



estec

European Space Research
and Technology Centre
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
T +31 (0)71 565 6565
F +31 (0)71 565 6040
www.esa.int

Request for Information

Lunar Exploration Campaign Science and Technology Payloads

Prepared by	HRE-S
Reference	
Issue/Revision	1.0
Date of Issue	09/11/2018
Status	Issued



Table of contents:

1 INTRODUCTION.....	3
1.1 Missions of Opportunity	3
1.2 Human exploration precursor mission	4
2 INFORMATION REQUESTED	4
2.1 Missions of Opportunity	4
2.2 Human exploration precursor mission	5
3 USE OF THE INFORMATION RECEIVED	6
3.1 Missions of Opportunity	7
3.2 Human exploration precursor mission	7
4 PAYLOAD INTERFACES	7
5 RFI PROCESS AND TIMELINE.....	8
5.1 Reference Documents	9
ANNEX 1: PAYLOAD SUBMISSION OUTLINE.....	10
ANNEX 2: POTENTIAL NEAR TERM MISSIONS OF OPPORTUNITY.....	12
ANNEX 3: HERACLES HUMAN EXPLORATION PRECURSOR MISSION	14
HERACLES Elements - Overview.....	15
Mission Profile	15
Landing Site	16
ANNEX 4: SSTL AND GES LUNAR MISSION OPPORTUNITIES.....	18



1 INTRODUCTION

The European Space Agency (ESA) is releasing this Request For Information to gather information on European payloads that could be contributed to a possible lunar mission campaign implemented within the framework of the European Space Exploration Envelope Programme (E3P). This mission campaign is currently in preparation and its implementation is subject to decisions at the ESA Council Meeting at Ministerial level planned for December 2019.

The campaign shall enable access to the Moon via missions that may be categorised as:

- Missions of Opportunity, where European payloads respond to flight opportunities made available by the private sector or international partners.
- Directed missions, where European payloads are contributed to missions, which are defined and driven by ESA, alone or with international partners, to achieve a predefined set of objectives.

In this RFI information is sought which will:

- a) Prepare for the later selection of payloads for flights as early as 2020 on Missions of Opportunity and
- b) Support the establishment of a strawman payload for an ongoing ESA directed mission study, conducted with international partners, on a human lunar exploration precursor mission (HERACLES) and prepares for a future Announcement of Opportunity.

1.1 Missions of Opportunity

The European Space Agency is establishing commercial partnerships with private sector lunar mission suppliers and is discussing potential lunar payload opportunities with international partners. As a result it is expected that a number of payload flight opportunities to the Moon may appear in the period between 2020 and 2025. A description of possible flight opportunities currently under discussion is provided in Annex 2.

This RFI aims to gather information that will allow the later down selection of candidate payloads for these opportunities once opportunities are confirmed. As such, this RFI should be considered as the first stage in a process that may lead to flight opportunities.

Responding to these opportunities will require a rapid development to flight readiness. As such it is likely that any selected payloads will use existing hardware or be derived from existing developments. Such payloads are the focus for Missions of Opportunity.

While the Agency does not commit to provide flight opportunities, an identification of possible payloads which could response to ad hoc opportunities may be made on the basis of any responses to this RFI. A final selection for flight will be made on the basis of a scientific, technical and programmatic assessment of individual payloads and their compatibility with



specific flight opportunities on offer. Respondents to this RFI will be contacted directly to support the preparation of this subsequent down selection.

1.2 Human exploration precursor mission

The European Space Agency is working with international partners on a robotic precursor to later human missions to the lunar surface, the HERACLES (Human Enabled Robotic Architecture Capabilities for Lunar Exploration and Science) mission. The mission study currently conceives a cooperation with the Canadian Space Agency (CSA), the Japanese Space Exploration Agency (JAXA) and the National Aeronautics and Space Administration (NASA) with a launch not earlier than 2026; noting that the study is open to the inclusion of other agencies that may be interested to join the partnership.

This RFI aims to gather information from European academia and industry on the nature and extent of interest in payload contributions to the mission and to prepare a strawman payload in support of HERACLES mission planning activities.

Following the information received through this Request For Information (RFI), and subject to mission approval by all participating agencies, a coordinated Announcement of Opportunity (AO) will be subsequently issued.

2 INFORMATION REQUESTED

Information is requested which may be submitted in response to either or both of the mission types presented. A model outline for responses to this RFI is provided on Annex 1.

2.1 Missions of Opportunity

Payloads of interest for Missions of Opportunity include both scientific instrumentation and payloads for technology demonstration and testing. Of particular interest are payloads addressing specific technical or scientific challenges for future exploration missions or addressing scientific topics which have been identified previously as being of high priority [RD1].

Examples of scientific topics that could be addressed but are not limited to:

- The bombardment history of the inner solar system
- The structure and composition of the lunar interior
- The diversity of lunar crustal rocks
- Volatiles at the lunar poles
- Volcanism
- Impact processes
- Regolith processes
- Atmospheric and dust environment
- Life sciences and astrobiology



- Fundamental physics
- Astronomy
- Space resource utilisation

Areas of interest for technology demonstration payloads include but are not limited to:

- Precision landing
- Hazard avoidance
- Mobility
- Autonomy
- Robotics
- Power generation and energy storage
- Low temperature operations and survival
- Dust mitigation
- Space Resource Utilisation
- Communication/ navigation

The earliest mission opportunities in 2020-2021 will require rapid payload development. It is assumed that any payloads in this timeframe will be derived from existing hardware (e.g. engineering models, flight spares, flight models).

Payloads from 2022 – 2024 may be subject to additional development effort but it is assumed that these will be derived from high TRL technologies and will build heavily on past and ongoing developments.

In all cases it is expected that a simplified approach to development will be adopted, with a single flight (proto-) flight model developed and tested; noting the increased risk, which is deemed consistent with the overall risk and cost of the opportunities under consideration. More comprehensive approaches to development may also be considered if time and resources allow.

Payloads should be compatible with the environment in and around the Moon (e.g. RD2).

2.2 Human exploration precursor mission

In the context of HERACLES the RFI is focused on requesting proposals for scientific mission payloads.

The RFI has been issued with the following major objectives:

- To enable the Agency to understand and take into consideration the level of interest of the European science community in the HERACLES mission, and to provide inputs to the ongoing design process.
- To inform discussions relating to the selection of a preferred landing site location.
- To prepare a strawman payload for implementation in the ongoing mission study.

The HERACLES Science Working Group has determined an un-prioritised list of science objectives from the Objectives and Requirements Document [RD3]:

Responding to International Space Exploration Coordination Group (ISECG)'s Science Theme [RD4]: Understanding our place in the universe	
S1	Constrain the impact chronology of the Earth-Moon system and test the cataclysm hypothesis by determining absolute ages for major impact events based on surface geological features
S2	Understand the Earth-Moon impact flux by determining the abundance, composition and isotopic nature of impactor remnants in regoliths of various ages
S3	Enhance understanding of dynamic processes on airless bodies by measuring the processes of space weathering, solar wind and magnetosphere interactions and the exosphere
S4	Enhance understanding of the origin and evolution of the Moon by determination of structural layering of the highland crust and mantle through in-situ geophysical networks, and determination of compositional layering and solidification age through sample return
S5	Understand volcanic processes on the moon through obtaining eruption information, composition and age of silicic domes, scoria cones and holes and youngest and oldest mare material
S6	Enhance understanding of cratering processes on the Moon through study of impacts of different size, age and complexity
S7	Understand the origins of lunar volatiles trapped in ancient rock
S8	Understand solar and galactic evolution by measuring the abundance of cosmic ray generated isotopes in minerals of various exposure ages
S9	Contribute to understanding the origin of life and prebiotic chemistry through constraining Solar System Conditions when life first arose
Responding to ISECG Science Theme [RD4]: Living and Working in Space	
L1	Determine the physical and chemical properties of dust and its toxicity
L2	Determine the composition and abundance of minerals in regolith as resources
L3	Identify the effects of exposure to the lunar radiation environment on DNA stability, mutation rates of exploration relevant microorganisms, including human cell analogues

Table 1 Initial HERACLES Science Objectives (un-prioritised)

3 USE OF THE INFORMATION RECEIVED

Upon receipt of responses to this RFI ESA shall perform a preliminary technical review identify submissions that are within the scope of the RFI and could feasibly be considered for future flight opportunities. Following this initial assessment different consideration will be given for the two mission scenarios.

Any information provided in response to this RFI will be held in confidence by ESA. In the event that information provided should be used the respondents shall be approached and permission sought for usage.

In order to facilitate discussions with Member States with regard to future opportunities it is advised that any respondents to this RFI inform their National Agencies of their submissions and that submissions include confirmation that ESA may contact the National Agencies of respondents with regard to the content provided.

Any proprietary information included in the submission should be clearly identified.

3.1 Missions of Opportunity

Submissions for consideration for missions of opportunity shall become part of a pool of payloads, which may be considered when opportunities are confirmed. In the event that a flight opportunity is confirmed this pool shall be accessed and payloads which are considered by the Agency to be compatible with the opportunity, technically, scientifically and programmatically shall be taken forward for further consideration. In this specific case the Principle Investigators identified in the submissions shall be contacted and requested to support further steps in payload down selection for flight.

3.2 Human exploration precursor mission

For HERACLES the RFI has been issued to gather information with the following major objectives:

- To enable the Agency to understand and take into consideration the level of interest of the European science and industry community in the HERACLES mission, and to provide inputs to the on-going design process.
- To inform discussions relating to the selection of a preferred landing site location.
- To support the establishment of a strawman payload for the ongoing HERACLES study and to support preparations of a possible future AO.

4 PAYLOAD INTERFACES

The interfaces associated with Missions of Opportunity (structural, mechanical, power, data, configuration) cannot be defined in detail today. Respondents to the RFI are invited to provide information on the interfaces with which payloads are currently compliant. Possibilities for adaptation to alternative interfaces should also be described, along with an assessment of the technical and cost related impacts of adaptation and any associated risks.

Examples of interfaces which are considered by potential missions can be found in RD5 and RD6.

While the specific flight opportunities which will transpire cannot be confirmed at this time examples of specific prospective missions of opportunity are provided in Annex 2. There is a particular interest in payloads that could be compatible with the following:

- Not earlier than 2020:
 - 2 – 3 kg payload on a lunar orbiting micro-satellite
 - 6U cubesats to be deployed in lunar orbit
 - Payloads of 10 kg or less delivered to lunar surface at a TBC near side location
- Not earlier than 2022:
 - Up to 60 kg delivered to lunar orbit, either as an accommodated payload or as a deployed free flying element (e.g. cubesat or penetrator)
 - Surface payloads of TBD mass to near side, far side or polar locations

For HERACLES the current design concept allows for 15 kg of rock and regolith samples and a total of 55 kg of in-situ instrumentation; 40 kg of which is on the mobile rover platform



and 15 kg is on the static lander. Detailed payload interfaces have not yet been defined. Currently assumed payload interfaces should be described in submissions.

5 RFI PROCESS AND TIMELINE

Responses to this RFI should be sent via email to:

lunarRFI@esa.int

by 24:00h CET, 15 December 2018.

Respondents are requested to submit their submissions using the outline provided in Annex A, completing all relevant fields. Submissions should be no longer than 10 pages in length, with additional information provided in annex.

Received submissions will be reviewed for technical and scientific content and compatibility with the identified missions.

Where follow up is required individual respondents will be contacted by the agency.

All respondents will receive confirmation of receipt of their submissions. It is not possible to assure feedback in response to all submissions received.

The schedule for the RFI is shown below.

Milestone	Date
RFI Issue	09/11/2018
RFI Closure	15/12/2018
ESA Review Closure	31/01/2019
Submission follow up initiated where needed	28/02/2019

Table 2. RFI schedule.

5.1 Reference Documents

- RD1. Crawford, I. A., Anand, M., Cockell, C. S., Falcke, H., Green, D. A., Jaumann, R., & Wieczorek, M. A. (2012). Back to the Moon: the scientific rationale for resuming lunar surface exploration. *Planetary and Space Science*, 74(1), 3-14.
<https://www.sciencedirect.com/science/article/pii/S0032063312001444>
- RD2. ESA Lunar Lander Environmental Specification, JS-08-11, iss. 1, August 2011.
- RD3. Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science (HERACLES) Objectives and Requirements Document, Version 4.0, 29 Sep, 2018, ESA-HSO-K-RS-0149
- RD4. Scientific opportunities enabled by human exploration beyond Low-Earth-Orbit, ISECG Science White Paper, 2018,
https://www.global-space-exploration.org/wordpress/wp-content/isecg/ISECG%20SWP_FINAL-web_2017-12.pdf
- RD5. Part Time Scientists Payload User Guide https://ptscientists.com/wp-content/uploads/2018/05/180320-PTS_MttM_Starter_PUG_001_V01-KAG.pdf
- RD6. Astrobotic Payload User Guide <https://www.astrobotic.com/payload-user-guide>



ANNEX 1: PAYLOAD SUBMISSION OUTLINE

The following outline should be used as a guide to preparing responses. Submissions once prepared should be no longer than 10 pages in length. Additional information can be provided as annex.

Lunar Payload Information Outline	
Submission applicability	Select one or more: Missions of Opportunity/HERACLES/Both
Name	Name of the payload
Instrumentation	Brief description of the instrumentation (e.g. retroreflector, x-ray spectrometer, seismometer, camera, LIDAR etc.)
Function / Measurements made	The function of the payload or the measurements that it makes
Science / technology / knowledge gaps	Scientific questions, knowledge gaps or technology needs that the payload can address
Mass	The expected mass of the payload with an indication of the confidence associated with the value
Volume and dimensions	The volume and dimensions of the payload
Data	The data rate and volume expected from the payload.
Interface details	Description, if known, of currently assumed thermal, mechanical, power and data interfaces (e.g. RS485 / Spacewire, voltage, regulated/unregulated power, heat flow across interfaces) and options for adapting to alternatives.
Other requirements	Additional requirements applied to the carrier (e.g. landing site dependency, minimum duration of operations, mobility requirements, high power requirements, deployment, visibility, pointing etc.)
Operations	Concept of operations.
TRL ¹ estimate	Current Technology Readiness Level (TRL) of the payload and justification.
Current status and development needs	The current development status, the earliest possible delivery date of a flight unit and development needs to achieve flight readiness.

¹ <http://sci.esa.int/sci-ft/50124-technology-readiness-level/>



Estimated cost to flight	Estimated financial resources needed to achieve flight readiness.
Funding options	Potential or secured funding contributions from sources other than ESA.
Major risks	Any major risks associated with the development of the payload.
Additional information	Any further information deemed relevant to the submission.
Relevant documents	Publications and other supporting documentation.
National Agency Informed	Have relevant national agencies been informed of this submission and is permission granted to ESA to discuss this submission with them.
Respondent Details	
Payload lead / Principle Investigator	
Organisations & address of lead organisation	
Website	
Email address	
Contact telephone	
Co-Authors / Co-Investigators of the submission	
Background experience of the authors	



ANNEX 2: POTENTIAL NEAR TERM MISSIONS OF OPPORTUNITY

Mission	Supplier	Notional Date	Payload Mass potentially available for ESA	Mission description	Partnership status
ALINA ²	Part Time Scientists	Not earlier than Q1 2020	10kg	Soft landing near to Apollo 17 site. Visit Apollo artefacts and shorty crater with two rovers.	Partnership in preparation. Confirmation anticipated during 2019.

Mission	Supplier	Notional Date	Payload Mass	Other information	Current status
Lunar microsat & cubesat mission	Surrey Satellite Technology Ltd (SSTL)	Q3 or Q4 2020	2-3kg payload on microsatellite.	Payloads accommodated on microsatellite and 6U cubesats in 100km x 800km lunar orbit For further details see Annex 4.	Existing partnership with ESA for preparation phase. Partnership for flight is anticipated during 2019

² <https://ptsScientists.com/products/alina/>

Mission	Supplier	Notional Date	Payload Mass	Other information	Current status
Lunar pathfinder ³	SSTL and Goonhilly Earth Station	2023	Up to 60kg	Hosted payloads on lunar communications spacecraft and deployment of 12U cubesats in lunar orbit with communications relay and ground stations supplied. For further details see Annex 4.	Existing partnership with ESA for preparation phase. Partnership for flight is anticipated during 2019

Mission	Supplier	Notional Date	Payload Mass	Other information	Current status
Chang'e 6	CNSA	2023 (TBC)	Up to 10kg	Payload accommodated on a lunar surface mission expected to include sample return. Landing site may be polar.	CNSA have announced that they are offering payload opportunities on this mission for international partners. ESA and CNSA are discussing potential scientific partnerships on future missions.

³ <https://www.sstl.co.uk/media-hub/featured/lunar-mission-services>, <http://www.goonhilly.org/lunar>

ANNEX 3: HERACLES HUMAN EXPLORATION PRECURSOR MISSION

In January 2018, the ISECG (International Space Exploration Coordination Group) released the third iteration of the Global Exploration Roadmap (GER)⁴, in which human missions to the lunar surface are envisaged to be initiated in the 2030 timeframe (Figure 1), and involve the deployment of planetary rovers for mobility and habitation. Also indicated in the figure is a human-assisted sample return mission in the mid-2020s.

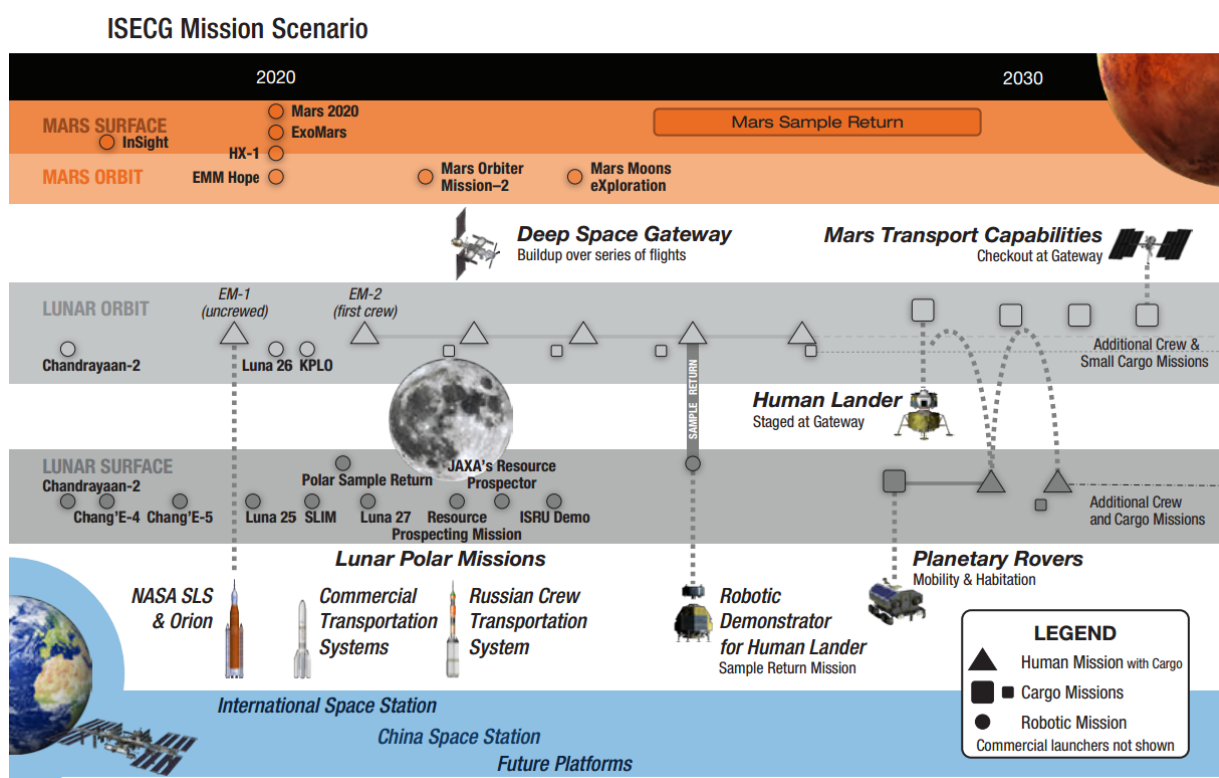


Figure 1: Global Exploration Roadmap (Issue 3). The HERACLES mission is referred to as “Robotic Demonstrator for Human Lander – Sample Return Mission”

The HERACLES mission concept has been built around this idea of utilising the potential availability of crew on the “Lunar Orbital Platform – Gateway” – or just “Gateway” in short – to develop and implement a robotic precursor mission, that in addition to incorporating human-assisted sample return, would also address key objectives for future human exploration of the Moon.

HERACLES is thus intended as a human-robotic architecture in the frame of preparations for future human exploration activities on the lunar surface.

⁴ https://www.globalspaceexploration.org/wordpress/wp-content/isecg/GER_2018_small_mobile.pdf

HERACLES Elements - Overview

The integrated 'Robotic Landing Stack' is the term used for the complete assembly of major elements that will land on the lunar surface in the HERACLES mission, which consist of:

- **Lunar Descent Element (LDE):** The LDE provides the propulsive means to transport the Robotic Landing Stack from Lunar Transfer Orbit (LTO) to the lunar surface, which following touchdown, is de-commissioned and becomes a passive element to support the Rover Garage Element (RGE) and Lunar Ascent Element (LAE).
- **Rover Garage Element (RGE):** The RGE is an interface between the LDE and the LAE providing a housing for the Rover and enabling Rover egress. Egress is possible via two ramps on opposite sides of the garage.
- **Rover:** The rover contains science instrumentation to enable the selection and a robotic arm to collect samples during a traverse around the landing site, and place them in Sample Container.
- **Sample Container:** The Rover carries a Sample Container into which a quantity of samples is stored temporarily. At completion of its local traverse, the Rover then returns to the landing site where the Sample Container is placed into the LAE.
- **Lunar Ascent Element (LAE):** The LAE transports the Sample Container (with samples) collected during the Rover traverse from the lunar surface to the Gateway, where it will be retrieved by robotic means and subsequently returned to Earth with the crew.

Mission Profile

The baseline scenario for the HERACLES mission profile is summarised in Figure 2.

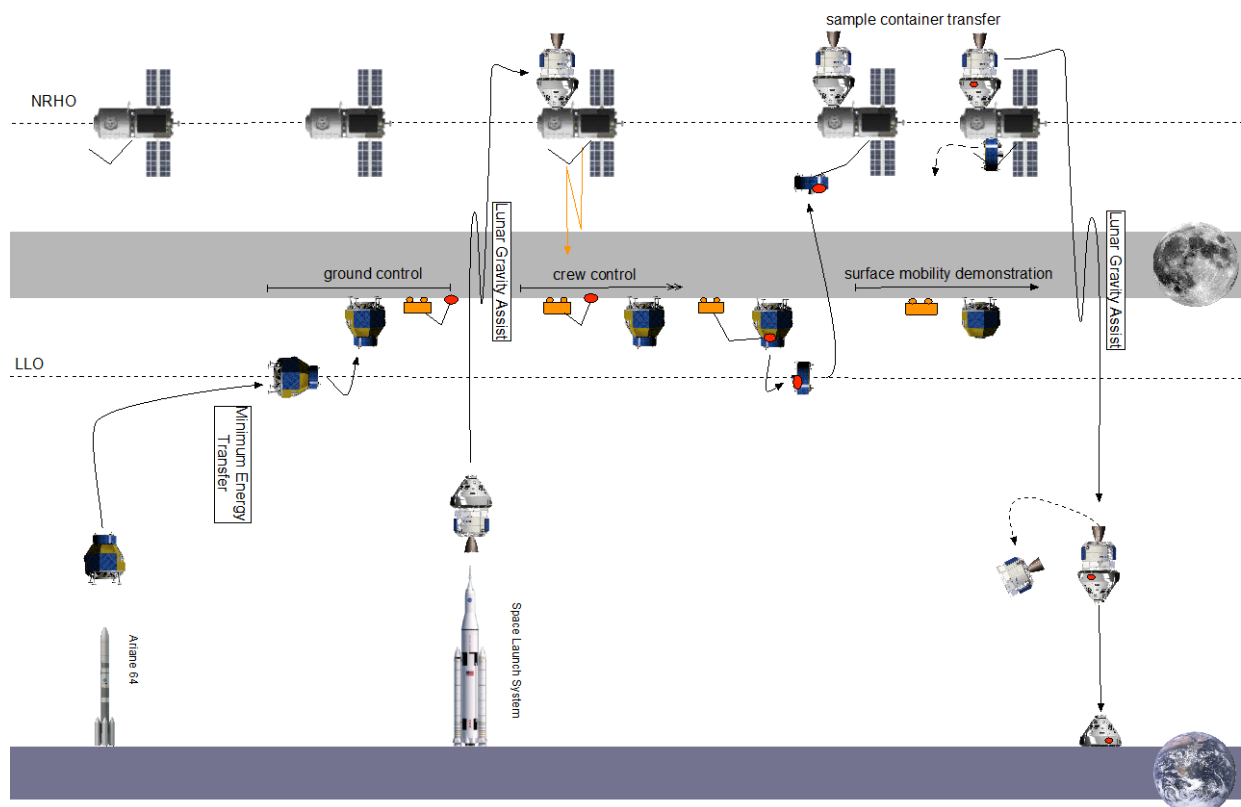


Figure 2: Baseline HERACLES Mission profile

The mission begins with the launch of a mid-sized launch vehicle to Lunar Transfer Orbit (LTO), where the main engine then performs the Lunar Orbit Insertion (LOI) via a Minimum Energy

Transfer orbit to arrive in Low Lunar Orbit (LLO), and subsequent descent of the Robotic Landing Stack to the lunar surface. The time period between touchdown on the lunar surface and lift-off of the ascender towards the Gateway is estimated at 70 Earth-days, i.e. three lunar days and two lunar nights, and is termed 'surface campaign'. During this time period, the rover performs a traverse in the area around the landing site (collecting samples on the way, and storing them in the sample container) controlled from Earth, and also by the crew during the period that the crew are present on the Gateway. The rover then returns to the landing site and the sample container installed in the LAE. Following ascent of the LAE, the rover then starts its surface mobility phase in which the rover travels long-distance for a period of ~ 1 year.

Landing Site

The ISECG have identified a number of reference landing sites for the first human landing mission⁴, each scientifically interesting in their own right, which collectively, could represent a long-distance traverse across the South Pole Aitken basin.

Based upon the ISECG potential landing sites, a series of investigations into suitable landing site locations were conducted where an extensive range of science objectives could be addressed.



Figure 3: The Schrodinger basin

The Schrödinger basin was one of those locations studied in detail, and which offers a landing area with reasonable slopes and operational constraints (e.g., illumination, communication) allowing the possibility to de-risk the technology for the future human landing and surface operations in a relatively controlled manner, whilst also offering significant science potential. The Schrodinger basin was thus selected as a baseline reference location for the HERACLES mission.

The HERACLES international Science Definition Team has tentatively identified an un-prioritised list of landing sites as follows:

- Jackson crater.
- Schrödinger crater.
- Theophilus crater.
- Flamsteed crater.
- Antoniadi crater.
- Mare Crisium/Proclus crater.



- TBD site to address anorthosite, olivine, young basalts or anorthosite, olivine and old (>3.9 Ga) samples.
- Copernicus crater.



ANNEX 4: SSTL AND GES LUNAR MISSION OPPORTUNITIES

Surrey Satellite Technology Limited (SSTL) and Goonhilly Earth Station (GES) plan to implement two lunar missions in the early 2020's that will offer flight opportunities for small hosted or deployed payloads. This document provides an outline of these opportunities, including a high-level description of the mission, technical interfaces and envisaged timelines.

SSTL and GES will offer a mission-level service to potential customers that includes:

- Assistance to the customer teams in design and implementation of their payload (e.g. information and data on the interfaces and expected environments for the mission)
- Integration of the customer payload into the larger SSTL/GES lunar mission spacecraft
- Delivery of the payload to lunar orbit
- Provision of communications bandwidth for command and control of customer payloads and the reception of payload data on ground
- A flexible software-based interface for principal investigators and customer operations teams to interface with the SSTL/GES mission

The SSTL and GES team are open to all kinds of payload proposals, as long as they can be accommodated within the constraints outlined below.

Opportunity #1: Small Payloads Delivered To Elliptical Polar Lunar Orbit

SSTL is currently planning to fly a small micro-satellite of the order 35 kg in mass that would be delivered directly to lunar orbit via a commercial lander enterprise. Alongside the micro-satellite, there is an opportunity to deliver Cubesats via the commercial lander too. Key characteristics of this mission are:

- Technical:
 - Volumes up to 6U are available for Cubesats.
 - Cubesats deployed into a 98 deg, 2 hour and 40 minute, 100Km x 800Km lunar orbit.
 - Interface via standard Cubesat deployer such as P-POD.
 - Power available during cruise is $\frac{1}{2}$ Watt per Kg; Release signal is 30 Watt peak for 60 seconds
 - Communication data rate during cruise is 10 bps per CubeSat (limited rate), 20 kbps/Kg (nominal rate). Higher data rates are possible in principle but subject to negotiation.
 - Once deployed, Goonhilly Earth Station provides the following X-band link for CubeSats:
 - Forward Link: up to 95 dBW
 - Return Link: G/T (@ f = 8.5 GHz) = 46 dB/K
 - The micro-satellite might also act as a proximity relay communications node for deployed CubeSats, but should not be relied upon for mission critical data return. Any such proximity services would be UHF.



- The proposed lunar transfer offered by the commercial lander involves a worst-case period of ~30 days waiting in a highly elliptical Earth orbit (e.g. GTO-like) prior to initiation of a Trans Lunar Injection (TLI) manoeuvre.
- **Timeline:**
 - The mission timing is driven by the commercial lander schedule. Currently the launch is foreseen in Q3 or Q4 2020.
 - Cubesats should be available for integration onto the lander ~6 months before launch (i.e. Q1/Q2 2020).
 - This timeline is approximate because, as noted above, it is largely driven by the programmatic timeline of the lander and its launch vehicle. Thus the fore-going is subject to change, although it represents the best current estimate.

Opportunity #2: Hosted or Deployed Payloads Delivered To Lunar Orbit

As part of a partnership between ESA, SSTL and GES, a larger dedicated spacecraft is planned to flown in the 2023 timeframe that would be the first ('Pathfinder') spacecraft in the establishment of a larger lunar communications and navigation system. This spacecraft will have the ability to carry up to 60 kg of customer payload mass, which may either be hosted payloads (remaining attached to the main spacecraft) or deployable payloads that are released into their own independent lunar orbit (e.g. CubeSats or other small nano-satellites). For these kind of payloads, the Pathfinder spacecraft will also offer communications relay services, potentially allowing better link budget performance for customers (compared with direct to Earth links), improving the data rates and data throughput, and increasing the utilisation of the customer payloads. Key characteristics of this mission are:

- **Technical:**
 - 60 kg of payload mass available
 - For deployable Cubesat customers it is anticipated that standard 'P-POD' deployment mechanisms will be carried on the spacecraft to enable transport
 - For deployable payloads a nominal maximum volume of 12U is foreseen to allow compatibility with standard hosting and deployment technology, although SSTL can consider non-standard sizes and volumes if requested by customers.
- The Pathfinder spacecraft will have a nominal mission lifetime of 5 years as a minimum. For hosted payloads, this therefore provides a platform for long-term operation outside of Earth orbit.
- The Pathfinder spacecraft will have ΔV capability to deploy payloads in different orbits during the mission
 - The final orbit for the Pathfinder used for relay will be an elliptical frozen orbit of ~1000 x 8000 km, inclined at ~55° to the lunar equator. The apoapsis of this orbit will be in the southern hemisphere. This would be long-term orbit for hosted payloads. Prior to this the spacecraft will offer several opportunities for deployment of free-flying payloads into different orbits:



- 1. If requested CubeSats can be deployed on-route to the Moon (i.e. after the final Trans Lunar Injection manoeuvre) to be placed onto a lunar flyby trajectory.
- 2. The initial orbit after Lunar Orbit Insertion will be highly elliptical (~200 x 15,000 km) inclined at ~75° to the lunar equator
- 3. A nominal Cube deployment orbit of ~200 x 4000 km is then baselined, after which the relay spacecraft transfers to the frozen orbit stated above. Customer payloads can also be deployed in this orbit if requested.
- The Pathfinder spacecraft also acts as proximity relay communications node for deployed users.
 - Both UHF and S-band proximity communications services will be offered to users.
 - The data rate is dependent on the characteristics of the user communications system. With a “minimal” system on the user side (e.g. low gain antenna, low power transmission) we expect a rate of 256 kbps should be feasible, with rates >1 Mbps possible with more capability on the user side of the link. SSTL will work with interested customers to determine the expected performance from the system.
 - Both forward (TC) and return (TM) communications services will be offered.
- Launch foreseen 2023
 - The initial launch orbit is an Earth-bound super synchronous (~300 x 76,000 km) orbit, from which the spacecraft uses its own propulsion to reach the Moon (total elapsed time from launch to lunar orbit insertion is envisaged to be ~30 days)