PAYLOAD USER'S GUIDE

ispace

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1 INTRODUCTION

1.1 Who we are

ispace, inc. (ispace) is a private lunar exploration company with a vision to extend human presence beyond Earth. The company has over 100 staff from 20 different countries with offices in Japan (HQ), Luxembourg and the United States. Further, ispace has signed agreements with the Japan Aerospace Exploration Agency (JAXA), the Government of Luxembourg, and with the National Aeronautics and Space Administration (NASA) through their Commercial Lunar Payload Services (CLPS) program. In 2017, ispace raised nearly $95 million (USD) in Series A funding—the largest on record in Japan and among the largest in the global space industry. Previously, ispace managed Team HAKUTO, one of the 5 finalists in the Google Lunar XPRIZE competition.

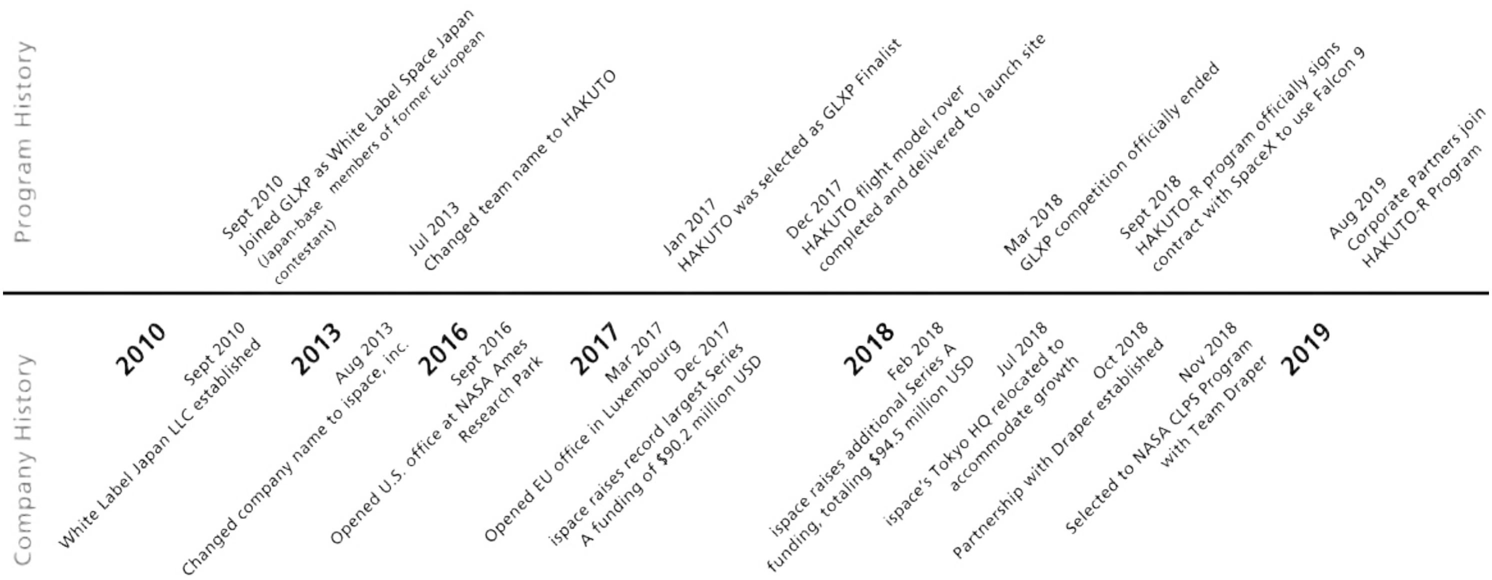
1.2 History

In 2008, a group of scientists and engineers began to build a team in the Netherlands with the goal of entering the Google Lunar XPRIZE (GLXP) competition. The GLXP was designed to encourage private teams and companies to send technology to the surface of the Moon, travel a distance of 500 m, and transmit high-definition video back to Earth.

As of May 2009, the team, known then as White Label Space (WLS), officially registered in the GLXP. In addition to the headquarters in the Netherlands, WLS set up a Japanese subsidiary, led by Takeshi Hakamada. After a few years of development, White Label Space officially moved their operations to Japan in January of 2013, and five months later, officially changed its GLXP team name to HAKUTO.

Over the past few years, ispace has expanded from Japan to include two subsidiary locations: in Luxembourg City, Luxembourg and at the NASA Ames Research Park in California, USA.

Having started with only a handful of full-time team members, ispace has grown to over 100 employees, and has received support in the past from over 50 pro-bono volunteers.



1.3 Vision

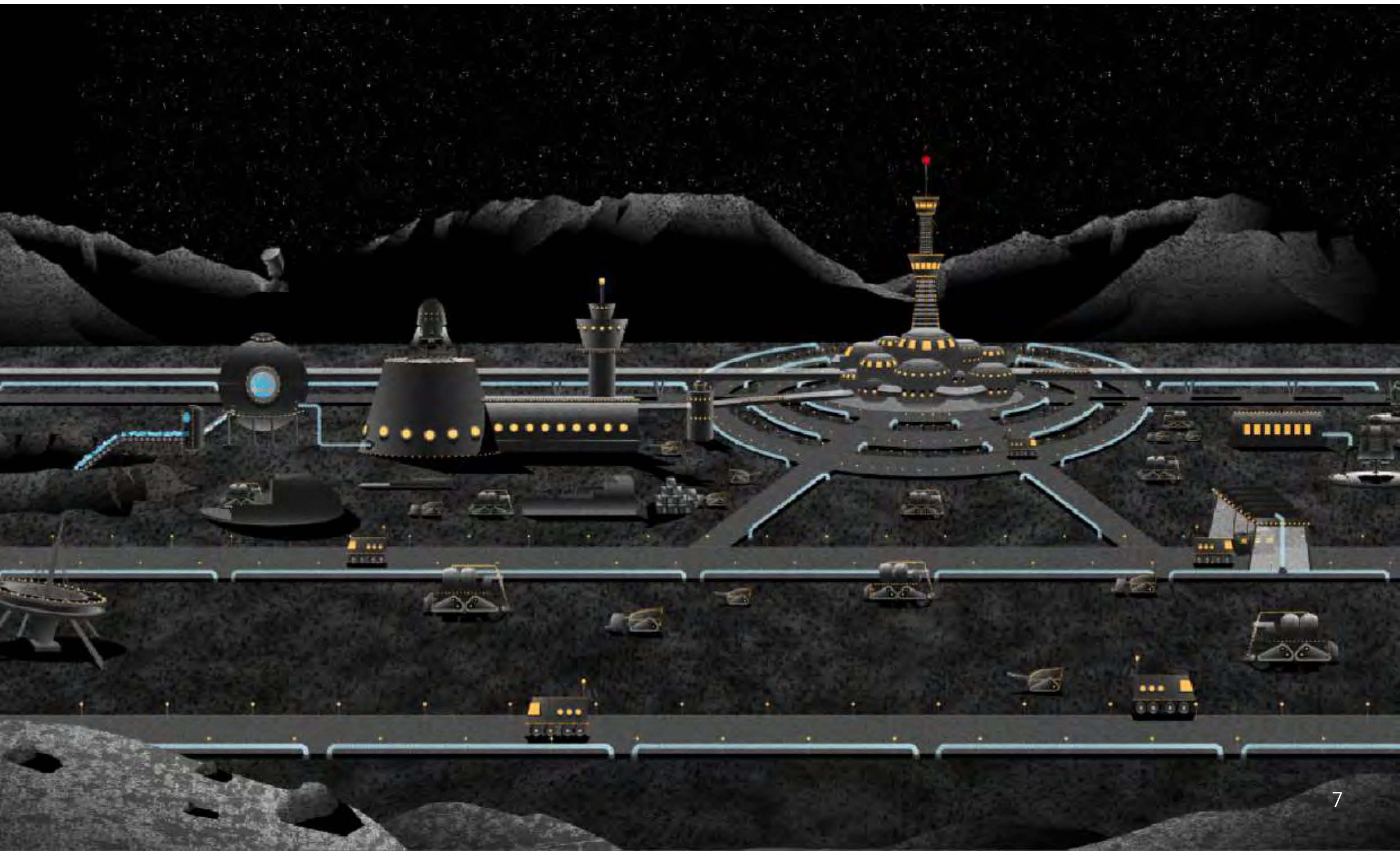
Expand our planet. Expand our future.

ispace's motto encompasses its vision: to develop the technologies necessary for establishing a permanent human presence in space. To this end, ispace has a three-staged approach to lunar exploration and the development of a permanent human settlement on the Moon.

The first step is technology demonstration, whereby ispace's landers and rovers will be deployed, tested, and validated in situ on the Moon. This will be achieved by 2021.

The second step is exploration and prospecting. In this stage, envisioned for the mid-2020s, ispace will develop fully-fledged exploration and prospecting campaigns to evaluate where to establish its first space resource utilisation operation, while continuing to offer lunar transportation and delivery services.

The third and final step is to deploy in-house developed technologies to use lunar resources to enable humanity to live and work on the Moon and beyond.



1.4 Missions

“HAKUTO-R” is the Program Name for ispace’s first two Lunar missions (Mission 1 & Mission 2). Mission 1 will perform a soft landing near Lacus Mortis in 2021. In 2023, Mission 2 will perform a soft landing and the deployment of a rover to explore the lunar surface. For both missions, ispace has secured launch contracts as secondary payloads on SpaceX’s Falcon 9 rocket.

"HAKUTO" means "white rabbit" in Japanese. Based on legendary folklore in Japan, it is said that a white rabbit lives on the Moon. This was the inspiration for the name of Team HAKUTO, one of the 5 finalists in the Google Lunar XPRIZE competition—a race to accomplish the first private lunar exploration. Managed by ispace, supported by sponsors and a large passionate crew of volunteers, HAKUTO competed in the race for the greater part of the past decade. Ultimately, there was no winner in the competition. However, six months after the competition ended, ispace brought back the "HAKUTO" name as the Program Name for its first two lunar missions. Thus, the "R" stands for "Reboot" in the spirit of re-energizing our motivation and drive toward our goal.

The HAKUTO-R program is not only the world’s first commercial lunar exploration program, but it is also a vehicle for companies on Earth to access new business opportunities on the Moon. Companies have the opportunity to leverage our missions for R&D and promotion of their lunar business endeavors.

1.5 Missions partners

ispace has a corporate partnership program for its 2 first missions. This program enables ispace to benefit from the expertise and technological support of its partners, and the partners benefit by being involved in an exciting and highly publicized mission. Further, the partners are provided with an optional opportunity to demonstrate their technology on a real Lunar mission.

HAKUTO-R Corporate Partners

JAPAN AIRLINES

Japan Airlines Corporation

Japan Airlines (JAL), Japan's flagship airline, is providing the HAKUTO-R Program with a facility near Narita International Airport for the assembly of the Lunar Lander. JAL also provides technical and logistical support and services, ranging from welding to the shipping of lander components by air to the launch site.

NGK Spark Plug Co., Ltd.

NGK Spark Plug manufactures spark plugs, as well as ceramic products.
The company is conducting research and development into solid-state battery technology, and will fly a prototype as a payload on HAKUTO-R's Mission 1 in 2021. The ultimate goal is to develop a sustainable energy storage solution for industries operating on the Moon.

Mitsui Sumitomo Insurance (MS&AD Insurance Group Holdings)

Mitsui Sumitomo Insurance, part of the MS&AD Insurance Group, will leverage the HAKUTO-R Program to co-develop the world's first Lunar insurance product with ispace. Learning from the costs, risks, challenges, and timeline of the HAKUTO-R Program, Mitsui Sumitomo will be best equipped to appropriately insure the burgeoning Lunar industry, as well as to mitigate the risk for new entrants.

CITIZEN

Citizen Watch Co.

Citizen, an electronics company primarily known for its watches, will apply its proprietary Super Titanium™ surface-hardening treatment to the titanium components used in the HAKUTO-R Lunar Lander and Lunar Rover. Combined with a diamond-like carbon coating, the treatment will not only strengthen the titanium components of the spacecraft, but it will provide a smooth and durable solid lubricant, which allows for reliable operation of the spacecraft by mitigating corrosion and other challenges brought on by the harsh environments of space.

SUZUKI

Suzuki Motor Corporation

Suzuki, a multinational automaker, will support the development of the shock absorption system, known as the "crush core", for the legs of the HAKUTO-R Lunar Lander during testing and simulation and informing on the design for a successful landing.

Sumitomo Corporation

Sumitomo Corporation

Sumitomo Corporation, a 100-year old Japanese general trading company and one of the world's largest general trading companies, has partnered with the HAKUTO-R Program as it sets its sights on the next frontier for its business: the commercial space industry, including the development of industry on the Moon. Sumitomo Corporation will promote collaboration among several industry stakeholders across various fields to encourage growth in the Lunar industry.

Takasago Thermal Engineering Co. Ltd.

Takasago Thermal Engineering Co. Ltd., Japan's largest company specializing in heating, ventilation and air conditioning (HVAC), aims to utilize ispace's lunar lander to send an experimental payload to the Moon in 2023—on HAKUTO-R's second mission—targeting to conduct the first-ever water-splitting experiment on the Moon.

1.6 What we offer

The following is a qualitative overview of the standard services, with quantitative details provided in the subsequent sections:

» **Delivery to Lunar Orbit**
Payload is deployed from the ispace lander into lunar orbit.

» **Delivery of Static Payloads to Lunar Surface**
Payload is integrated within the lander and delivered to the lunar surface. The payload is mounted statically and is not deployed.

» **Delivery of Deployable Payloads to Lunar Surface**
Payload is integrated inside the lander, delivered to the lunar surface, and deployed from the lander to the surface.

» **Delivery of Rover-Mounted Payloads to Lunar Surface**
Payload is integrated inside a rover, delivered to the lunar surface, and operated as the rover moves on the surface.

» **Consulting**
ispace can provide additional consultancy services for payload design and validation for space readiness.

» **Rover Bus**
ispace offers a standard rover bus that can accommodate several payloads simultaneously. The bus can be reconfigured rapidly for a customer's specific payloads or mission requirements. Assembly, testing and operation of the rover can be done from ispace's control room or at the customer's chosen location.

All services can be tailored to specific missions. ispace offers shared payload space in its missions as well as dedicated missions, as specified by the customer.

1.6.1 LANDER/ROVER CAPABILITIES

ispace's lander has a baseline payload mass capacity of:

- Up to 60 kg in lunar orbit
- Up to 30 kg to the lunar surface

Within this mass capacity, up to two ispace rovers can be delivered to the surface, each capable of carrying up to 3.5 kg of payload.

Any combination of orbital, static and mobile payloads can be supported within the available payload volumetric and mass budgets.

Orbital Payload
60 kg

Rover Payload
3.5 kg per Rover

Lander Payload
30 kg

The following table shows the general combined capability of the lander and rover:

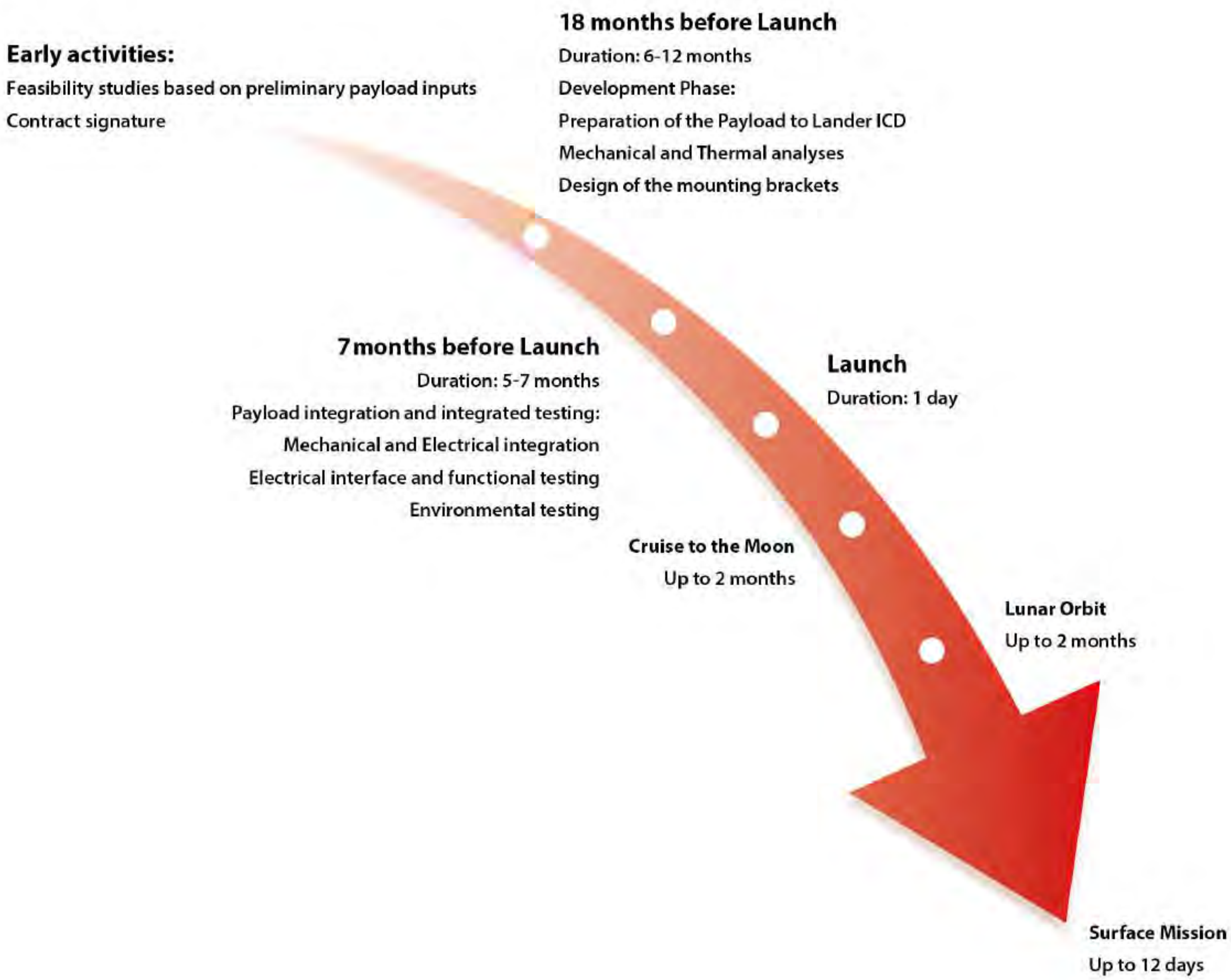
PAYLOAD DELIVERY	To lunar orbit: 60 kg To lunar surface: 30 kg To lunar surface on rover: 3.5 kg Configurations can be adapted depending on customer needs. Lander equipped with deployment mechanism,
POWER	On lander: 3.0 W/kg, 28 VDC unregulated, 12 V, 5 V regulated On rover: 1.0 W/kg
COMMUNICATIONS	Rates during surface operations: » 50 kbps per kg of payload for downlink Rates for check-out during cruise: » 2 kbps per kg of payload for downlink » X band for lander-Earth uplink and downlink » Wi-Fi and sub-Ghz communications between mobile payloads and lander
DATA STORAGE	100 MB/kg
THERMAL CONTROL	Payload bays maintained between -10°C and 40°C during cruise and surface operations
FLIGHT DURATION	Maximum 4 months
ROVER MOBILITY	Up to 0.1 m/s, up to 500 m from landing site
SURFACE OPERATIONS	The duration of nominal surface operations is 12 days (sunlit). ispace provides lander and payload mission operations services for the duration of the mission

Additional data rate and power are available on demand, please contact us for more information.

1.6.2 PAYLOAD CUSTOMER EXPERIENCE

At the start of the contract, a customer officer will be assigned to coordinate milestones, interfaces and information sharing.

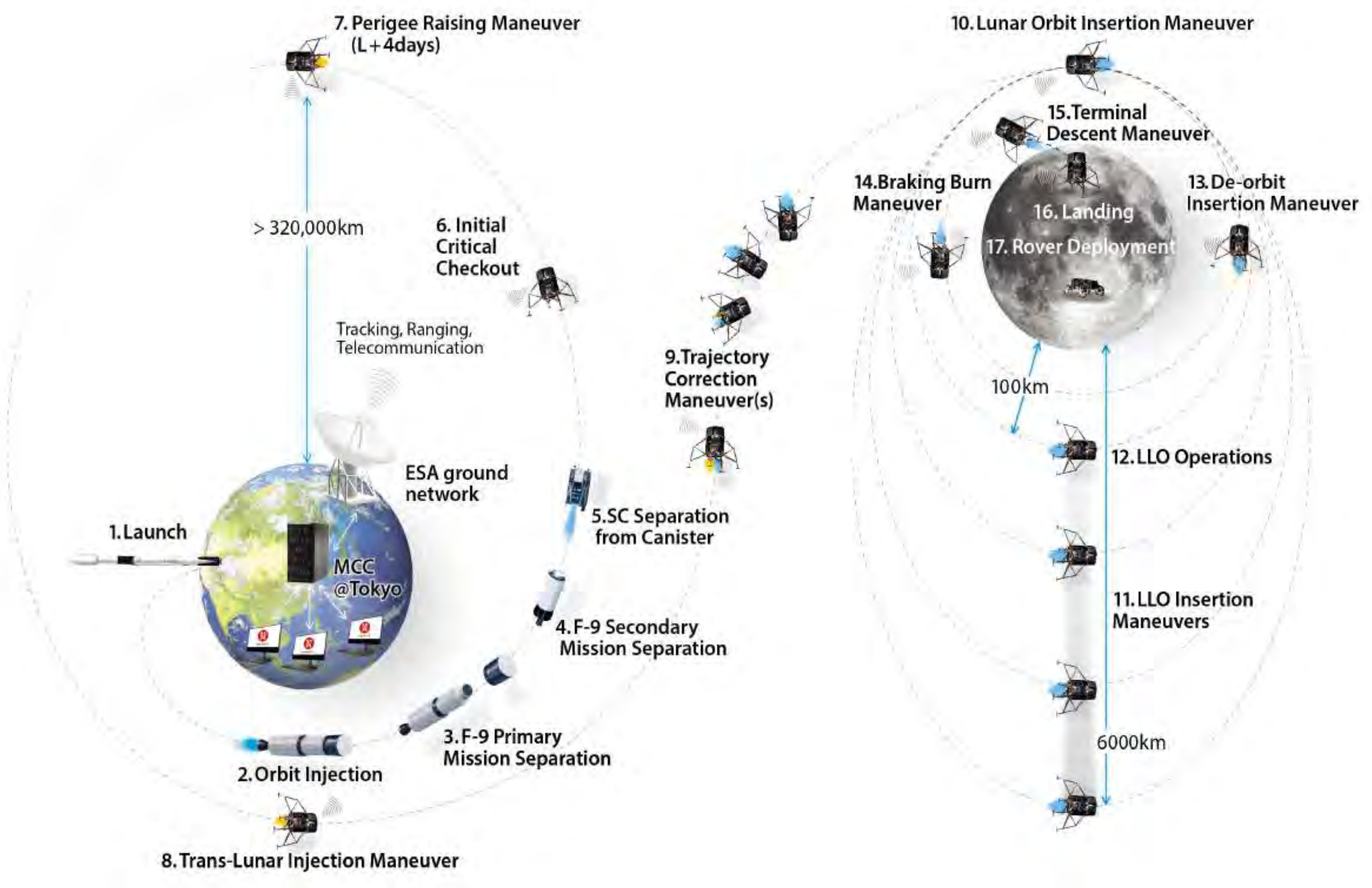
The following presents a high-level overview of the mission development phases that will be followed following the start of the contract:



Details are provided in sections 5 and 6.

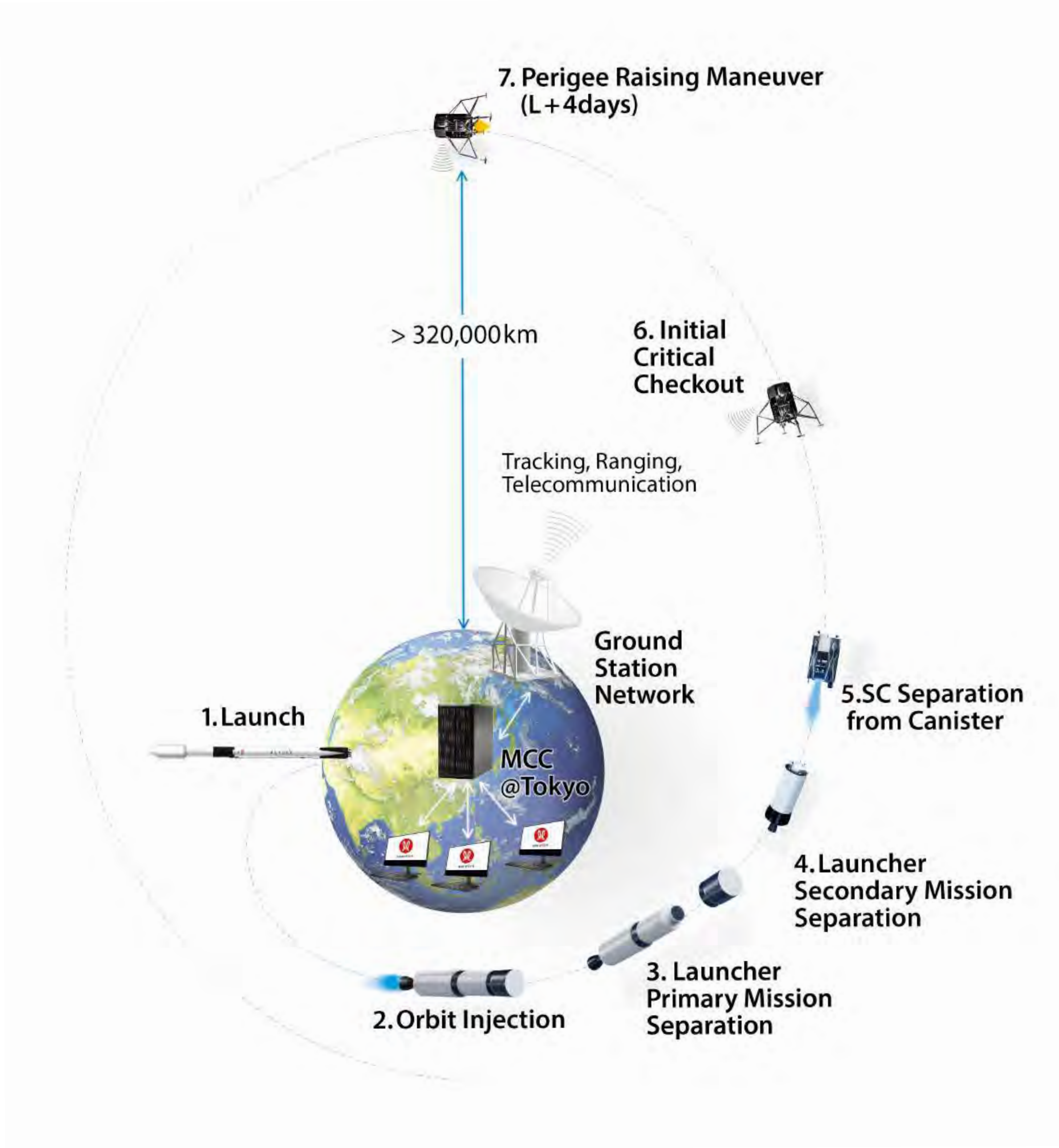
2

MISSION PLAN

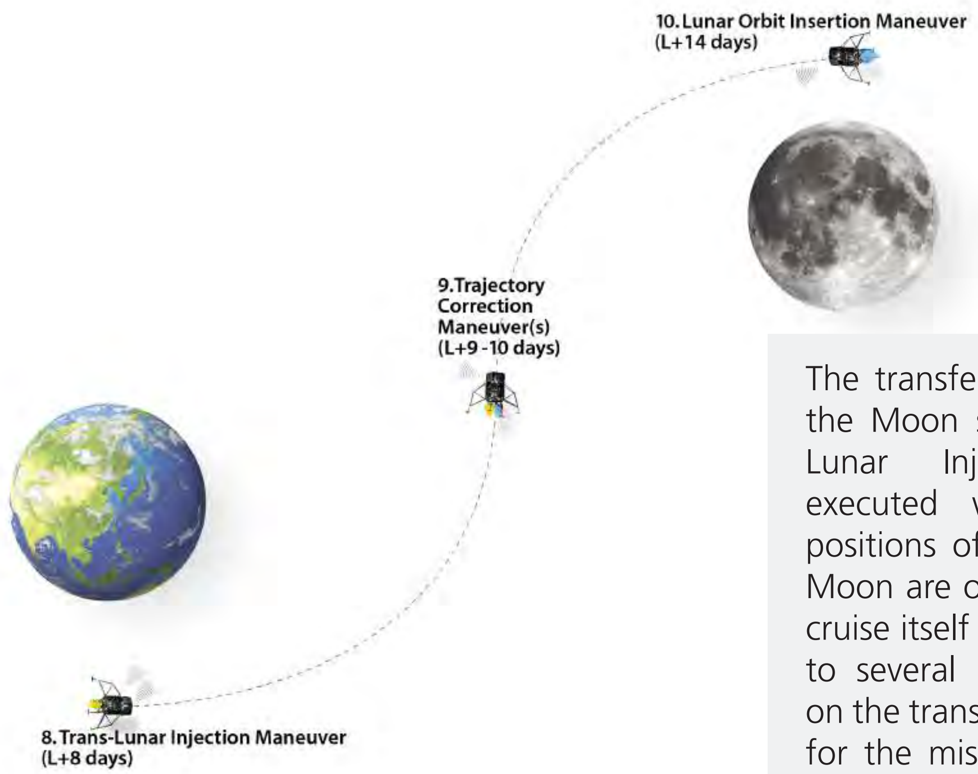


2.1 FLIGHT

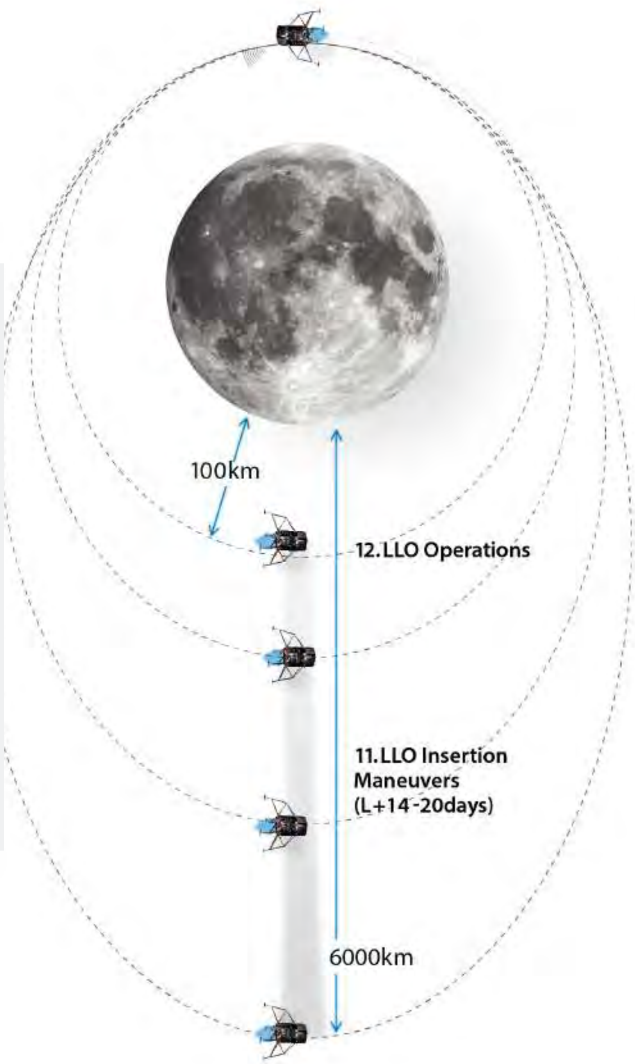
The flight phase starts after with a separation from the launch vehicle in a baseline super-synchronous Earth orbit. The ispace lander is manifested as a secondary payload on the launch vehicle, and as such, will be the last element separated following the primary payload and the secondary payload canister.



After ground stations on Earth establish contact with the lander, the Mission Operations Center (MOC) will immediately perform an initial check-out of the lander to ensure its readiness for the upcoming mission. When this check-out is completed successfully, an orbital maneuver will be performed to raise the perigee and prepare for transfer to the Moon.

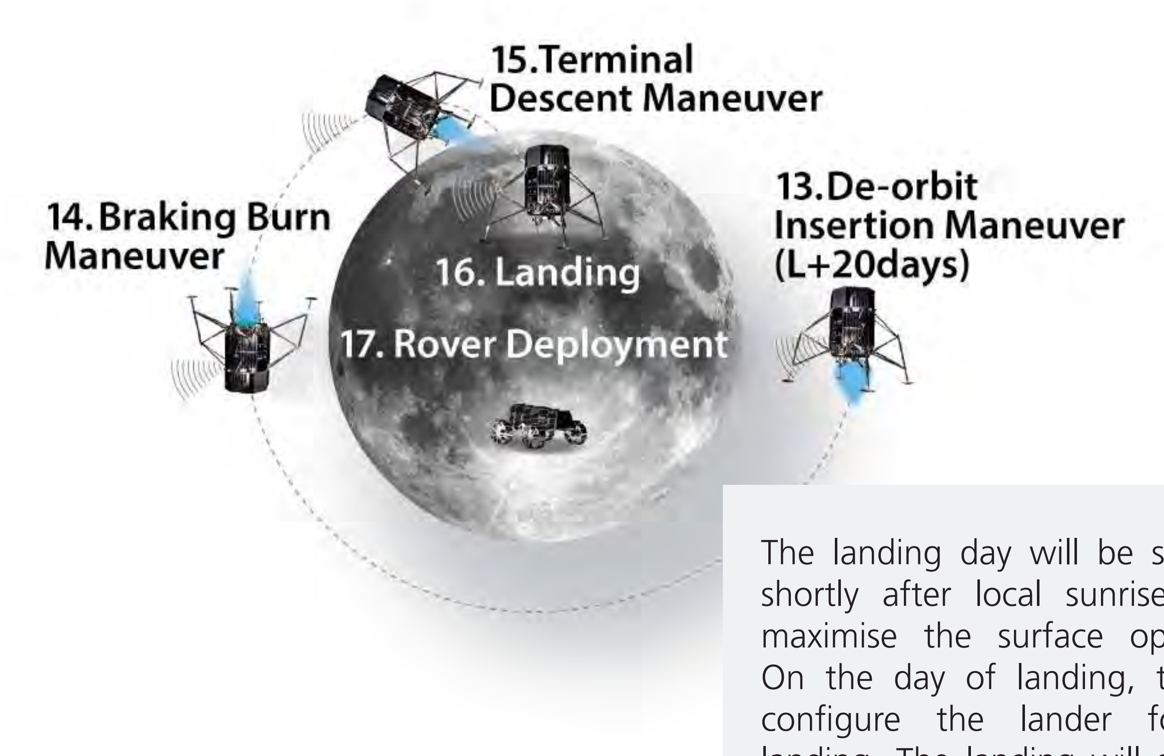


The transfer from the Earth to the Moon starts with a Trans-Lunar Injection maneuver, executed when the relative positions of the Earth and the Moon are optimal. The transfer cruise itself takes from five days to several months, depending on the transfer strategy selected for the mission (direct transfer or low-energy transfer).



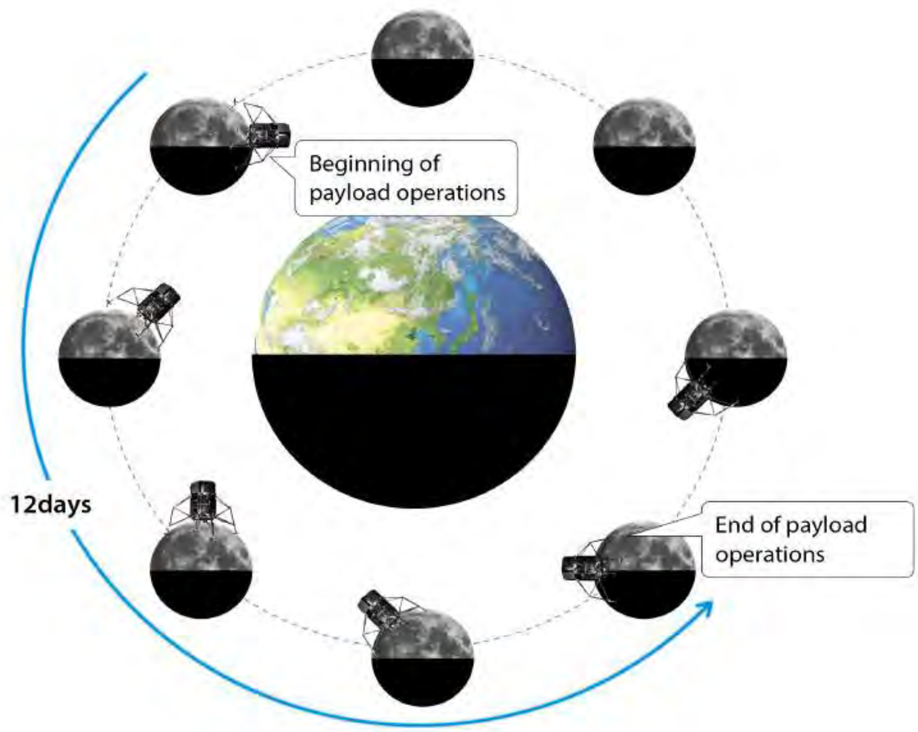
Arriving at the Moon, the MOC will command a Lunar Orbit Insertion maneuver. This maneuver allows the lander to be captured by the Moon's gravity. Following this, the lander will undergo an adjustment of its Lunar orbit.This adjustment consists of a series of maneuvers to lower the orbit to about 100 km above the lunar surface. This relatively stable Low Lunar Orbit (LLO) will allow orbital operations for about a month, and synchronisation of the orbit above the selected landing site for up to a month as well.

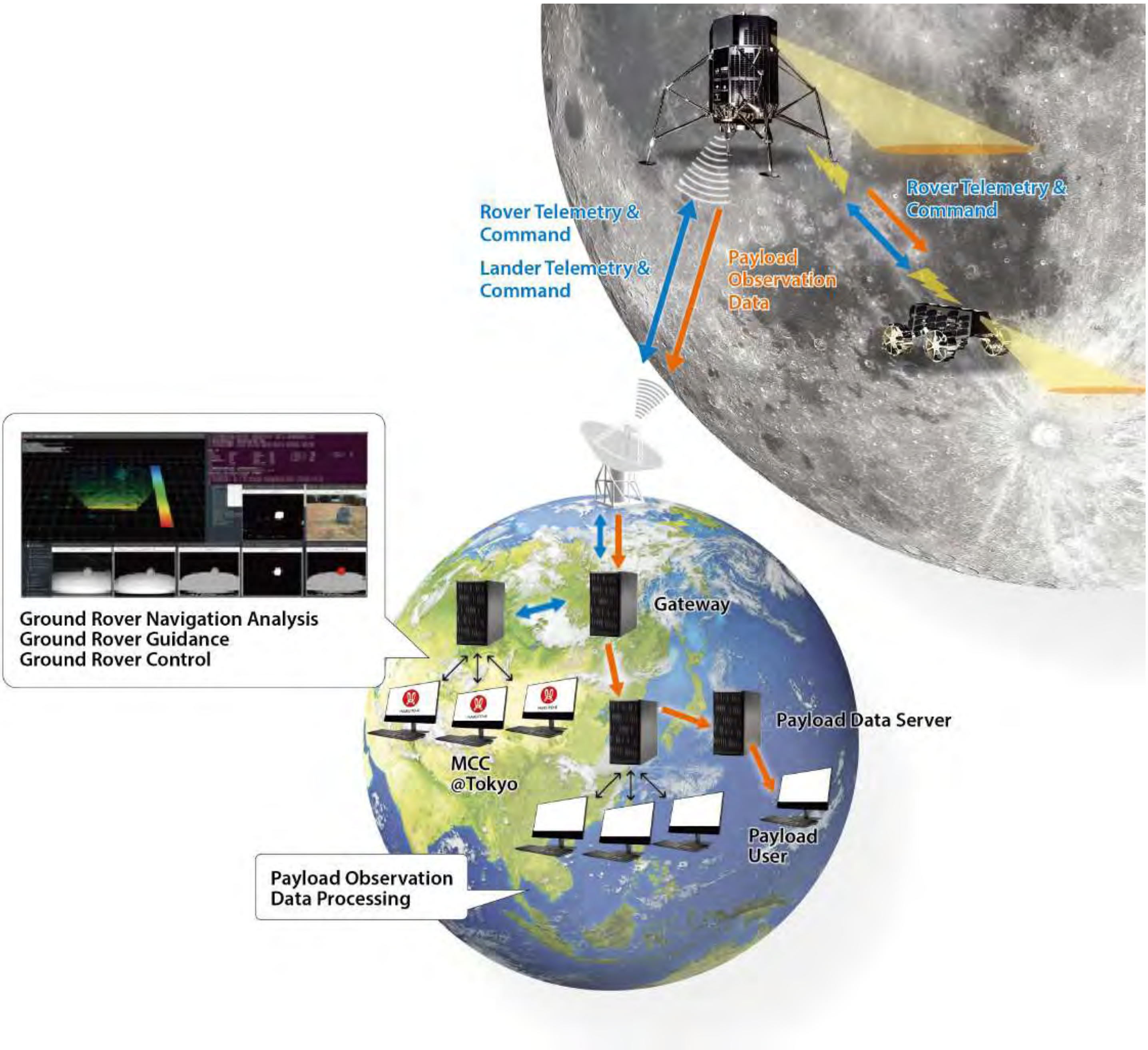
2.1 LANDING



The landing day will be selected to be shortly after local sunrise in order to maximise the surface operation time. On the day of landing, the MOC will configure the lander for automatic landing. The landing will start by a De-orbit Insertion Maneuver, followed a few minutes later by a braking burn, to slow down above the selected landing site, and finally a terminal descent reaching a low downwards vertical speed.

The surface operations will be limited to the local day duration, from local sunrise to local sunset.

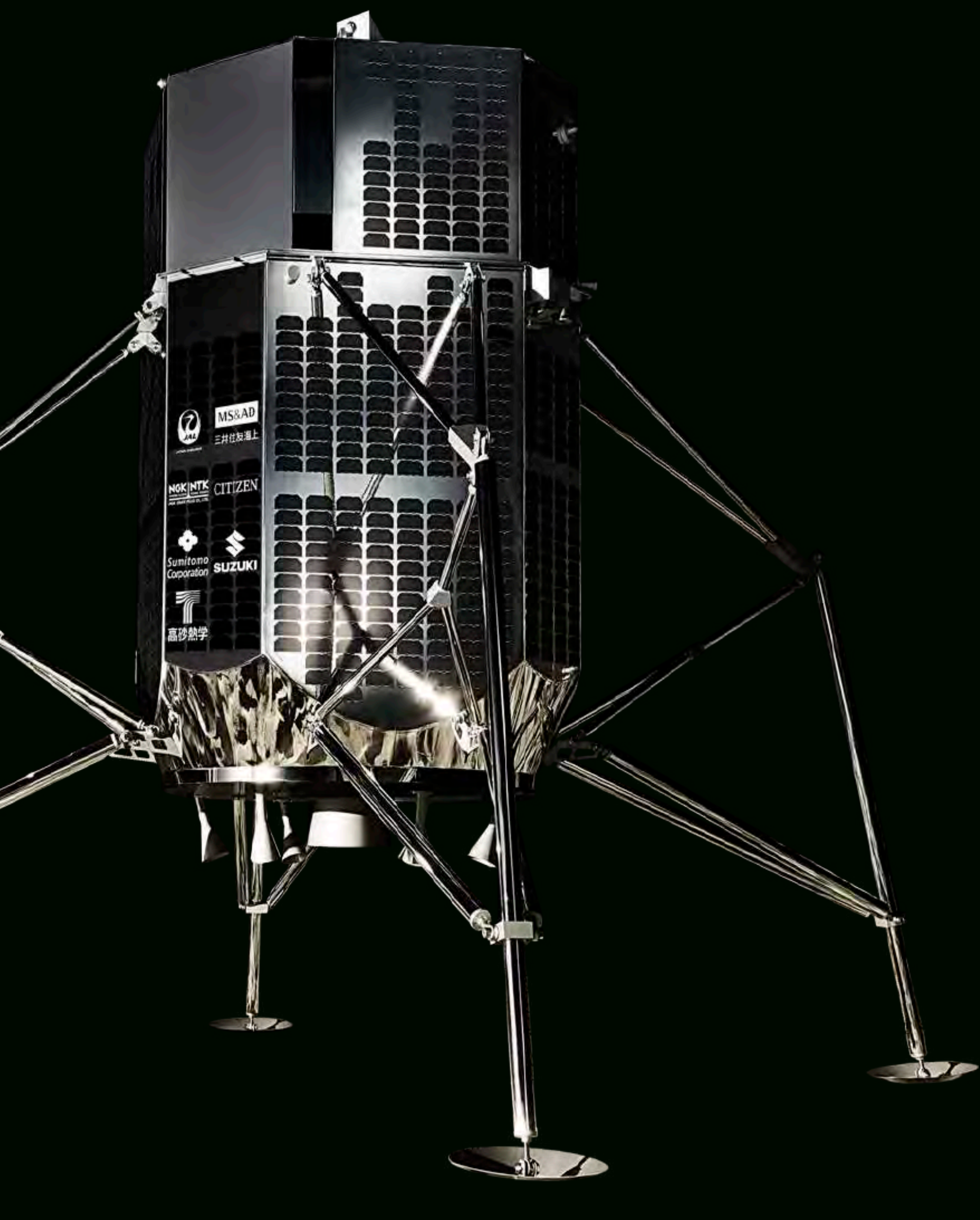




After a check-out, the MOC will command power on of the payloads, deployment of the deployable payloads, and enable data relay functionality to allow the Payload Operations Center (POC) to command and control the payloads.

3

TECHNOLOGY DESCRIPTION



3.1 LANDER

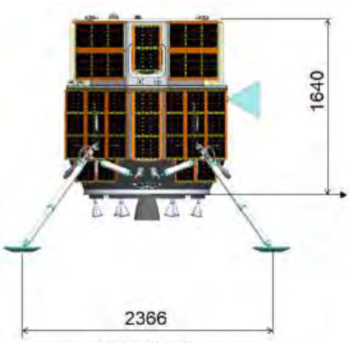
3.1.1 SYSTEM DESCRIPTION

The ispace lander is a compact and single-stage spacecraft with deployable landing gear, released in Earth orbit by the launcher. It goes to Lunar orbit with a sequence of orbital maneuvers. From Lunar orbit, it autonomously performs a soft landing to a selected landing site. It switches on customer payloads, can deploy them for direct contact with the lunar surface (if applicable), and relays the data back to Earth.

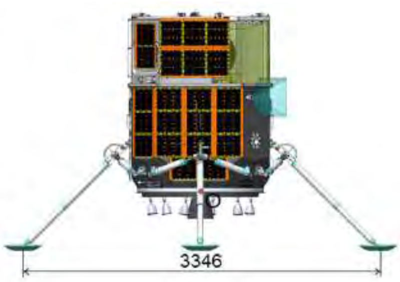
3.1.2 MASS

The lander's dry mass without payloads is about 300 kg, with a wet mass about 1000 kg.

3.1.3 DIMENSIONS



Side View

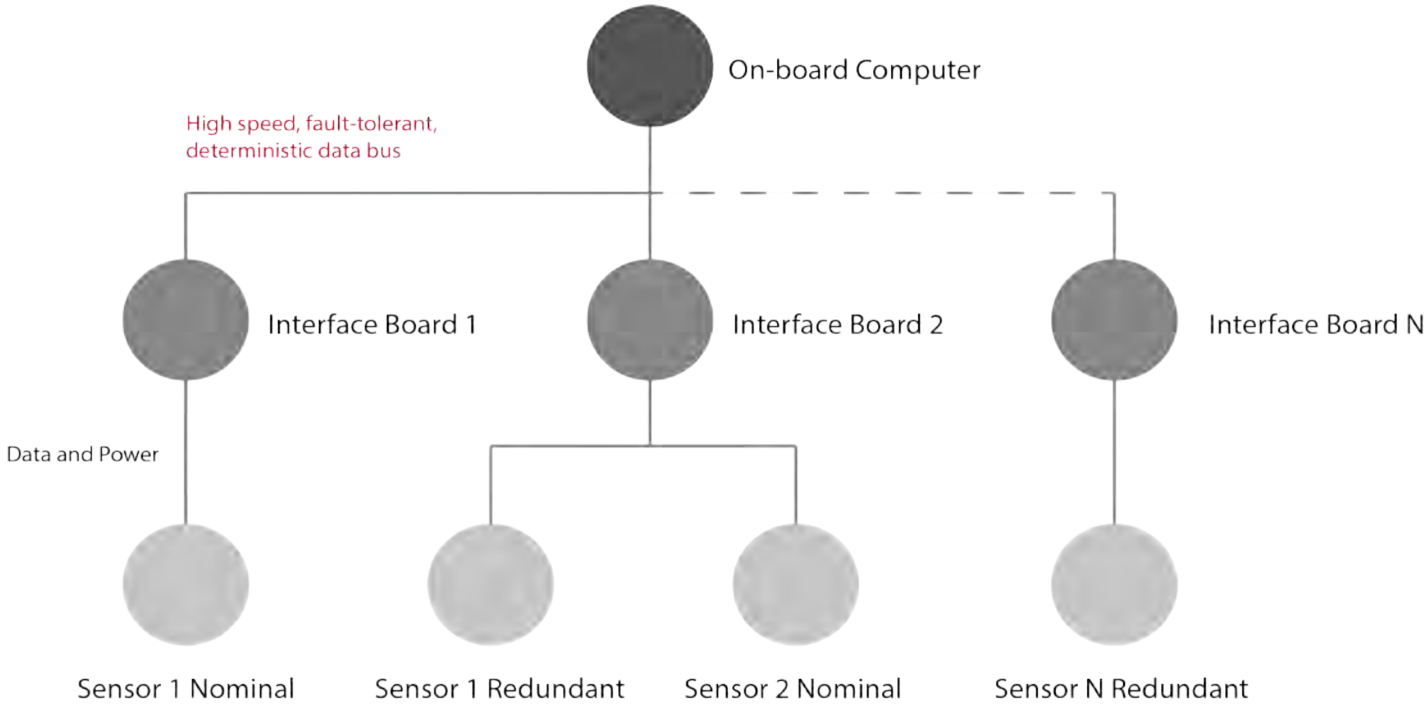


Side View (45deg)

The Lander has a compact structure of 1.5 m in diameter by 1.8 m in height in launch configuration. After the deployment of its 4 landing legs, the lander footprint has a diameter of more than 3 m to ensure maximum stability.

3.1.4 AVIONICS

The lander uses a distributed architecture based on a central on-board computer providing the bulk of the computing resources. This computer is connected to a set of interface boards through a high-bandwidth real-time and fault-tolerant bus located close to the sensors and actuators they interface with.



The computer and interface boards are developed in-house with performance and fault-tolerance in mind. Redundant sensors are distributed to different interface boards, and cross-strapping is ensured by the fault-tolerant bus. To achieve the raw performance, reliability and low cost targets, ispace has selected electronic components and sensors from space-grade commercial off-the-shelf (COTS) components, industrial-grade COTS, and custom-built units with additional environmental testing and validation (radiation, thermal vacuum, vibration).

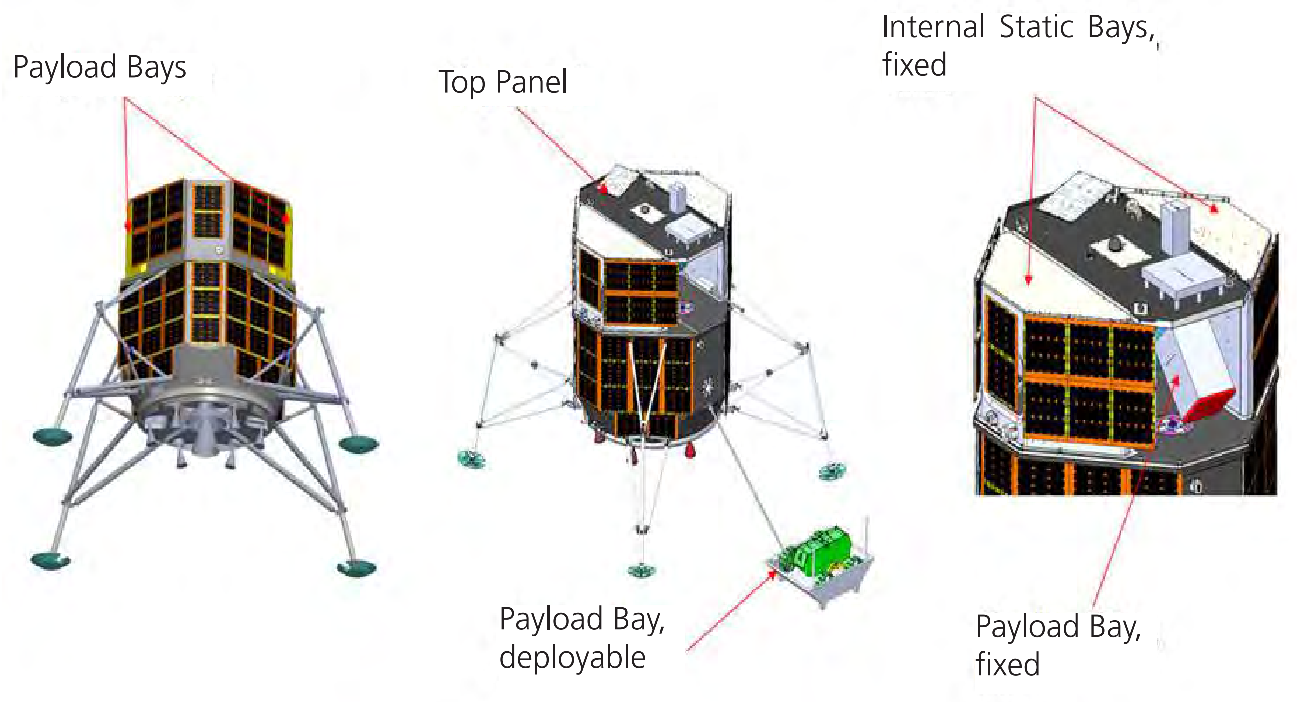
3.1.5 POWER

The lander uses a custom power conditioning and distribution unit based on components with space heritage to handle the solar array, battery management, and switching. It provides an unregulated 28 V power bus to all loads. For units that require lower supply voltages, this function is performed by the same interface boards mentioned in the previous section.

The Solar Array consists of several body-mounted panels around the lander structure, to provide the whole lander with more than 350 W of peak power during sun-pointing flight phases flight, as well as sufficient power for Payloads after landing on the lunar surface at any latitude and with any orientation with respect to the sun direction.

A space-qualified Li-Ion battery is used:
- during eclipse phases around the Earth or the Moon,
- during Maneuver phases where the sun illumination cannot be guaranteed,
- during flight or surface phases when the payload needs temporarily exceed the available solar power

3.1.6 PAYLOAD ACCOMODATION



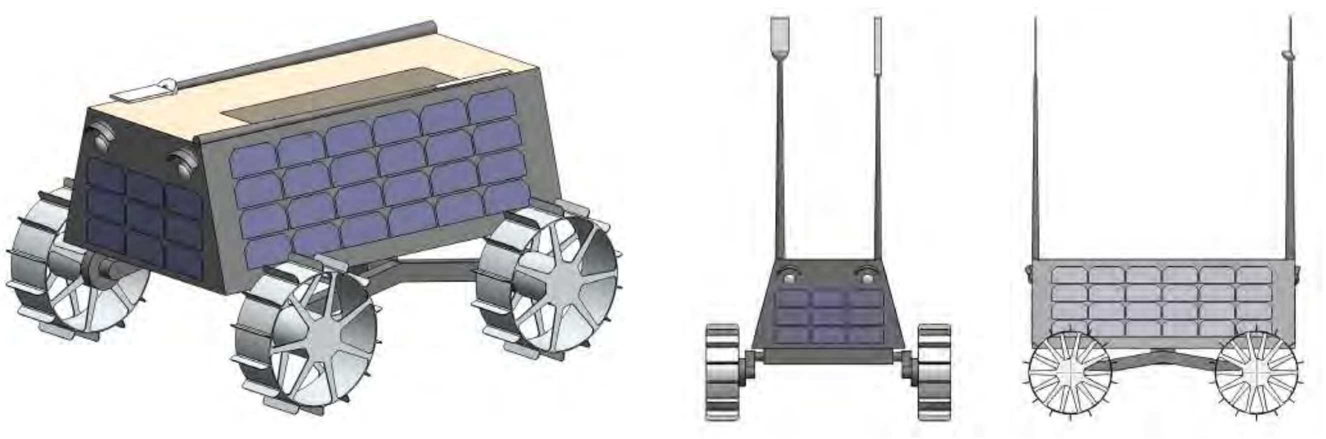
The lander can accommodate Payloads in a variety of locations:

» In the payload bays, fixed, with or without protection from outside
» In the payload bays, deployable, mounted on a payload deployment gear for physical access to the lunar surface
» In the lander's internal static bays, fixed, next to the lander's equipment
» Outside on the top panel, fixed
» Details with available Payload envelopes are provided in section 4.1.3. Other custom mounting locations can be studied with ispace.

3.2 ROVER

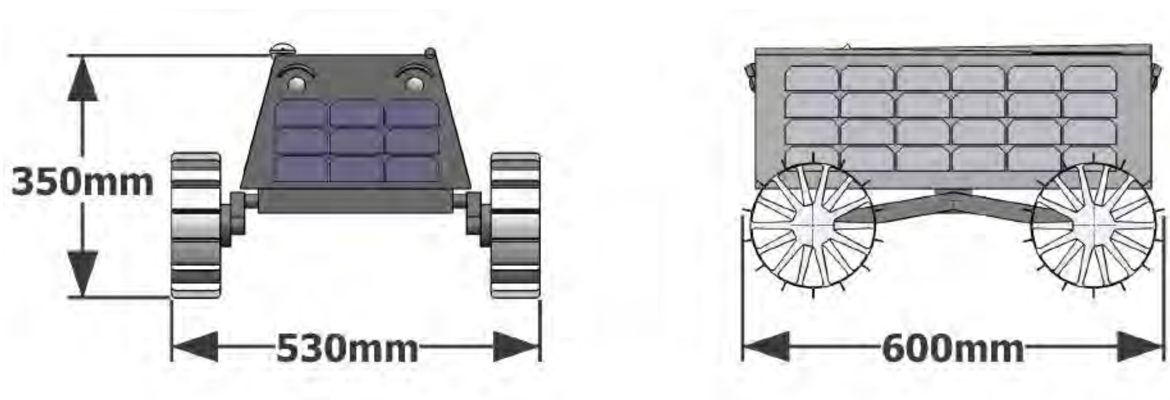
3.2.1 SYSTEM DESCRIPTION

ispace's rover is low-mass, low-power and high-performance, able to cover more than 2 km in one lunar day. Its design is universal in nature, consisting of a "rover bus" comprising standard structural, thermal management and mobility systems with basic functionality for imaging, near-real-time video and near-real-time teleoperation. Depending on customer needs, this can be made up of several payloads from different customers, or from a tailored suite of payloads for a dedicated, customer-specific mission.



3.2.2 DIMENSIONS

The following dimensions are maximum rover dimensions, and subject to change based on specific mission requirements.



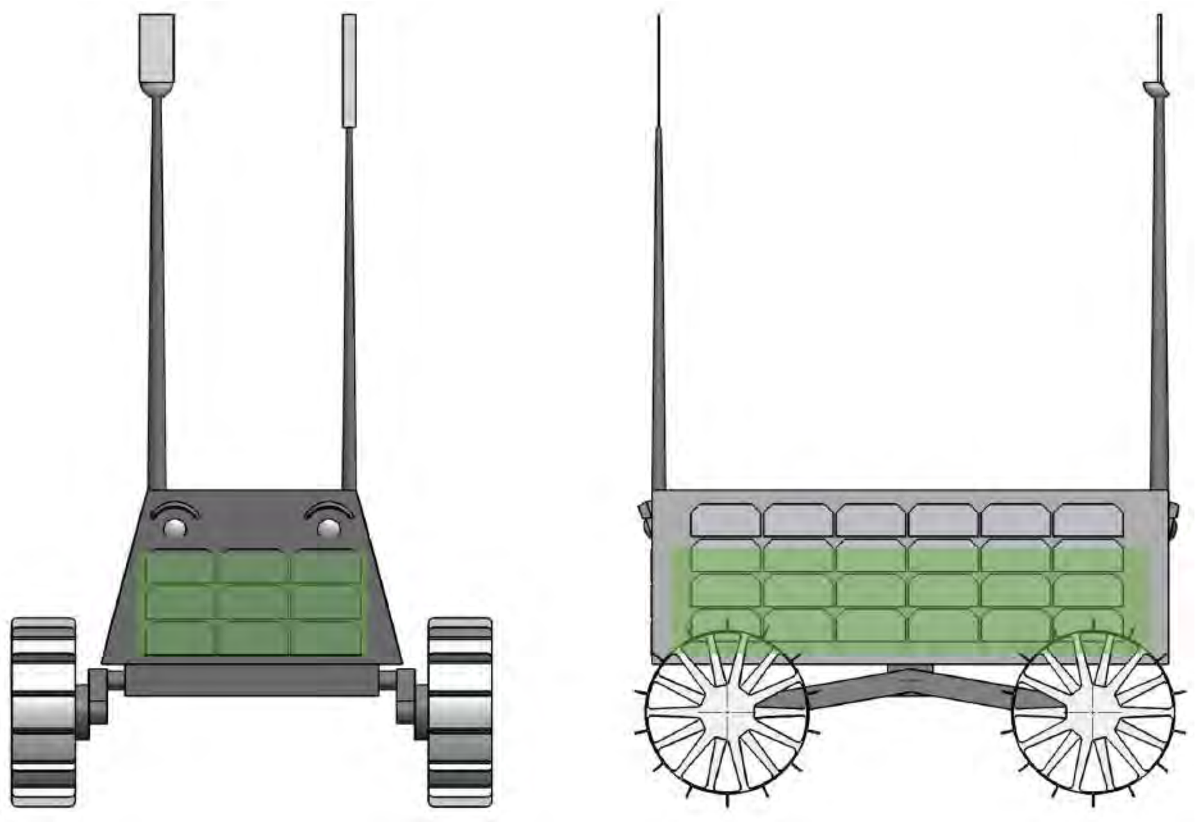
3.2.3 POWER

The rover generates up to 20 W of power depending on its orientation and time of day. When stationary, it uses approximately 5 W of power for housekeeping and communications. When moving, it uses approximately 40 W of power.

Payloads can use up to 35 W of peak power, and sustained 25 W of power for more than 30 minutes when the rover is stopped and up to sustained 10 W of power when the rover is moving.

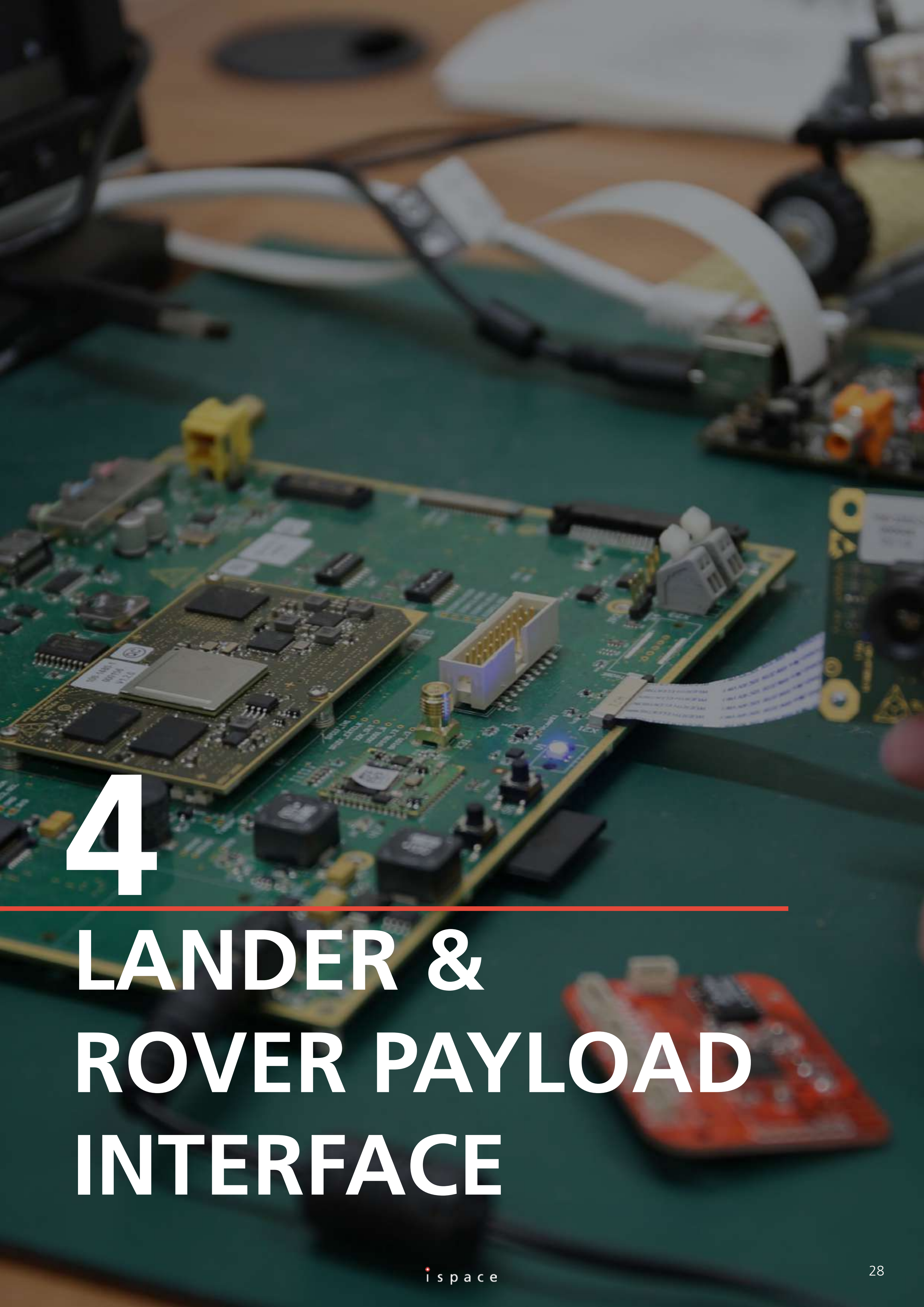
Exact details of power capacity depends on needs for each payload including power consumption and distance between measurements.

3.2.4 PAYLOAD ACCOMODATION



At least 3.5 kg payload capacity is available. More may be available on a case-by-case basis.

The highlighted green regions indicate typical payload accommodation areas. The large space is ideal for surface sensing instruments such as ground penetrating radar or spectrometers and includes access to the surface. Space is also available on the top, rear and front for payloads that require it.



4 LANDER & ROVER PAYLOAD INTERFACE

4.1 LANDER

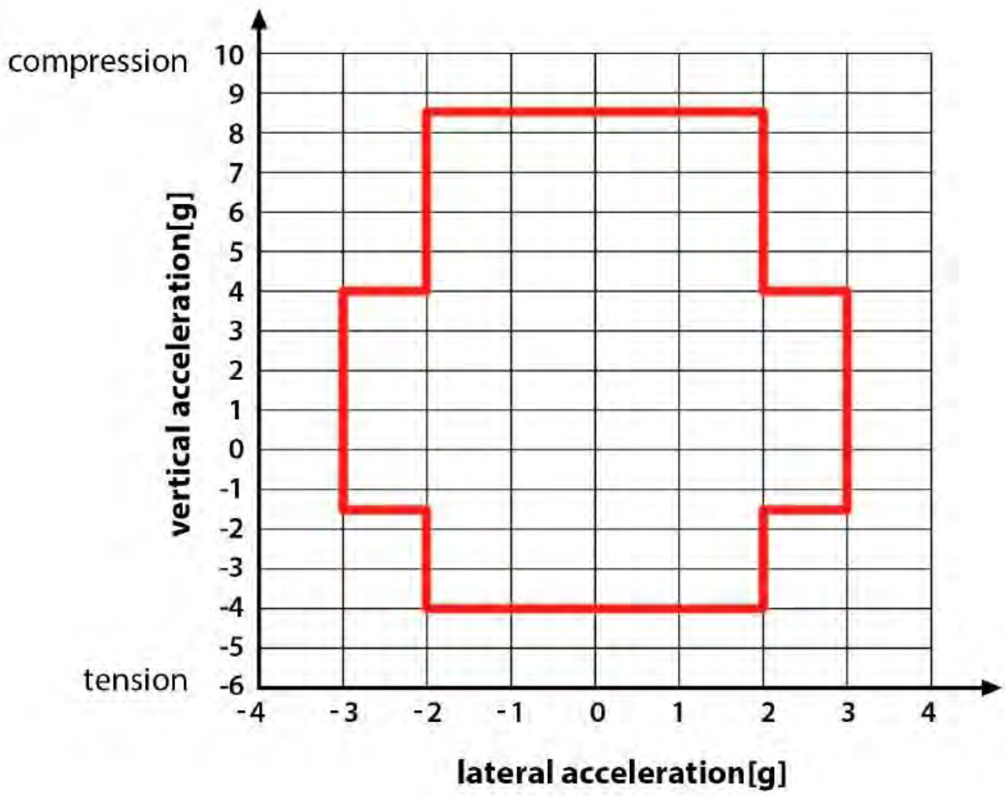
4.1.1 ENVIRONMENTAL

4.1.1.1 Mechanical Environment

In order to avoid modal coupling with Lander's structure, the payload should have all its fundamental vibration modes above 140 Hz.

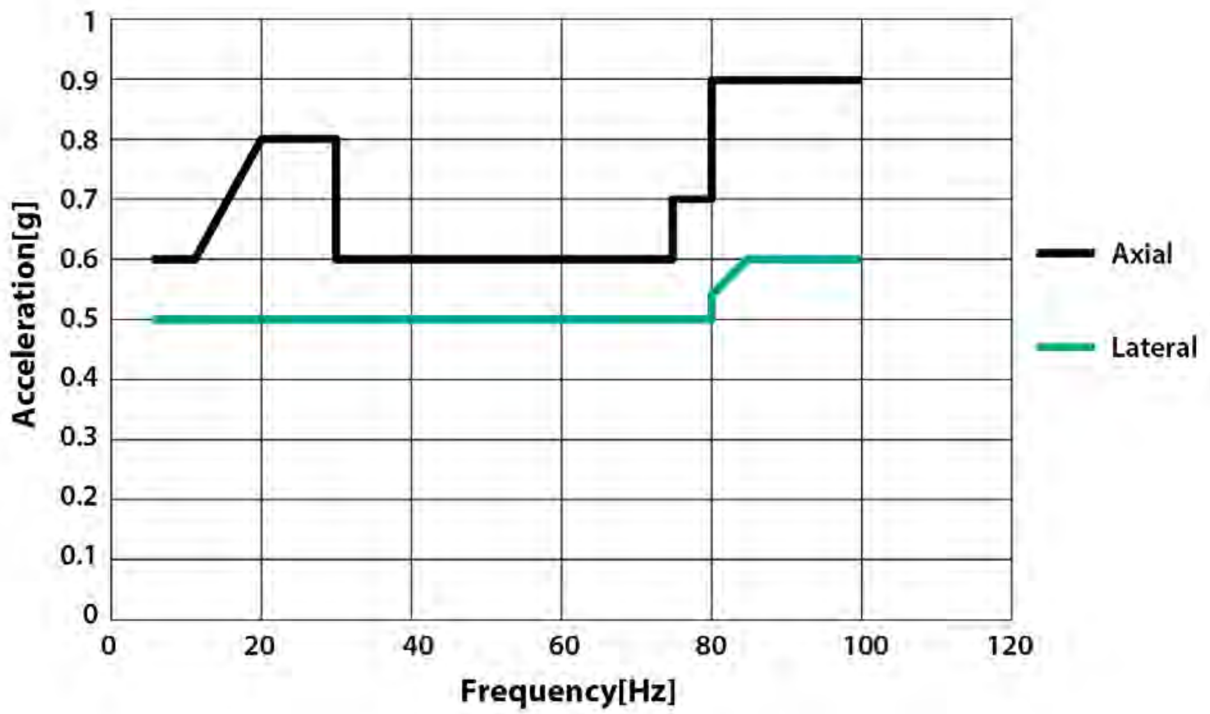
Lower requirements may be negotiated on a case by case basis, after coupled load analysis.

Quasi-static Loads
The quasi-static loads at the Lander to Launch Vehicle interface are shown in the following figure. The design loads at payload interface will be defined during the Initial Payload Integration Assessment, and will later be refined with a Coupled Loads Analysis. More severe loads than the ones displayed here are to be expected.



Sine Vibration

The sine vibration environment at the Lander to Launch Vehicle interface is shown in the figure below. The design loads at payload interface will be defined during the Initial Payload Integration Assessment, and will later be refined with a Coupled Loads Analysis. More severe loads than the ones displayed here are to be expected.



Random

The maximum expected random loads at the Payload interface are shown in the following table, summarized as 14.12 Grms

Frequency (Hz)	PSD Level (g^2/Hz)
20	0.026
50	0.16
800	0.16
2,000	0.026

Shock

The main shock events are the lander separation from the launcher and the actuation of the pyrovalves. As such, prospective payloads must be compatible with the following Shock Response Spectrum (SRS) characteristics:

Freq (Hz)	g (SRS)
100	40
1,500	2,500
10,000	2,500

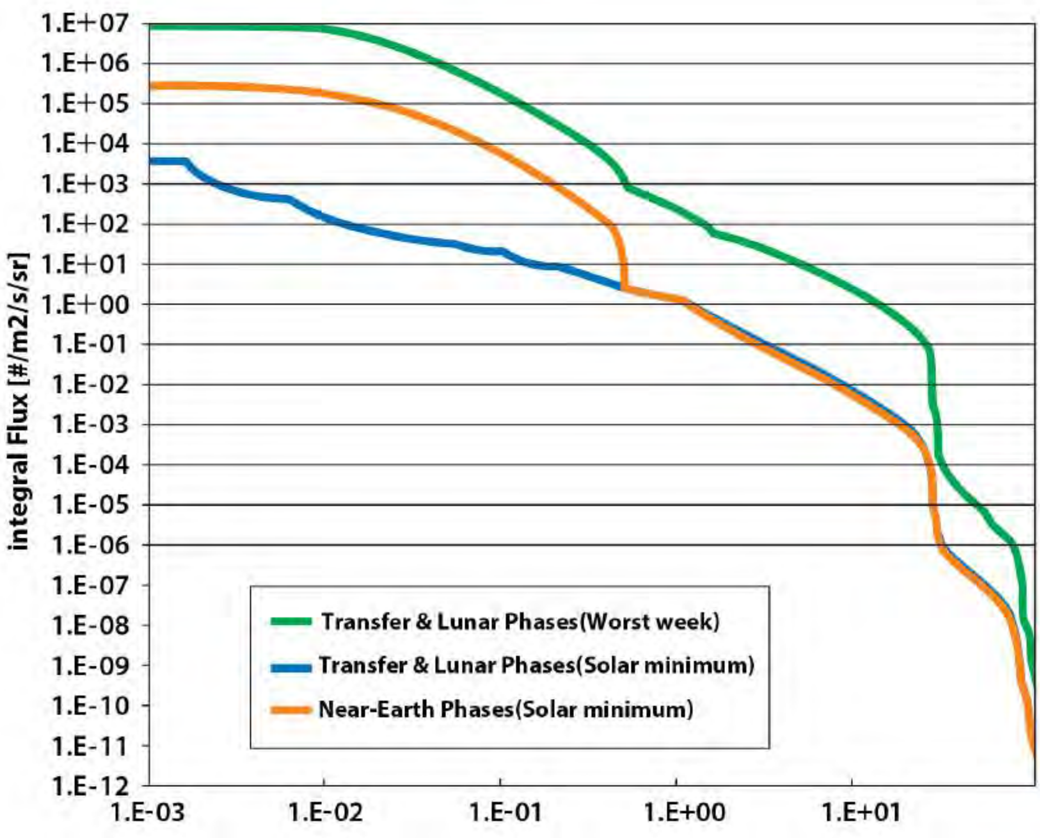
These are maximum values and can be lowered depending on location of the payload relative to the shock source.

4.1.1.2 Radiation Environment

Total Ionising Dose (TID)
The estimated TID requirement to guarantee the Payload's correct function until the end of the baseline mission duration is 10 krad (SI) with Aluminium shielding of 2mm.

Non-ionising Displacement Damage Dose (DDD)
The estimated DDD requirement for the baseline mission is 4.0E+9 p/cm2 of 10 MeV protons.

Non-ionising Linear Energy Transfer (LET)
The estimated spectra observed during the various mission phases are described below.

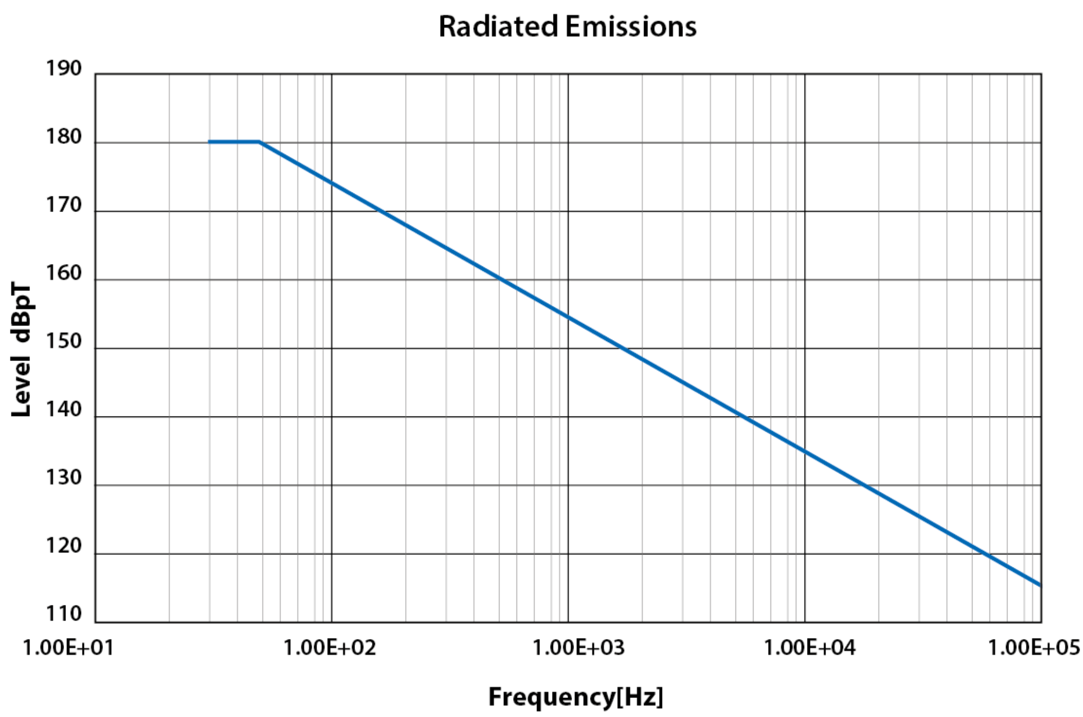


ispace can provide consultancy services to assist customers with suitable payload design for compatibility with these radiation environments, as well as updated requirements for custom mission durations.

4.1.1.3 Electromagnetic Environment

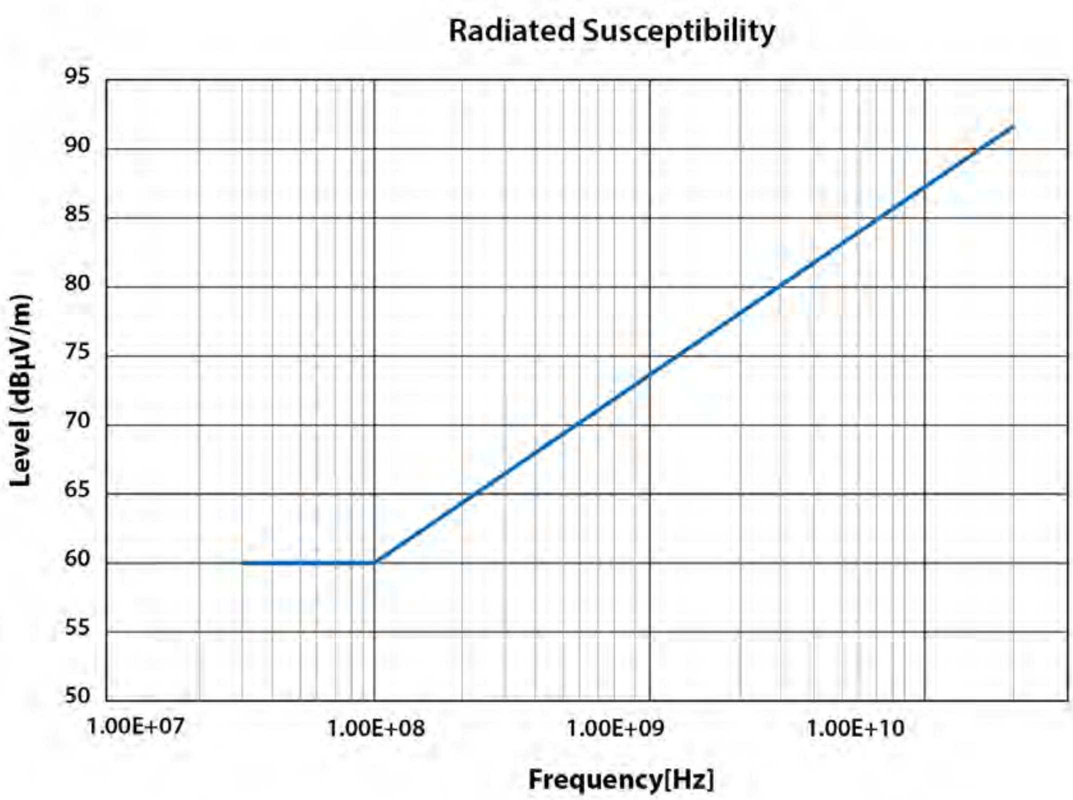
Radiated Emissions

The payload emissions shall be below the limit defined by the following curve:



Radiated susceptibility

The payload shall be compatible with emissions from the launcher and lander at levels defined by the following curve:



4.1.2 ELECTRICAL

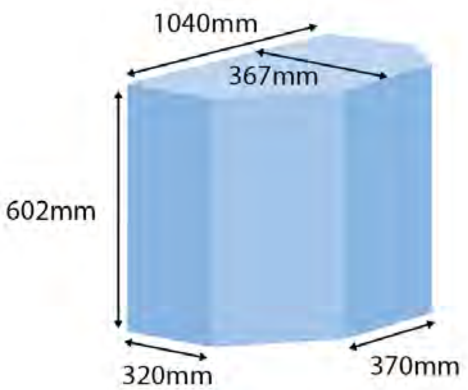
The lander has several available power rails dedicated to payloads, with or without redundancy, as required.: A 28 V unregulated (23-33.6 V) bus is standard, as are regulated 12 V or 5 V buses; other voltages can be made available with customisation.

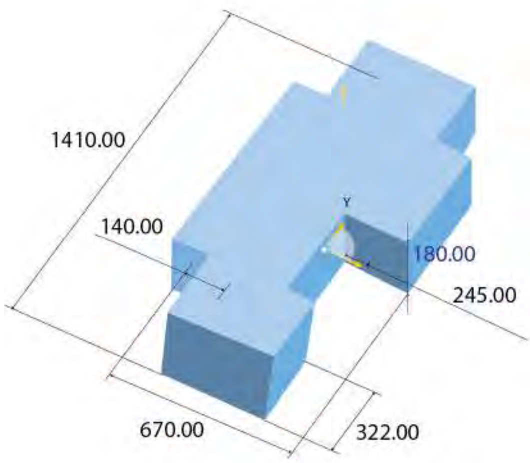
A wide variety of power profiles from more than 100 W continuously available, up to 350 W of maximum payload power can be achieved to suit the majority of payload needs.

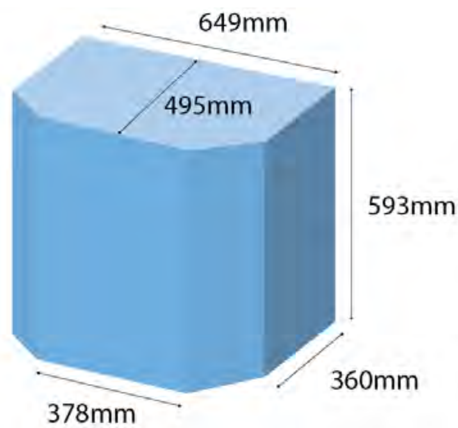
The lander provides several data interface options for payloads. RS-422 and Ethernet are the standard wired options, and 2.4 GHz WiFi and 900 MHz LoRa are the standard wireless options for rover-mounted and deployable payloads.The lander data management system has been designed with flexibility in mind to allow for the accommodation of custom data interfaces as well.

4.1.3 MECHANICAL

Dimensions of the available locations for accommodating payloads as described in 3.1.6 are shown here, for payloads inside the payload bays and for externally mounted payloads respectively:







Depending on payloads type, ispace will design a payload rack for supporting payloads and provide the mechanical interface to the customer. When necessary, or because of payload specific needs, ispace will design custom brackets for holding the payload, while ensuring that payload requirements are met. An example of payload accommodation can be seen below:

As part of the payload interface customization, ispace will perform a Coupled Loads Analysis with the payload in order to specify the mechanical environment envelope. If needed as a result of the analysis, ispace will aim to reduce loads by considering passive dampening in the interface.

4.1.4 THERMAL

The lander provides a default thermal environment inside the payload bays of **-10°C to +40°C** without active control during flight phases. Different thermal ranges can be achieved using heaters, and radiating elements.

On the Lunar surface after landing, the expected temperature range will be between **0°C and +50°C .**

4.2 ROVER

4.2.1 ENVIRONMENTAL

For preliminary assessment, the lander's environmental characteristics presented in section 4.1.1 may be used.

4.2.2 ELECTRICAL

The rover provides a total of 18 W of power for Payloads, with a base allocation of 1.0 W per kg of Payload. Peak power may be higher after agreement with ispace.

Ethernet, RS422 and 3.3V UART are provided as standard interfaces. Others can be provided on a case by case basis.

For both power and data connectors, lightweight, space-heritage connectors have been selected. Connector part numbers and pin allocations will be provided to the customer during preliminary studies.

4.2.3 MECHANICAL

The rover structure and mounting brackets are readily updated to support any payloads that fit within the volume and mass constraints. The green areas in 3.2.4 may be combined as needed to accommodate larger payloads.

4.2.4 THERMAL

During flight phases, the thermal environment is the same as presented for the lander: **-10°C to +40°C** without control.

During the lunar surface phase, the range of **-40°C to +60°C** without control may be reduced to **-10°C to +40°C** with control.

5 PRE-LAUNCH

5.1 INTEGRATION AND TESTING

The schedule for payload integration and testing is shown below. This will be tailored for each payload, depending on the type and complexity. The number of milestone reviews can be reduced as requested by the customer.

Document deliverables are identified for each milestone, although a full list will be later defined in the Payload Service Agreement.

Milestone	Due Date	Description	Document Deliverables
"Initial Payload Integration Assessment"	L-18 months		Initial Payload Integration Assessment report (ispace)
Delivery of models	L-16 months	CAD models and structural and thermal analysis models provided to check fit, configure interfaces and check thermal and structural loads.	CAD, structural and thermal analysis models (customer)
Coupled load analysis results	L-15 months	After checking and performing coupled load analyses, results will be returned and inputted into ICD.	Structural and thermal coupled load analysis results (ispace)
Payload to Lander ICD	L-14 months		ICD (ispace)
Payload Test Completion	L-9 months	Functional and environmental testing of the payload should be completed.	Preliminary test report (customer)
Payload Pre-Ship Review	L-8 months	Demonstrate compliance of payload to the ICD and review Payload Integration and Test Procedures document.	Payload Pre-Integration report (ispace)
Payload Delivery	L-7.5 months		
Payload Pre-Integration Review	L-7.5 months	Review to verify that facilities, hardware, documentation and personnel are ready to support payload Integration.	Payload Pre-Integration report (ispace)
Payload Integration	L-7 months		
Payload Post-Integration Review		Verify that all integration and test procedures are completed and results reviewed.	Payload Integration report (ispace)

Milestone	Due date	Description	Document Deliverables
Test Readiness Review	L-5 months	Prior to Integrated Environmental Testing, review configuration for test and verify that facility, personnel and procedures are ready to execute testing.	Test Readiness report (ispace)
Pre-Environmental Payload Performance Test	L-5 months	Functional check conducted after completion of environmental testing to verify correct performance of payload. TBD depending on the needs of the customer.	
Post-Environmental Payload Performance Test	L-2 months	Functional check conducted after completion of environmental testing to verify correct performance of payload. TBD depending on the needs of the customer.	Payload test report (ispace)
Operational Readiness Review	L-5 weeks	Following the completion of the Integrated Environmental Testing, this review ensures that all procedures, the ground segment, personnel and documentation are ready for operations.	
Flight Readiness Review	L-4 weeks	Review to verify the lander is ready for shipment to launch site, launch campaign and flight.	
Final Payload Functional check before Lander mating to Launch Vehicle	L-3 weeks	At launch site, payload hardware and software finalisation. Functional test completed.	

5.2 CUSTOMER INVOVLMENT IN INTEGRATION

The nominal payload integration process and the customer's role is described below. The schedule is provided in section 5.1 above.

Around the time of contract signature, ispace will perform an Initial Payload Integration Assessment, evaluating the compatibility between the payload and the lander interfaces. All open issues will be identified and a plan for addressing these will be outlined. The plan will include technical and programmatic aspects; will define the necessary payload design reviews' and the documentation required throughout the development process; and schedule the regular meetings between the payload customer and ispace. These reviews will be led by the customer and ispace will be included as a reviewer. Upon request, ispace can support payload design process with iterative technical feedback and interfaces tailoring.

Following the Initial Payload Integration Assessment, ispace will work with the payload customer to jointly develop the Payload to Lander ICD. The ICD will be generated by ispace, however multiple feedback cycles with the customer are expected until the interfaces are frozen.

Before delivering the payload for integration on the lander, a Pre-Ship Review led by the customer is expected, in which the compliance to the Payload to Lander ICD will be demonstrated. Moreover, Payload Integration and Test Procedures generated by ispace will be reviewed by the customer at this point. Review of Integration & Test Procedures (preparation of these led by ispace with customer inputs).

Prior to integration, the payload to lander data interfaces will be tested on a lander engineering model (EM). The payload customer can define whether this test will be performed with the flight model (FM) of the payload or with an EM. Following this test, a Payload Pre-Integration Review will be held, verifying that all facilities, hardware, documentation and personnel are ready to support payload integration. Customers participation in this review is optional, as well as in the Post-Integration Review, which will verify that all integration and test procedures are completed and the results will be reviewed.

Following the completion of all integration activities on the Lander, a Test Readiness Review will be held. A payload representative should be present to sign-off on payload readiness. Once the payload has been signed off for testing, and once the facilities, procedures and personnel readiness have been reviewed, the Integrated Environmental Testing phase will commence. The scope of payload performance tests to be conducted throughout this phase will be defined beforehand together with the customer. The customer can request to be present to witness the payload functional checks done pre- and post-environmental testing.

Once the Integrated Environmental Testing is completed, an Operational Readiness Review will take place to ensure that all procedures, ground segment, personnel and documentation are ready for operations. For this review, the mission will be rehearsed using an end-to-end representative setup, with a lander test bench or a mission simulator. A Flight Readiness Review will follow, prior to the delivery of the Lander to launch site, to verify the lander, procedures, facilities and personnel are ready for launch campaign and flight.

6

POST-LAUNCH

6.1 PAYLOAD SERVICES

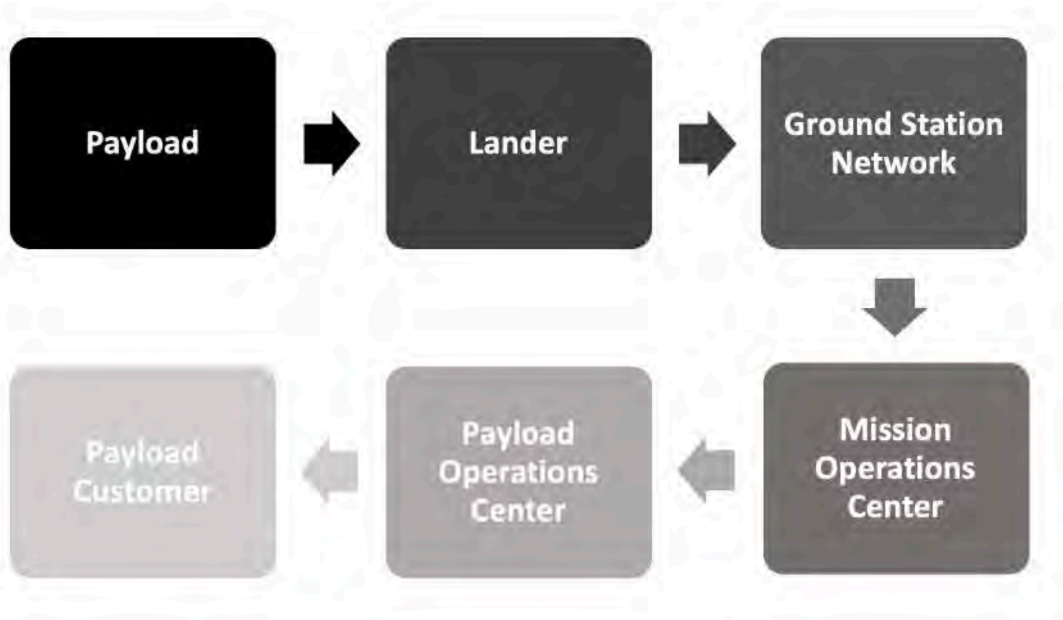
The following table shows the various services available to payloads in each mission phase:

Mission phase/ Service	Pre-launch	Launch	Earth orbit, Cruise to Moon, Moon orbit	Orbit maneuvers (including landing)	Moon surface
Payload switch-on and checkout	Custom	No	Yes[1]	Custom	Yes
Payload deployment	N/A	N/A	Yes[2]	No	Yes[2]
Data relay to Earth	No	No	Yes, up to 1Mbps	Custom	Yes, up to 1 Mbps
Data storage up to 3 GB	No	No	Yes	Custom	Yes
Thermal control[3]	Launcher environment	Launcher environment	Yes	Yes	Yes
Payload battery charging[3]	Custom	No	Yes	No	Yes

1 Limitations may apply to orbits with eclipse phases.
2 Capability for combinations of payload deployment in lunar orbit and on the lunar surface is highly dependent on the launch orbit, the strategy for Earth-to-Moon transfer, the required lunar orbit and deployment mechanism. An example of possible combinations is shown in the table below, and specific cases will be studied with the customer inputs.
3 Thermal control and payload battery charging apply only until payload separation.

Payload Delivered at 100 km LLO	Payload Deliverable to Lunar Surface
0 kg	16 to 30 kg depending on transfer strategy
20 kg	11 kg
40 kg	7 kg
60 kg	3 kg

6.2 OPERATIONAL SETUP



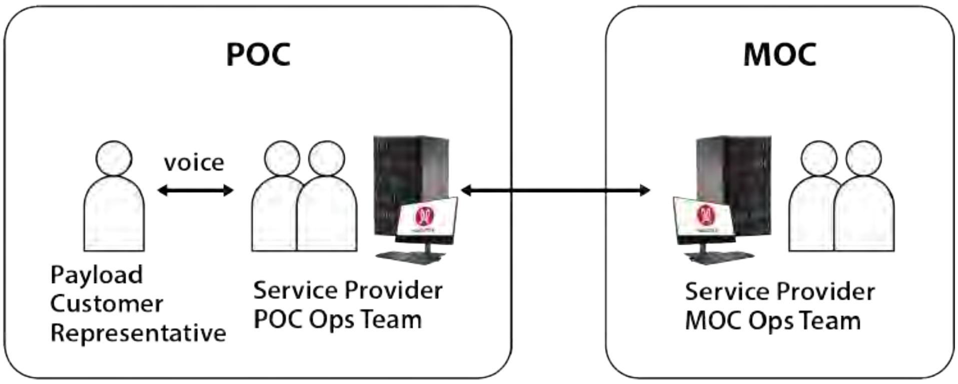
Overview of the data flow between Payload Customer and Payload

After landing, the Lander MOC is responsible for monitoring the lander, performing housekeeping activities including lander-side payload service provision, activation of payload data and power connections, and the configuration of the payload operational thermal environment. The remaining communications bandwidth is available for payload operations, coordinated at the POC.

The POC generates payload telecommands, and sends them to the MOC. The MOC forwards telecommands from the POC to the lander according to the agreed mission timeline. The MOC also forwards in near real-time all received payload data to the POC. The POC may be located next to the MOC, or in a remote location using standard protocols to connect to the MOC.

Payload customers are offered one or more of the following operations schemes:

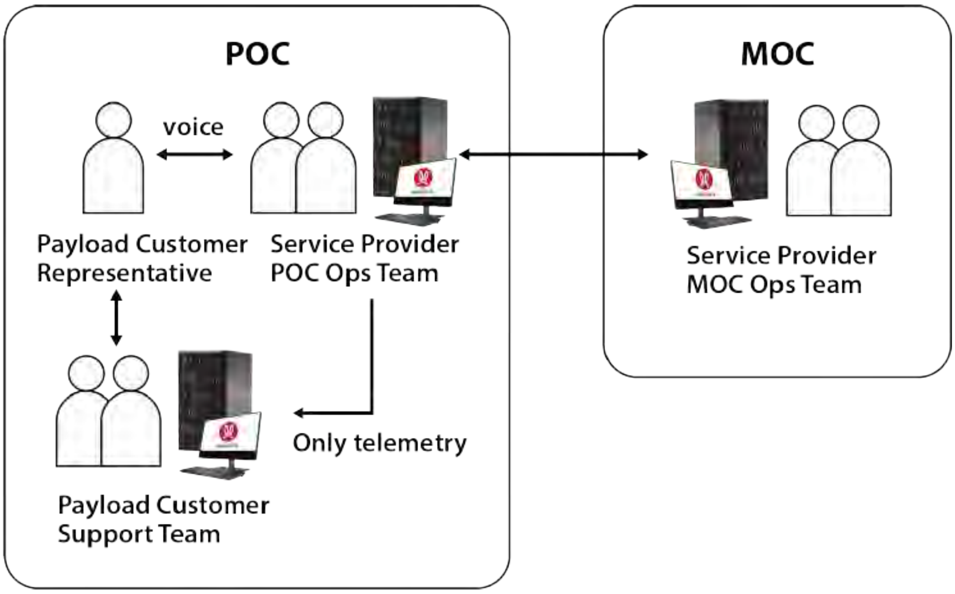
Full Service:



The payload customer only prepares operating instructions. ispace writes Payload Operations Procedures and submits them for approval by the payload customer. They are rehearsed and executed by ispace. A representative of the payload customer is invited to attend the execution of the procedures at the POC. Payload data is made available for retrieval to the payload customer.

Example payload for which this scheme may be suitable: instrument periodically making measurements (e.g. radiation dosimeter).

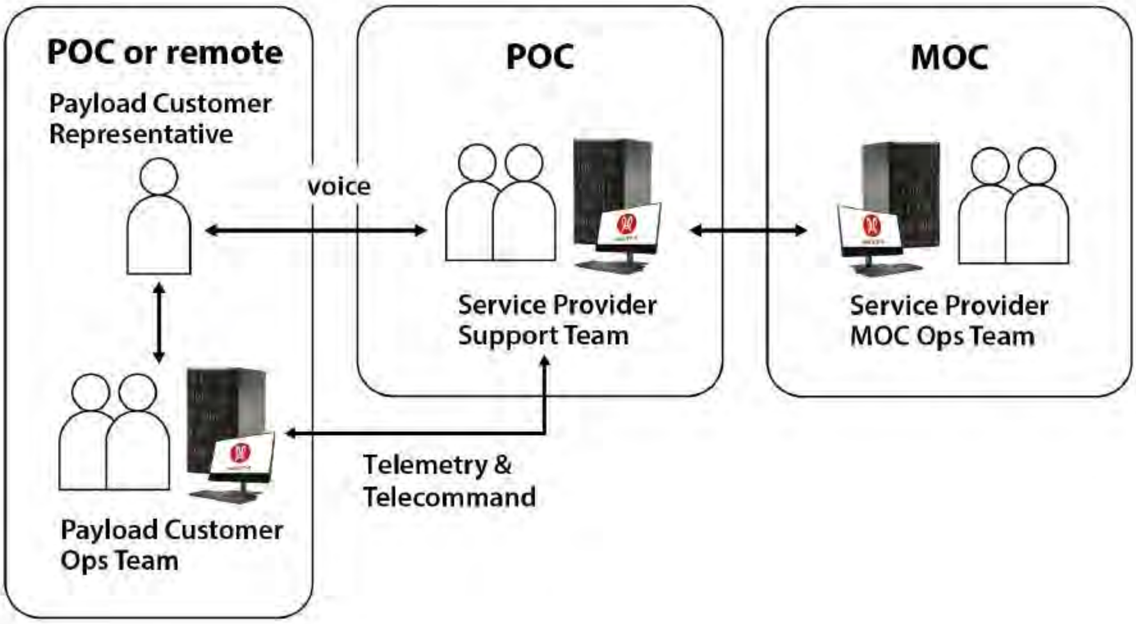
Cooperative:



The payload customer prepares Payload Operations Procedures, which ispace reviews, rehearses, and executes. The payload customer support team attends the full procedure execution at the POC, observing live payload data on dedicated terminals. At agreed breakpoints, the payload customer representative provides approval for proceeding.

Example payloads for which this scheme may be suitable: payloads that will react to the data during the mission and whose procedures depend on the data received during the mission (e.g. changing acquisition parameters). For rover payloads this may include defining which areas to explore and where to perform sensing activities.

Self-Service:



The payload customer prepares Payload Operations Procedures, and ispace reviews and approves them. During the mission, when the agreed conditions are met, ispace enables the payload customer to execute the Payload Operations Procedures. Payload telecommands are immediately forwarded to the payload, and any data are provided live on dedicated terminals.These operations are either from the POC, or from a remote location using standard communication protocols with the POC.

Example payload for which this scheme may be suitable: a customer's own rover that needs the highest level of interactivity to make the most of the short surface operation duration.

Payload data generated while the lander is visible to the ground station, and configured to be sent to the MOC, will always be forwarded to the POC in near real-time. Payload data generated when the lander is not visible to the ground station, and payload data generated without a configuration to be sent to ground, will always be stored on-board the lander, and available for later retrieval, by sending a Lander telecommand. Continuity of ground communications and data storage availability is ensured by redundancy of servers and data connections. Ground station visibility requirements during Surface Operations are agreed with the Payload Customer and described in the Payload ICD.

6.3 FLIGHT OPERATIONS

All payload operations are executed according to procedures agreed with ispace and rehearsed, to ensure that no erroneous commanding endangers the mission for the lander and all payloads.

6.3.1 CHECK-OUT

Payload operations can be performed during flight phases. They shall nominally take place under the following conditions:

- » Outside of orbit maneuvers or lander housekeeping activities
- » At times of visibility from ground stations, or with a time-tagged procedure
- » According to an agreed and rehearsed procedure, and in accordance with the payload operations schemes agreed (described in section 6.2)

The following can be performed:

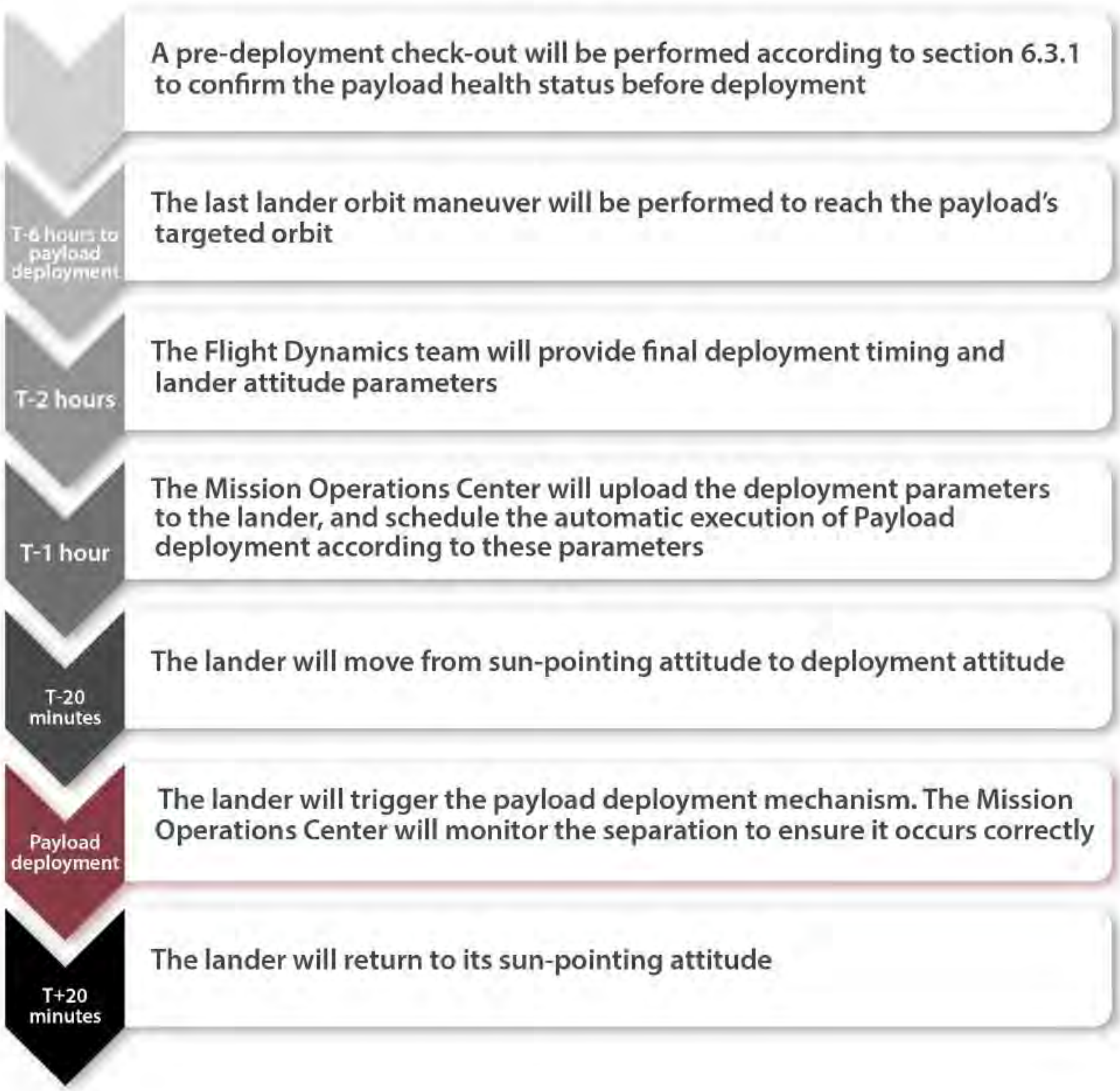
1. Payload powered on, payload independent battery top-charging;
2. Wired data communication initialisation;
3. Check-out commanding;
4. Telemetry recording and downlink to ground; and,
5. Payload powered off.

For the above, the result of the commands and the payload data are downlinked live during visibility or at the next downlink opportunity.

The duration of this operations set from point 1 to point 5 above ranges from 2 hours under the worst lunar orbit configuration, to several Earth days during sun-pointing cruise and orbits with short sun eclipses. Such operations sets may be repeated even in long eclipse orbits, after the lander battery has been recharged. Such scenarios will be analysed by ispace according to customer requirements.

6.3.2 DEPLOYMENT

Payload deployment operations performed during the lander flight phase will generally follow the following timeline:



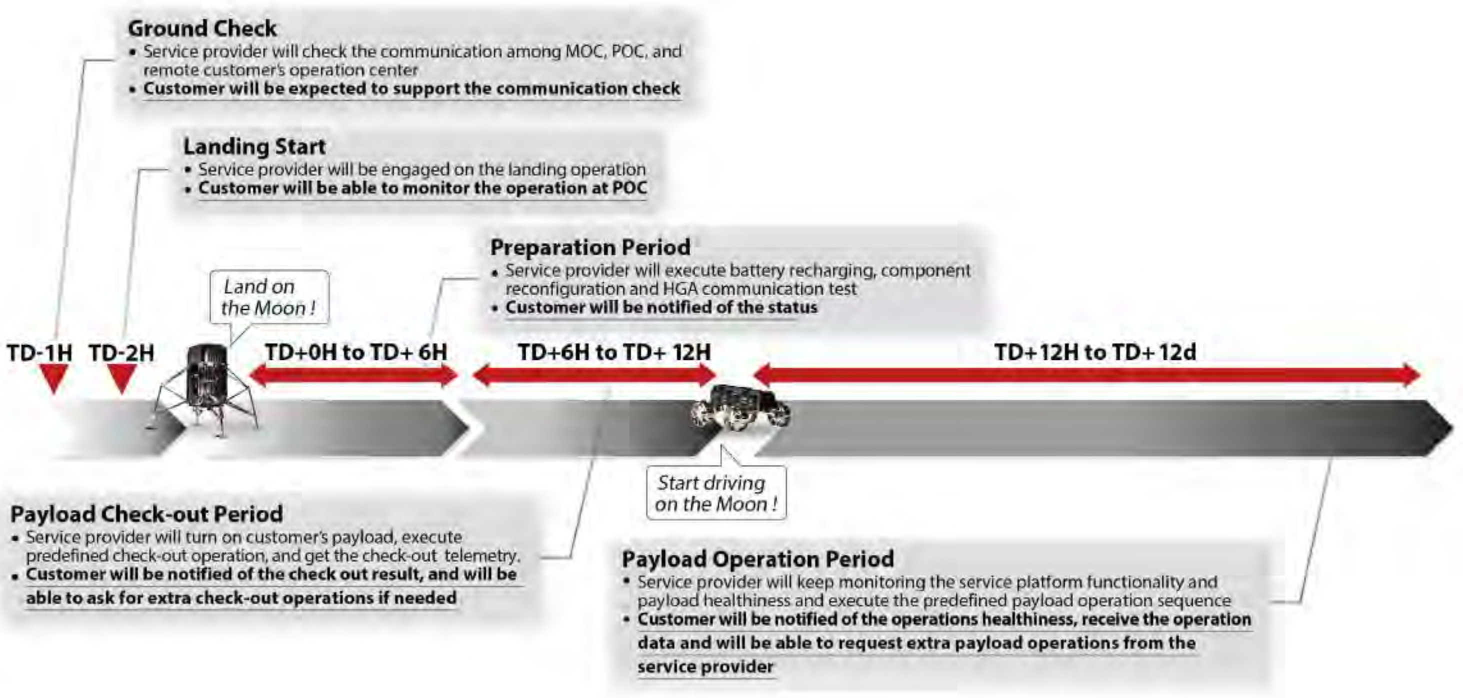
6.4 SURFACE OPERATIONS

6.4.1 SURFACE EXPLORATION

ispace provides mission support to three types of payloads:
- » Static payloads that stay attached to the lander
- » Deployed payloads that separate from the lander
- » Payloads that are hosted by the ispace rover deployed by the lander

The overview of the events during surface operation are shown below:

Mission Time	Events and Provided Services
Touchdown (TD) -2h	Surface Mission Readiness: Communications check between MOC, POC, and customer's operations center
From TD+0 to TD+6 h	Payload Operations Preparation: » Lander battery recharging » Lander System reconfiguration » High Gain Antenna communications test » Payload thermal control
From TD+6h to TD+12h	Payload Commissioning: » Payload power on and thermal control » Payload check-out » Payload deployment (if applicable) and rover deployment
Until 2 days before lunar sunset (~TD+10 days)	Payload Nominal Operations: » Power and thermal control services (for payloads hosted by the lander) » Payload commanding and monitoring » Payload data relay » Payload data storage
Until lunar sunset	Extended Operation Phase and Decommissioning: » Depending on the performance of the system, the Mission Director and payload customers select the End of Mission and decommissioning operations timing: • Passivation of Payload critical units • Passivation of Lander



6.4.1 ROVER-HOSTED PAYLOADS

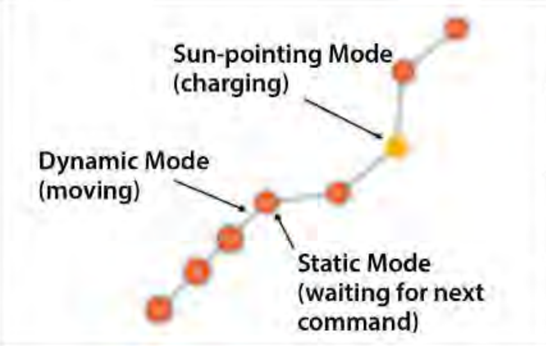
Additional services are provided specifically to rover payloads.

During the Surface Operation phase, ispace expects to continue to interact closely with payload customers inside the POC as described in section 6.2.

The rover payload operation service provides customers with a reliable mobile platform on the Moon to collect the required data. ispace will update the mission plan based on the data analyzed by the payload customers during the mission and the actual performance of the rover system.

Based on experience with field testing of rovers and the survey of terrestrial robotics, a teleoperation concept of operations has been selected, with human operators in the decision loop. Near real-time lunar surface operation of the rover and payloads by human operators allows a simple system with robust validation of every function, efficient exploration of the lunar surface and resilient operations against unexpected conditions. This concept also provides flexibility to conduct opportunistic payload operations.

The rover payload operation service includes providing customers with position and contextual data, and customers can be involved in selecting the next waypoints for measurement. Position data is obtained using the rover's onboard cameras, Inertial Measurement Unit and wheel odometry.



#	Operation Phase and Mode		Duration per Cycle
1	Roving Phase	Dynamic Mode (20%)	Depends on Payload
2		Static Mode (80%)	
3	Sensing Phase		
4	Resting Phase		Approximately 3 hours

In the Roving Phase, the rover drives on the lunar surface by teleoperation. Within this phase 20% of the time will be spent moving and 80% on decision making and commanding. Payloads that collect data while the rover is moving are active during this phase.

If a payload needs high power supply or stable operation, its operation will be done in the Sensing Phase, with rover orientation controlled to maximize power generation.

The Resting Phase is used to recharge the battery. During this phase, the rover orientation is controlled to maximize power generation while complying with thermal requirements (Sun-Pointing Mode). The Resting Phase is timed to coincide with long term decision making, data downlink, operator shift changes and other activities to optimize the limited time of surface operation.

The rover payload operation service is designed to accommodate the specific payload requirements. For example, the type of payload will dictate minimum or maximum distances travelled between Sensing Phases. It will also change the power requirements and therefore the amount of time in the Resting Phase. The payload integration time requirements will dictate the length of the Sensing Phase.

The baseline mission plan will be jointly developed between ispace and customers. Specific rover mission rehearsals in lunar analog terrains will give the teams a strong knowledge of their needs and capabilities.

GLOSSARY

CAD	Computer Aided Design
CLPS	Commercial Lunar Payload Services
COTS	Commercial-off-the-shelf
DDD	Displacement Damaging Dose
EM	Engineering Model
FM	Flight Model
GLXP	Google Lunar XPRIZE
HQ	Headquarters
ICD	Interface Control Document
JAL	Japan Airlines
JAXA	Japan Aerospace Exploration Agency
LET	Linear Energy Transfer
LLO	Low Lunar Orbit
MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
POC	Payload Operations Center
SRS	Shock Response Spectrum
TD	Touchdown
TDB	To be determined
TID	Total Ionizing Dose
USD	United States Dollars
WLS	White Label Space

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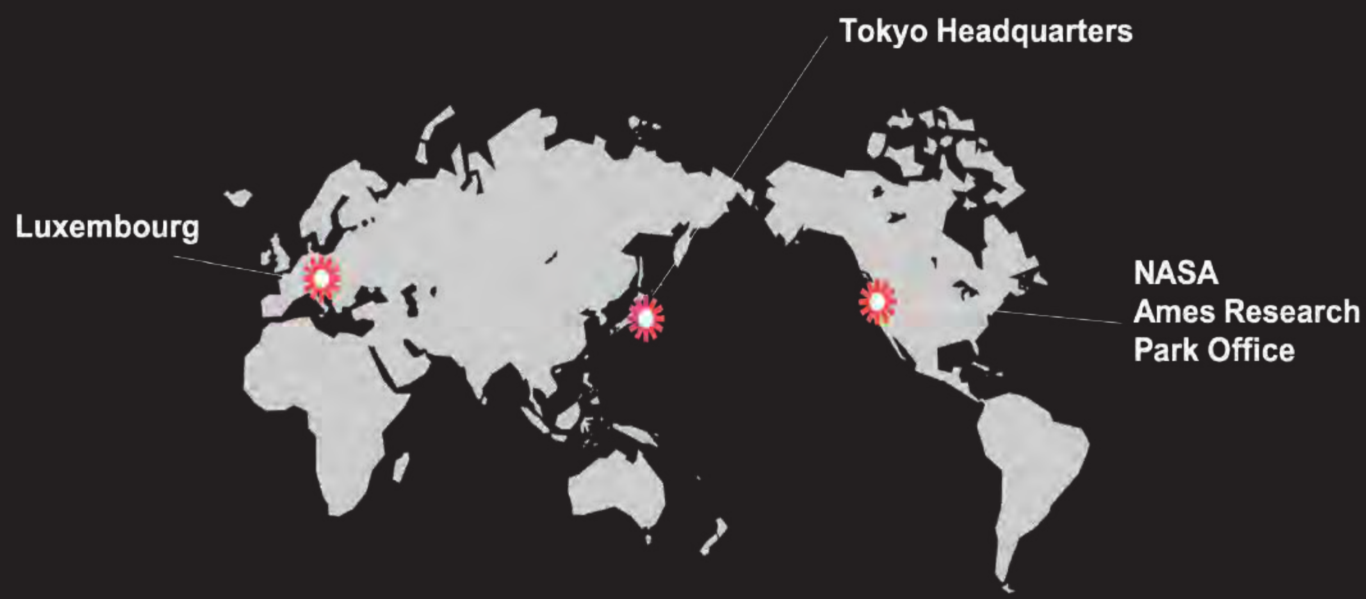

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