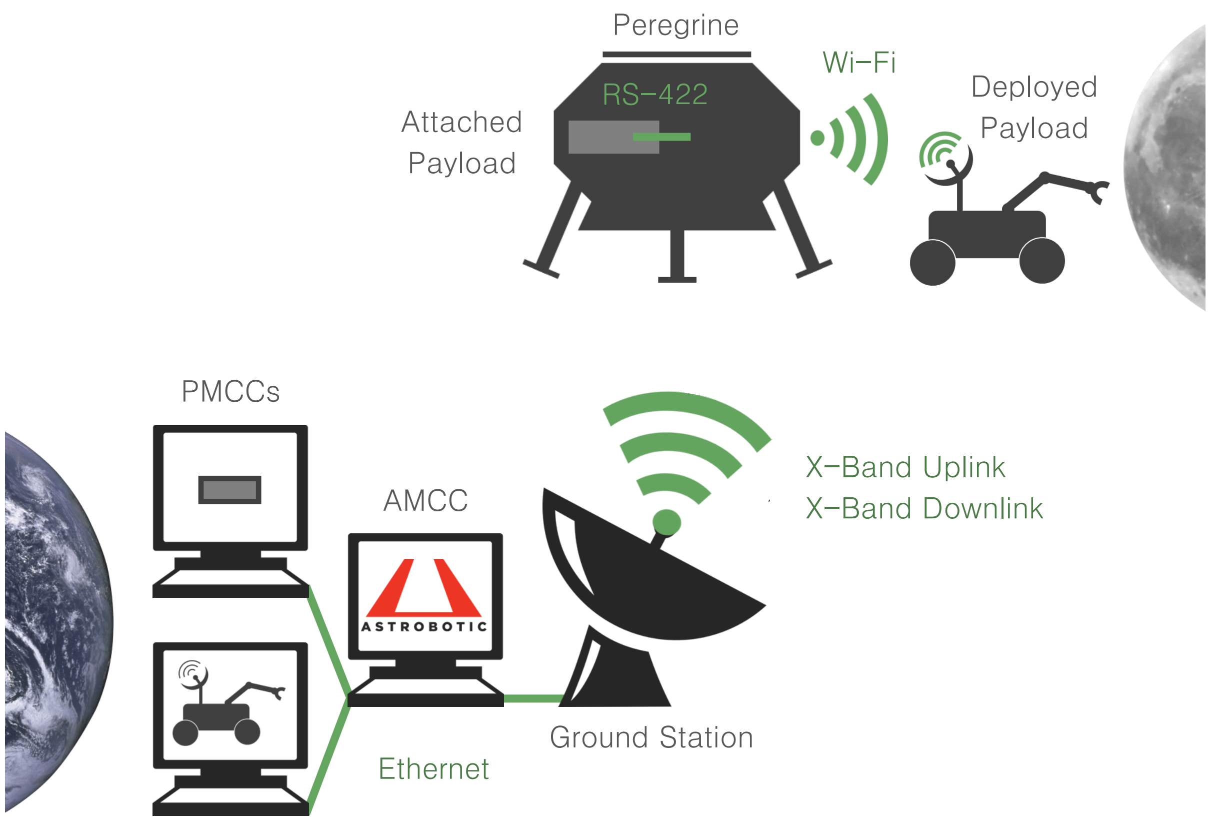
Wired services are provided through the SEC or HSDC. Therefore wired data services are available only while the payload is attached to the lander. Orbit deployable payloads necessitate independent communication connections with Earth and surface deployable payloads must utilize the wireless data services following release from the lander.

Astrobotic is working on providing an increased nominal bandwidth to payloads; for additional data needs, please contact Astrobotic.

COMMUNICATION NETWORK

ASTROBOTIC FACILITATES TRANSPARENT COMMUNICATION
between the customer and their payload.

The Astrobotic Mission Control Center (AMCC) forwards payload telecommands and telemetry between the individual Payload Mission Control Centers (PMCCs) and the ground network provider. Ground stations communicate with Peregrine using X-Band for uplink and downlink. Communication between the lander and payloads is completed via the defined wired and wireless methods.



One-way latency in the connection between the customer and their payload on the Moon is nominally approximately 3 seconds.

NOTE: Premium laser communication services are directed through an alternate communication chain utilizing the Atlas Space Operations laser communications terminal on board the Peregrine Lunar Lander and dedicated ground stations on Earth.

THE ASTROBOTIC MISSION CONTROL CENTER SERVES AS THE DATA HUB providing standardized, transparent, and safe networking to payload customers.

The features, outlined below, make the communication network standardized, transparent, and safe creating a simple and minimally-invasive ground segment interface for payload customer.

- Custom protocols are not imposed on the customer to relay either payload telecommands or telemetry; Astrobotic relies strictly on standardized and easily implementable networking standards.

- Astrobotic transparently delivers payload telecommands and telemetry verbatim without the customer having to consider the different mediums and channels traversed by their data packets. Customer data is not opened or reformatted; packetization, performed by Astrobotic, allows payload data to navigate these different mediums and channels.

- All payload telecommands and telemetry are securely addressed, and the AMCC verifies each packet's meta-data for compliance, ensuring safe transmissions. Customers may implement their own supplementary encryption protocols for increased security, if desired.

The AMCC facilitates remote access for payload customers. Each payload is provided a dedicated station within the AMCC location. The station is outfitted with the appropriate interface to enable effective communication with the AMCC. The customer then connects with their dedicated station via Virtual Private Network (VPN). The customer may implement a custom PMCC application within this structure.

Each payload customer is required to provide an onsite representative at the AMCC during mission operations for rapid response to off-nominal situations. This requirement may be waived for static passive payload types.

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PAYLOAD OPERATIONS

PAYLOAD OPERATIONAL MODES

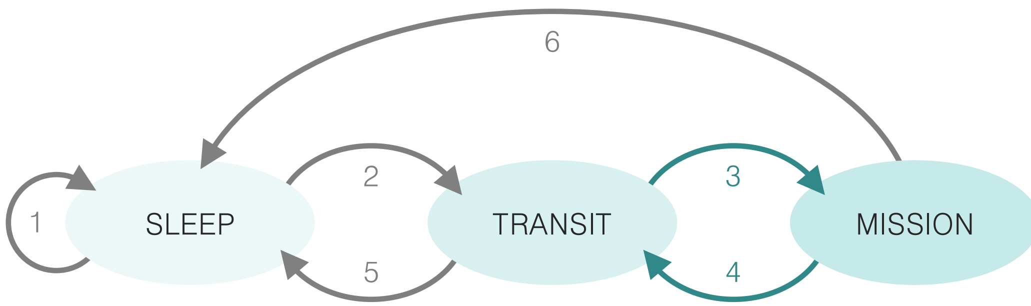
Payloads must provide the following modes of operation to ensure SAFE AND EFFECTIVE COOPERATION WITH THE LANDER.

MODE:	SLEEP	TRANSIT	MISSION	
			Orbital	Surface
LANDER SERVICE AVAILABLE:				
Nominal Power Services	No	Yes	Yes	Yes
Power (Release) Signal Services	No	No	Orbital Only	Surface Only
Wired Data Services	No	At Limited Data Rates	At Limited Data Rates	At Nominal & High–Speed Data Rates
Wireless Data Services	No	No	No	At Nominal & High–Speed Data Rates
ARMING OPERATION PERMITTED:				
Mobile Aspects	No	No	No	Yes
Surface Radios	No	No	No	Yes
Egress	No	No	Orbital Only	Surface Only
APPLICABLE TO PAYLOAD TYPE:				
Static Passive	Yes	No	No	No
Static Active	Yes	Yes	No	Yes
Deployable Passive	Yes	No	Orbital Only	Surface Only
Deployable Active	Yes	Yes	Orbital Only	Surface Only

PAYLOAD OPERATIONAL MODES

Astrobotic monitors payload operational mode transitions to ensure safe operations.

Mode transitions, illustrated by the labeled arrows in the diagram below, are achieved either by the provision or removal of power, shown in grey, or by telecommand, shown in turquoise.



1 The payload remains powered off and in SLEEP mode until provided power by the lander.

2 Once provided power by the lander, the payload boots up in TRANSIT mode where it may operate minimal avionics and monitor health.

3 & 4 Customer command allows the payload to transition between TRANSIT and MISSION mode. Hazardous actions such as egress may be armed and performed in MISSION mode according to the schedule overseen by Astrobotic.

5 & 6 The removal of power to the payload transitions it to SLEEP mode. Payload power is removed during launch, spacecraft maneuvers, emergency procedures, and in order to contain unruly payloads. Astrobotic provides advance notice of such action when possible to allow for safe power down operations of the payload.

NOTE: Transitions 1, 2, 5, and 6, shown in grey, are controlled by Astrobotic while the payload is attached to the lander. Deployable payloads become responsible for their own power generation and management following egress and thus responsible for these transitions.

NOTE: Deployable Passive payloads transition directly from SLEEP to MISSION mode. These payloads are powered up by Astrobotic only once right before egress.

CONCEPT OF OPERATIONS

Astrobotic works with each payload customer
TO ALIGN THEIR PAYLOAD CONCEPT OF OPERATIONS
to the integrated mission concept of operations.

The payload customer should plan only for the permitted payload operations of the available payload operational modes for each mission phase as shown below.

PRE-LAUNCH	LAUNCH	CRUISE	LUNAR ORBIT	SURFACE
SLEEP as required for payload testing	SLEEP as nominal mode of operation	SLEEP during spacecraft maneuvers	SLEEP during spacecraft maneuvers	SLEEP during landing and initialization
TRANSIT as required for payload testing		TRANSIT as nominal mode of operation	TRANSIT as nominal mode of operation	TRANSIT during spacecraft checkout
MISSION as required for payload testing			MISSION for orbital deployment only	MISSION as nominal mode of operation

Pre-Launch phase begins with integration and continues to launch initialization. Launch phase continues until spacecraft separation from the launch vehicle. Cruise phase continues until the first insertion into lunar orbit. Lunar Orbit phase continues until touchdown on the lunar surface, or designated End-Of-Mission (EOM) for purely lunar orbit delivery missions. Surface phase begins with touchdown on the lunar surface and continues until the designated EOM.

NOTE: Spacecraft maneuvers typically last no more than 15 minutes except the initial detumble at the beginning of the Cruise phase and the descent to the lunar surface at the end of the Lunar Orbit phase. The duration of the Launch phase depends on the specific mission.

1

SYSTEM CHECK

Following a successful touchdown, the Peregrine Lunar Lander transitions to surface operational mode. The craft establishes communication with Earth and performs a system check. As a precaution, excess helium is vented.

2

PAYLOAD CHECK

Peregrine powers up payloads and facilitates diagnostic system checks as well as software and firmware updates by the payloads as they prepare for mission operations.

3

MISSION SUPPORT

Peregrine provides power and data services to payloads for the nominal lunar surface operations period. Payload egress procedures and other hazardous operations are permitted at this time. For Mission One (M1), the nominal duration of lunar surface operations is approximately eight Earth days.

4

END OF MISSION

Prior to designated EOM, Peregrine transitions to hibernation mode and discontinues all payload services. For M1, the onset of lunar night signifies the end of mission; future missions may support an extended mission with lunar night survival for the lander and payloads.

EGRESS PROCEDURE

ASTROBOTIC SCHEDULES THE EGRESS PROCEDURES OF PAYLOADS to ensure safe and efficient operations for the lander and payloads.

Each deployable payload is given a time window to perform deployment and any payload-specific preparations. Astrobotic informs the payload customer once their egress window is open. The following compliant arm and fire techniques must be implemented in the payload design.

- ARM — The payload deployment is armed by means of a specific customer command to transition the payload to Mission mode and internally distribute power services to the release mechanism.
- FIRE — The power (release) signal serves as the fire command. Upon customer request, Astrobotic provides the defined power signal to the Standard Electrical Connector (SEC) interface.
- Peregrine maintains power authority over attached payloads and can, by the removal of nominal power services, render payload release mechanism devices inert.

A sample egress procedure guideline is provided below.

- The payload charges its batteries with power provided by Peregrine. The payload customer performs any necessary system diagnostic checks and firmware or software updates for the payload.
- The payload transitions to Mission mode, allowing the use of internal power systems and, for surface payloads, onboard radios. A diagnostic check may be performed by the payload customer to verify internal power sources and wireless communication.
- Upon request of the payload customer, Astrobotic commands Peregrine to send the power (release) signal to the payload. Peregrine-provided power and wired communication are discontinued to the SEC.

NOTE: For orbit deployable payloads, Astrobotic may interface directly with the release mechanism and apply the ARM and FIRE signals with customer confirmation of payload readiness. If desired, this also allows the payload to deploy in an unpowered state until separation from the lander.

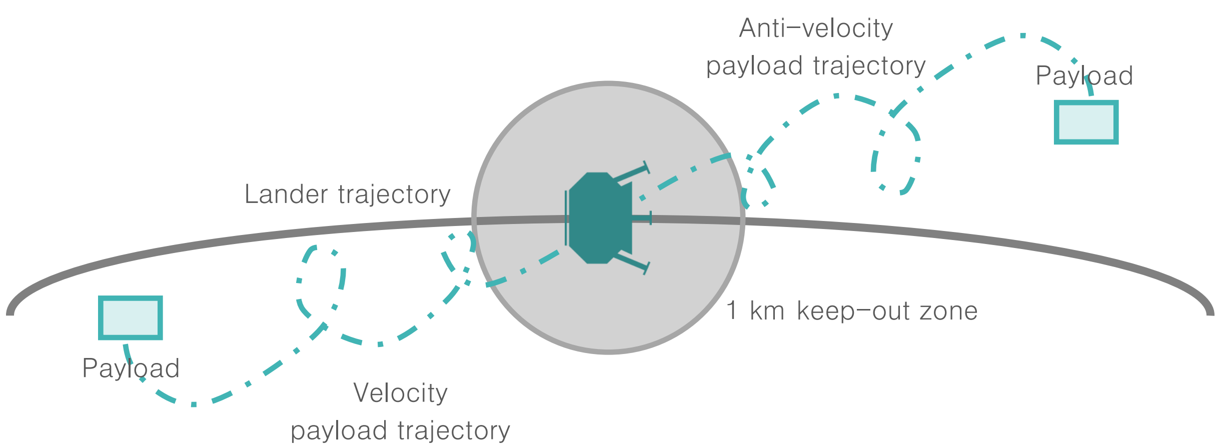
Astrobotic provides the following forms of confirmation of payload separation.

- Confirmation of provision of the power (release) signal to the SEC interface.
- Visual confirmation of payload separation using the lander status cameras.

Following deployment, all payloads are responsible for their own power management. Orbit deployable payloads also need to ensure separate communications with Earth. Please contact Astrobotic for recommendations on an independent power and communications concept of operations for payloads.

Lunar orbit deployments introduce distinct complexities, which require additional precautions to be enacted.

Payloads are deployed in either the velocity or anti-velocity direction; this results in orbital dynamics that appear to loop back relative to the lander orbit. Astrobotic requires that these loop backs occur outside of a 1 km radius keep-out zone as shown in the diagram below. To be compliant, payloads must provide at least 0.04 m/s velocity relative to the lander upon separation.



Peregrine nominally holds in several different lunar orbits during the Lunar Orbit phase; not all lunar orbits are available for orbital payload deployment as some may be less stable than others. Astrobotic identifies the available and preferred lunar orbits for payload customer orbital deployments for each mission. To ensure safe lunar orbit operations for all payloads, orbital deployments may occur at slightly varied altitudes for each payload.

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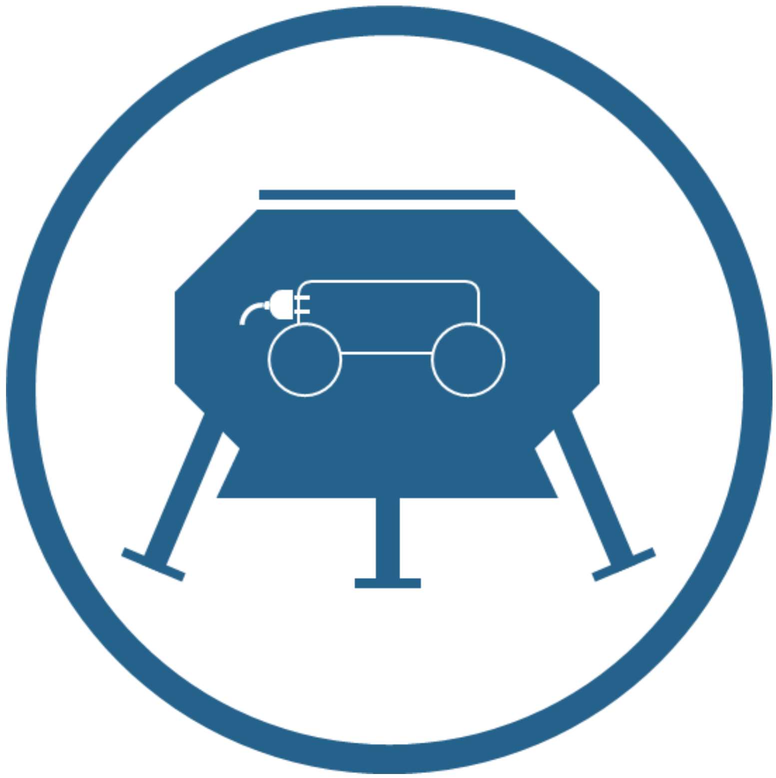
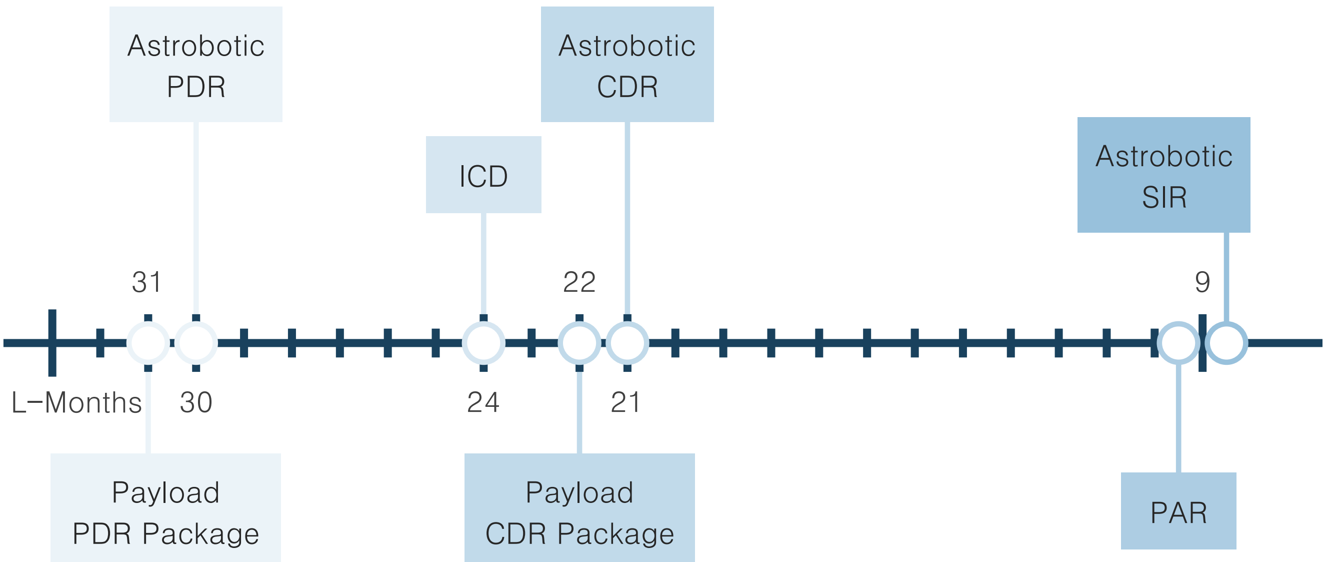


PAYLOAD INTEGRATION

PRE-INTEGRATION SCHEDULE

Following contract signature, a payload manager works with the customer to DEVELOP A PAYLOAD SCHEDULE AND ALIGN IT TO THE MISSION SCHEDULE.

The diagram below provides a high-level overview of the mission schedule. Astrobotic recognizes that a full set of formal milestone reviews is not necessary for every payload and works with the customer to appropriately tailor the schedule to the payload type and complexity.



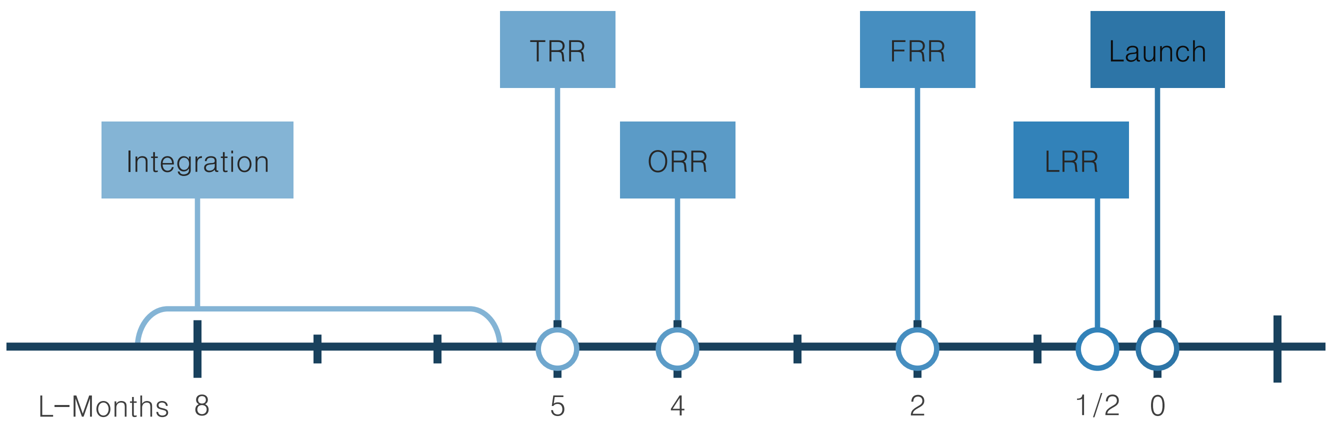
PAR takes place at the Astrobotic integration facility and is led by the Astrobotic payload management team; it is mandatory for every payload. The relevant payload deliverables for the PAR must be submitted to Astrobotic prior to SIR at L-9 months. The physical testing aspect of the PAR can be completed separately prior to Integration such that the customer can plan to deliver their flight configuration payload for acceptance and integration between 9 and 5 months prior to launch. Leniency in the deadline is possible for less complex payloads utilizing fully standard interfaces.

Payload milestones prior to PAR are customer-led at facilities of the customer's choosing. For major milestones, as agreed upon during schedule development, an Astrobotic representative must be included in the review panel. This flexibility in payload schedule is achieved by means of payload deliverables packages that ensure Astrobotic milestone reviews are informed by the latest payload specifications.

POST-INTEGRATION SCHEDULE

Following Integration, Astrobotic takes ownership of the payload and supervises the integrated lander throughout the campaign of readiness reviews prior to launch.

The Astrobotic integration facility hosts Integration and TRR; subsequent events take place at the launch service provider's facilities. Astrobotic schedules the integration of individual payloads within the time span illustrated below based on payload complexity and readiness as well as overall accessibility requirements.



A payload customer representative should plan to be present for post-integration milestones to sign-off on payload readiness to proceed past the milestone. A payload representative must be physically present in the Astrobotic Mission Control Center during launch.

The ORR includes an end-to-end system test. The payload customer must provide a connection to their flight-configuration Payload Mission Control Center for this review.

NOTE: Timeline dates are L-minus in months, i.e., months before Launch

PDR	—	Preliminary Design Review	TRR	—	Test Readiness Review
ICD	—	Interface Control Document	ORR	—	Operational Readiness Review
CDR	—	Critical Design Review	FRR	—	Flight Readiness Review
PAR	—	Payload Acceptance Review	LRR	—	Launch Readiness Review
SIR	—	System Integration Review			

PAYLOAD ACCEPTANCE REVIEW

The Payload Acceptance Review determines whether the payload is
FIT FOR INTEGRATION WITH THE PEREGRINE LUNAR LANDER.

The PAR is nominally scheduled no later than 9 months prior to launch. Additional flexibility can be afforded to less complex payloads utilizing fully standard interfaces and services.

The PAR nominally takes place at the Astrobotic integration facility located at the company headquarters in Pittsburgh, PA and is led by the Astrobotic payload management team.

The customer delivers the fully-assembled flight-configuration payload to Astrobotic. To be considered safe to integrate with Peregrine, the payload must complete all verification and validation activities without failures. The final agenda for the review is tailored to the specific payload type and complexity.

The PAR consists of two stages with distinct verification and validation activities.

Initial Assessment

Astrobotic reviews payload-provided materials such as analyses of compliance with external standards and regulations as well as tolerance of the expected mission environments. Astrobotic also verifies the physical payload mass, dimensions, and center of gravity.

Interface Simulation Testing

The payload is connected to spacecraft structural and electrical simulators to verify interface compatibility and safe payload operations.

Upon request, the two stages of the PAR may be completed separately. The customer must provide sufficient material to allow for the completion of the Initial Assessment stage prior to Astrobotic's SIR at L-9 months. The Interface Simulation Testing stage can be completed prior to the payload's scheduled Integration between L-9 and L-5 months, allowing for a later delivery of the flight-configuration payload to the Astrobotic integration facility.

The Payload Integration Plan (PIP) provides further details on the PAR schedule and procedures. Please contact Astrobotic for the latest version of this document.

Following a successful Payload Acceptance Review,
ASTROBOTIC INTEGRATES THE PAYLOAD WITH THE PEREGRINE LUNAR LANDER.

Integration is nominally scheduled between 9 and 5 months prior to launch. Additional flexibility can be afforded to less complex payloads utilizing fully standard interfaces and services. The integration schedule developed by Astrobotic also takes overall accessibility requirements for integration and testing into account.

Integration nominally takes place at the Astrobotic integration facility located at the company headquarters in Pittsburgh, PA and is led by the Astrobotic payload management team.

Astrobotic integrates the accepted payload with the Peregrine Lunar Lander. The integration specialists follow the payload-specific guidelines for integration provided by each payload customer in a Payload Operations Plan (POP). Additional verification and validation activities are undertaken to confirm a successful integration between payload and lander. The final agenda is tailored to the specific payload type and complexity.

The integration assessment consists of two stages with distinct verification and validation activities.

Individual Payload Integration Assessment

The compatibility of the flight payload and spacecraft interfaces as well as safe payload operations are verified following integration with the lander.

Integrated Spacecraft Testing

The fully integrated lander system is functionally tested and several environmental tests such as thermal and vibration are performed.

The PIP provides further details on the Integration schedule and procedures. Please contact Astrobotic for the latest version of this document.

NOTE: The customer may request or require additional time between the PAR and Integration. Astrobotic reserves the right to repeat aspects of the PAR to ensure any changes to the payload in that time did not impact Astrobotic's ability to accept the payload for integration.

PAYLOAD REQUIREMENTS

THE ASTROBOTIC PAYLOAD REQUIREMENTS (APRs) are defined to be minimally obtrusive to payloads while ensuring a safe and successful mission.

APR-1	The Payload System shall comply with all Astrobotic mission constraints.

Astrobotic mission constraints are overarching requirements on the lander that inform more specific requirements on the payload, e.g., Astrobotic has an overall mission payload mass capacity, and the payload has a requirement for its specific allotment of that overall mass capacity. The same concept also applies to the lander's overall constraints on volume and center of gravity offset.

APR-2	The Payload System shall be compatible with all Spacecraft-provided interfaces.

Astrobotic and the payload customer agree on the final interfaces between the lander and the payload in an ICD signed by both parties. This document informs requirements on the lander to provide these interfaces and requirements on the payload to accept the provided interfaces.

APR-3	The Payload System shall comply with all Astrobotic operational safety regulations.

The integrated lander must be in compliance with several standards and regulations that govern safety; these include Range Safety requirements for ground operations, Planetary Protection guidelines for limiting contamination of planetary bodies such as the Moon, Orbital Debris Mitigation for limiting potential debris deposited in Earth and lunar orbit, and FAA regulations for communication frequency allocations. Please contact Astrobotic for copies of any relevant standards and regulations.

NOTE: The standard interfaces and operations are defined to be APR-compliant. The Interface Definition Document contains a design guide to easily meet these requirements. Nonstandard payloads may need to perform additional analyses or testing to demonstrate compliance.

INTEGRATION WORKING GROUPS

Astrobotic provides guidance throughout the payload design process
TO ENSURE COMPLIANCE AND A SUCCESSFUL INTEGRATION WITH THE LANDER.

The Payload Customer Service Program sets up several check-in points as well as opportunities for technical exchanges to ensure development of the payload with compliance in mind. Integration Working Groups (IWGs) serve as the primary mechanism by which Astrobotic maintains technical dialogue with the customer.

Astrobotic also evaluates the payload deliverables packages produced by the customer for Astrobotic's PDR and CDR and as part of the customer's PAR. To support customer development of the required deliverables, Astrobotic provides formatting guides, templates, and additional IWG sessions. Depending on payload complexity and design stage, the packages may include the following deliverables.

- Payload Mission Schedule
- Payload Concept of Operations
- Payload Operations Plan
- Payload Design Specification
- Payload Hazard Analysis
- Payload Failure Modes Analysis
- Payload Risk Assessment
- Payload System Requirements

Additionally, Astrobotic participates in formal payload mission milestone reviews and performs analyses as defined in the Payload Services Agreement (PSA) to inform compliant payload design. These analyses examine aspects such as appropriate clearance upon payload separation from the lander and the integrated thermal design.

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GLOSSARY

GLOSSARY OF UNITS

Unit	Significance
bps	bits per second [data rate]
dB	decibel [sound pressure level referenced to 20×10^{-6} Pa]
°	degree [angle, latitude, longitude]
°C	degree Celsius [temperature]
g	Earth gravitational acceleration [9.81 m/s^2]
Hz	Hertz [frequency]
kg	kilogram [mass]
m	meter [length]
N	Newton [force]
Pa	Pascal [pressure]
%	percent [part of whole]
rad	rad [absorbed radiation dose]
s	second [time]
$	United States dollars [currency]
V (dc)	Volt (direct current) [voltage]
W	Watt [power]

GLOSSARY OF TERMS

Term	Significance
A(D)CS	Attitude (Determination and) Control System
AMCC	Astrobotic Mission Control Center
APR	Astrobotic Payload Requirement
CPU	Central Processing Unit
EDAC	Error Detection And Correction
EMI	Electro-Magnetic Interference
EOM	End-Of-Mission
FPGA	Field-Programmable Gate Array
GNC	Guidance, Navigation, and Control
GTO	Geosynchronous Transfer Orbit
HDLC	High-level Data Link Control
HSDC	High-Speed Data Connector
IAU	Integrated Avionics Unit
IWG	Integration Working Group
LEO	Low Earth Orbit
LO(I)	Lunar Orbit (Insertion)
M1	Mission One
MMH	MonoMethylHydrazine
MON-25	Mixed Oxides of Nitrogen - 25% nitric oxide
PMCC	Payload Mission Control Center
SEC	Standard Electrical Connector
SEU	Single Event Upset
SSO	Sun-Synchronous Orbit
TCP/IP	Transmission Control Protocol / Internet Protocol
TLI	Trans-Lunar Injection
VPN	Virtual Private Network

Document	Significance
ICD	Interface Control Document The document defines the final spacecraft-payload interfaces and is signed by Astrobotic and the customer; the IDD is used as a template for this document.
IDD	Interface Definition Document The document defines the standard spacecraft-payload interfaces.
PIP	Payload Integration Plan The document details the Payload Acceptance Review and Integration schedules as well as verification and validation procedures.
POP	Payload Operations Plan The document details the appropriate handling of the payload system; it is produced by the payload customer and guides Astrobotic operations.
PSA	Payload Services Agreement The document serves as the initial contract between Astrobotic and the payload customer; it defines programmatic expectations.
PUG	Payload User's Guide The document provides a high-level overview of the vehicle, mission, as well as the interfaces and services provided to payloads. (this document)
SOW	Statement of Work The document is outlines the responsibilities of Astrobotic and the payload customer; it is part of the PSA.

GLOSSARY OF MILESTONES

Milestone	Significance
CDR	Critical Design Review The review focuses on the final design of the spacecraft/payload and determines readiness to proceed with fabrication and testing.
FRR	Flight Readiness Review The review focuses on the integrated launch vehicle and determines readiness to proceed with launch operations.
LRR	Launch Readiness Review The review focuses on the integrated launch vehicle and determines readiness to fuel the vehicle and proceed with launch operations.
ORR	Operational Readiness Review The review focuses on the ground segment and determines end-to-end mission operations readiness.
PAR	Payload Acceptance Review The review focuses on the flight-model payload and determines readiness to integrate with the spacecraft.
PDR	Preliminary Design Review The review focuses on the preliminary design of the spacecraft/payload and determines a feasible design solution to meet mission requirements exists.
SIR	System Integration Review The review focuses on the flight spacecraft/payload systems and determines readiness to proceed with assembly and testing.
TRR	Test Readiness Review The review focuses on the integrated spacecraft and determines readiness to proceed with testing.

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CONTACT US

CONTACT INFORMATION

ASTROBOTIC PROVIDES SEVERAL POINTS OF CONTACT
to address the varied needs of payload customers.

- Our Business Development team is available to current and potential customers for questions on the products and services we provide.
- Our Customer Relations team is available to signed customers for general programmatic inquiries.
- Our Payload Management team is available to signed customers for any mission-specific or technical needs.

Email: payload@astrobotic.com

To begin your payload journey, please contact us and we will be happy to direct you to the appropriate Astrobotic team member.

We can also be reached using the following contact information:

ASTROBOTIC

2515 Liberty Avenue

Pittsburgh, PA 15222

Phone | 412.682.3282

www.astrobotic.com

contact@astrobotic.com

QUESTIONNAIRE

FOR A MORE PERSONALIZED EXPERIENCE,
please include your specific payload needs when you contact us.

Payload Name

Payload Point of Contact: Name, Email/Phone

Payload Mission Objectives

Payload Preferred Launch Date

Payload Delivery Location: Lunar Destination [Orbit/Surface], Additional Parameters (e.g., orbital altitude, orbital inclination, surface region, proximity to a lunar surface feature)

Payload Mass

Payload Dimensions: Length × Width × Height, Description of Shape

Payload Power Needs: Nominal Power [Yes/No], Power (Release) Signal [Yes/No], Additional Needs

Payload Communications Needs: Wired Communication [Yes/No], Wireless Communication [Yes/No], Nominal Surface Bandwidth [Yes/No], Limited Flight Bandwidth [Yes/No], Additional Needs

Payload Concept of Operations

Additional Requirements

NOTE: You can also share your payload mission details with us through our website: Configure Your Mission.

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