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REQUEST FOR INFORMATION

Technologies, science payloads, and commercial services for lunar missions

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Table of contents:

1 INTRODUCTION AND CONTEXT.....3
1.1 European Exploration Envelope Programme (E3P)4
1.2 Partnering with ESA4
1.3 Reference Documents5
2 SUBMISSION AND EVALUATION..... 6
3 ISRU PAYLOADS7
3.1 Submission template..... 8
4 LUNAR SCIENCE PAYLOADS 11
4.1 Submission template..... 11
5 LUNAR SERVICE CAPABILITIES..... 14
5.1 Submission template..... 14
6 CIS-LUNAR COMMUNICATIONS INFRASTRUCTURE 16
6.1 Submission template..... 18
6.2 Appendix A: Technical Description – requested data..... 20



1 INTRODUCTION AND CONTEXT

The European Space Agency (ESA) is requesting information relating to the elements of a mission primarily aimed at demonstrating lunar In-Situ Resource Utilisation (ISRU) technologies at the lunar surface and demonstrating commercial services and capabilities in support of future lunar missions. This ISRU Demonstration Mission is under consideration as part of a broader approach to ISRU preparation that seeks to establish the opportunities that ISRU may offer in support of future space exploration missions and to prepare the technologies, capabilities, knowledge and partnerships that will ensure that these opportunities are realised. The payloads operated on the mission will provide an essential in situ qualification and testing of technologies that are key to the eventual local production of consumables and materials to support the sustainability of future human exploration to the Moon and to other destinations.

This Request for Information (RFI) is open to European and non-European entities.

The goal of the ISRU mission is to demonstrate the feasibility of critical technologies that enable the production of water or oxygen at the lunar surface, and to prepare for the production of materials for manufacturing and construction in the future. The mission should also characterize potential ISRU feedstocks at a location, which is representative of those visited by future human missions. A first iteration of the mission's objectives and requirements are summarised in RD1. These objectives and requirements will be reviewed in the frame of ongoing work into the technical and programmatic feasibility of the mission, the preparation needs of future ISRU, and the outcomes of ongoing mission studies, technology activities, background research, and this RFI.

The mission may also provide opportunities for scientific investigations, which could be realised by scientific payloads addressing science questions in domains including astronomy, space physics, and planetary science. Of particular interest would be investigations that provide a scientific return whilst addressing knowledge gaps of importance for future utilisation of lunar resources.

Furthermore, the implementation of the ISRU mission shall demonstrate commercial lunar mission support services such as payload delivery, communications and mission and payload operations, thereby opening pathways for ESA commercial service procurements in support of future lunar missions. The Agency is interested in understanding the currently available or planned capabilities in these service segments.

This RFI has been issued in order to support the identification of potential suppliers, service providers, partners, technical options, and implementation approaches for:

- ISRU enabling technology demonstration payloads;
- Lunar Science payloads;
- Commercial services for payload delivery (incl. lander, mission and payload operations);



- Commercial cis-lunar communications infrastructure supporting robotic and human exploration (e.g. technologies, systems, and services)

For all aforementioned elements there is interest in identifying opportunities for implementation through commercial partnerships (see Section 1.2).

Important note: All information requested and provided in the frame of this RFI will be used for information and planning purposes only and is not part of an ESA procurement process. This RFI does not bind ESA to any present or future procurements actions nor does it create any rights for respondents in relation to any present or future ESA procurements.

1.1 European Exploration Envelope Programme (E3P)

The ISRU Mission is an intended technology demonstration missions currently identified as potential future element in the Agency's 'European Exploration Envelope Programme' (E3P) Period 2 (2020-22). With regard to ESA's long-term strategy for space exploration and the growing market for commercial lunar services, the Agency's role of a customer for commercial lunar mission support services may not be limited to the ISRU demonstration mission. ESA may use commercial services as they become available to implement future lunar missions consistent with the E3P mission roadmap. Missions of interest may include three classes of payloads: technology demonstrators (< 200 kg), lunar surface mobility platforms (200 to 500 kg), and ascent stages to return lunar samples (~ 1 tons).

1.2 Partnering with ESA

The Agency is supporting innovative partnership opportunities with the European space industry, SMEs, and new (non-space) actors to realise the ISRU Demonstration Mission. Various partnership approaches could be considered including contributions in kind, co-investments, and other shared approaches to realise the mission and the development of technologies. Related opportunities may include:

- joint mission implementation achieving common goals of the mission (jointly implementing mission with bigger payload complement);
- joint payload development;
- joint R&D and data exploitation (sharing scientific outcomes own provided payloads);
- leveraging competences outside the space sector;
- identifying joint business and technology development interests, resulting in a possible share of responsibilities, risks and benefits between the partners;
- alleviating cost of developing technologies through pursuing innovative funding sources;
- driving innovation and identifying markets for space & non-space applications that may result from implementing the partnership;
- other



1.3 Reference Documents

The following documents may contain relevant information to prepare the submission:

- RD1. Design Rationale & Requirements for Lunar ISRU Demonstration Mission (DRM), ESA-HSO-K-TN-0010, 26 February 2018, Issue 1, Rev 1
- RD2. Heiken, Grant, David Vaniman, and Bevan M. French, eds. Lunar sourcebook: A user's guide to the Moon. CUP Archive, April 1991
- RD3. ESA PROSPECT webpage, <http://exploration.esa.int/moon/59102-about-prospect/>
- RD4. ESA ISRU webpage, http://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/Water_and_oxygen_made_on_the_Moon
- RD5. ISECG polar volatiles bibliography, <https://lunarvolatiles.nasa.gov/>
- RD6. ESA Exploration Strategy, April 2015, https://esamultimedia.esa.int/multimedia/publications/ESA_Space_Exploration_Strategy/offline/download.pdf
- RD7. ISECG Global Exploration Roadmap, January 2018, https://www.nasa.gov/sites/default/files/atoms/files/ger_2018_small_mobile.pdf
- RD8. International Deep Space Communications Standard, www.internationaldeepspacestandards.com

All documents are publicly available, except for RD1. The document can be found in the following location during the submission phase for this RFI (see Section 2):

<https://esabox.esa.int/owncloud/index.php/s/qWnm36LJCId9CUC>
Password: LunarRFI%2018



2 SUBMISSION AND EVALUATION

Responses to this RFI should be sent to **lunarRFI@esa.int** by 08 June 2018.

Respondents are asked to prepare submissions using the provided templates (see following sections), completing all relevant fields. Proprietary information submitted in response to this RFI should be clearly marked.

Responses should be less than 10 pages. Additional information can be provided as annex. There is no limit to the number of submissions from any given entity. However, it is requested, that individual submissions are prepared and submitted as separate files.

Once received, a panel of specialists will review the submissions within ESA to inform future procurements and potential partnerships. After the review, ESA will use the information received as a reference for preparing the early phases of the ISRU mission including technical definition, approaches to procurement, and community engagement. ESA may contact respondents for further information on their submission and may invite them to provide support to mission preparation activities.

A dedicated ESA Workshop on Space Resources¹ is planned at ESTEC on 3-5 July 2018, followed by an industry day focused on upcoming related ESA procurement actions.

By submitting their responses, respondents agree that ESA may use material received to inform and support its further actions concerning the development of its programmes, which may include releasing part of it in the context of exchanges between ESA and its Member States and of future requests for information or tender actions, subject to the following:

- ESA will not release individual RFI responses as such.
- ESA will not release any information that a respondent has clearly identified as being “Proprietary Information” in its submission. Note: If a respondent requires additional non-disclosure arrangements before submitting its RFI response, ESA is ready to discuss this upon specific request.

¹ <http://exploration.esa.int/moon/59878-workshop-towards-the-use-of-lunar-resources/>

3 ISRU PAYLOADS

Information is requested on potential technology demonstration payloads that prepare for future ISRU applications at the lunar surface. These payloads could address knowledge gaps for future ISRU, qualify or reduce risk for critical technologies in an ISRU process chain or demonstrate end to end systems for the production of usable products in situ and from locally sourced materials.

Products for consideration might include, but are not limited to:

- Oxygen
- Water
- Metals and other materials for manufacturing of hardware (e.g. tools, structures) and/or equipment (e.g. solar cells, cables)
- Materials for construction (e.g. habitation)
- Other chemical consumables for life support, power systems and fuels.

Technologies to be demonstrated are expected to be associated with the various stages of product production including but not limited to:

- Regolith excavation and handling
- Beneficiation
- Loading and sealing
- Production of oxygen and water:
 - Chemical reactors (e.g. fixed bed, fluidised bed, rotating)
 - Chemical reactions for reduction (e.g. hydrothermal or carbothermal reduction, molten oxide electrolysis, FFC Cambridge etc.), product purification (e.g. desulphurisation) and reactant reclamation (e.g. methanation)
 - Heating and thermal management
 - Product handling and storage
- Production of metals and other materials (for manufacturing and construction):
 - Regolith mixing with binders/reagents
 - Sintering/melting of regolith
 - Handling of heated regolith (solid or molten) through the process chain
 - Processing of regolith-derived materials into final/semi-final products
 - Disposal/re-use of process by-products

Payload types to be considered could include:

- End to end system demonstrators in which a product is produced from lunar raw materials.
- Discrete technology demonstrators in which isolated technologies are demonstrated. These technologies would be those that are critical in the end to end process of product production, which must be demonstrated in the lunar environment and which cannot be sufficiently demonstrated in terrestrial environments.

- Prospecting payloads that important address unknowns about possible lunar feedstocks and their properties
- Payloads that prepare enabling technologies for resource utilisation (e.g. power systems that could enable lunar night survival or operations in dark and low temperature environments; systems which allow mitigation of potentially detrimental effects of the lunar environment – dust, thermal variations – on the long term operation of ISRU equipment)

Payloads for consideration would need to be feasibly ready for flight no later than 2025 on the envisaged ISRU demonstration mission. Potential procurement approaches for payloads based on partnerships between ESA and other parties (e.g. where development of the payload or underlying technology is co-funded with an industrial or international partner) are encouraged. In addition, submissions are sought that build on past flight heritage and previous technology investments, in particular those that apply technologies and expertise derived from terrestrial industries (e.g. mining, mineral processing and metallurgy). ESA may consider using early flight opportunities (2020 to 2023) made available by commercial lunar missions (e.g. cubesat on orbiting platforms, small payloads on lunar lander missions).

3.1 Submission template

The following template 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.

	ISRU Payloads	
3.1	Concept title	Title of the concept being proposed
3.2	Objective of the payload	The ISRU relevant objectives of the payload
3.3	ISRU applications	Rationale for the payload, including a justification for in situ demonstration on the lunar surface as opposed to relying on terrestrial facilities.
3.4	Working principle	A description of the principle by which the payload achieves the objectives
3.5	Scientific outcomes (if any)	A brief description of additional scientific results (e.g. for lunar and planetary sciences, exobiology, physics of granular matter, dusty plasma physics) that may result from the application of the payload at the lunar surface.
3.6	Mass	The expected mass of the payload with an indication of the confidence associated with the value
3.7	Volume	The volume and dimensions of the payload

3.8	Payload interfaces	Estimates of interface requirements from the payload, including power, data, thermal and mechanical interfaces.
3.9	Other support services required (e.g. robotics)	Additional requirements on service capabilities not provided by the payload. Examples include proximity to certain feedstock(s), surface mobility, or a robotic arm/manipulator.
3.10	Operations	Short description of the concept of operations.
3.11	Mission driving factors	Describe aspects of the proposed technology which are likely to drive the design of the overall mission (e.g. dependence on landing site, minimum duration of operations, requirements for mobility, high power requirements etc.).
3.12	TRL ² estimate and requirements to reach TRL 5-6	Current Technology Readiness Level (TRL) of the concept (1-9) and a brief description of the steps required to achieve TRL 5-6 by 2023.
3.13	Heritage, current status and ongoing relevant activities	The current development status including heritage, ongoing activities, and earliest delivery date of flight unit.
3.14	Related publications and/or patents	A list of relevant publications. This field should also be used for notification of any patents existing or pending relating to any part of the proposed concept.
3.15	Level of support/ funding	Information on present or previous funding for the development
3.16	Development funding options	Potential sources for development other than direct support from ESA.
3.17	Applications in other domains	Potential applications of the technology to other domains in both space and non-space sectors.
3.18	Major risks	Any major risks associated with the development of the payload or the application of the ISRU approach which it prepares.
3.19	Flight opportunities	General interest of making use of early commercial mission opportunities (cubesat, few kg lunar surface payload).
3.20	Partnership opportunities	Outline the potential for pursuing a commercial partnership with other providers, or ESA, including the partnership idea, high-level business case, and addressable market;

² <http://sci.esa.int/sci-ft/50124-technology-readiness-level/>

		<p>Identify partner(s) to jointly mature related technologies, products or service capabilities. Explore potential synergies with other industrial sectors;</p> <p>Suggest contributions that would be required from partners or ESA in order to implement the partnership.</p>
3.21	Additional information	Any further information deemed relevant to the submission.
	SUBMISSION AUTHOR DETAILS	
3.22	Lead author	
3.23	Organisation & address	
3.24	Email address	
3.25	Contact telephone	
3.26	Co-authors of the submission	
3.27	Background experience of the authors	

4 LUNAR SCIENCE PAYLOADS

The ISRU demonstration mission may also provide an opportunity for the delivery and operation of scientific instrumentation at the lunar surface. While scientific investigations are not the driving rationale for the mission it is foreseen that flight opportunities for scientific experiments should be provided.

Information is therefore sought on scientific instruments that could be accommodated as secondary payloads on the mission. No boundary conditions are placed on the scientific scope of investigations that can be considered, however mission resources (mass, power, data, robotics) for science payloads are expected to be limited and this should be taken into account. A preference is given to investigations that could also support the broader goals of preparing ISRU knowledge and capabilities (e.g. by characterising the composition or physical properties of ISRU feedstocks or the operational environment in which resources would be produced).

ESA may consider using early flight opportunities (2020 to 2023) made available by commercial lunar missions (e.g. cubesat on orbiting platforms, small payloads on lunar lander missions).

4.1 Submission template

The following template 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 Science Payloads	
4.1	Concept title	Title of the concept being proposed
4.2	Objective of the payload	The scientific objectives of the payload
4.3	Scientific context	Rationale for the scientific investigation and expected impact in the field
4.4	Working principle	A description of the principle by which the payload achieves the objectives
4.5	ISRU relevance (if any)	A brief description of how the results from the investigations performed using the payload could support preparations for ISRU.
4.6	Mass	The expected mass of the payload with an indication of the confidence associated with the value
4.7	Volume	The volume and dimensions of the payload
4.8	Payload interfaces	Estimates of interface requirements from the payload, including power, data, thermal and mechanical interfaces.

4.9	Other support services required (e.g. robotics)	Additional requirements on service capabilities not provided by the payload. Examples include proximity to certain feedstock(s), surface mobility, or a robotic arm/manipulator.
4.10	Operations	Short description of the concept of operations.
4.11	Mission driving factors	Describe aspects of the proposed technology which are likely to drive the design of the overall mission (e.g. dependence on landing site, minimum duration of operations, requirements for mobility, high power requirements etc.).
4.12	TRL ³ estimate and requirements to reach TRL 5-6	Current Technology Readiness Level (TRL) of the concept (1-9) and a brief description of the steps required to achieve TRL 5-6 by 2023.
4.13	Heritage, current status and ongoing relevant activities	The current development status including heritage, ongoing activities, and earliest delivery date of flight unit.
4.14	Related publications and/or patents	A list of relevant publications. This field should also be used for notification of any patents existing or pending relating to any part of the proposed concept.
4.15	Level of support/ funding	Information on present or previous funding for the development
4.16	Development funding options	Potential sources for development other than direct support from ESA.
4.17	Applications in other domains	Potential applications of the technology to other domains in both space and non-space sectors.
4.18	Major risks	Any major risks associated with the development of the payload or the application of the ISRU approach which it prepares.
4.19	Flight opportunities	General interest of making use of early commercial mission opportunities (cubesat, few kg lunar surface payload).
4.20	Partnership opportunities	<p>Outline the potential for pursuing a commercial partnership with other providers, or ESA, including the partnership idea, high-level business case, and addressable market;</p> <p>Identify partner(s) to jointly mature related technologies, products or service capabilities. Explore potential synergies with other industrial sectors;</p>

³ <http://sci.esa.int/sci-ft/50124-technology-readiness-level/>

		Suggest contributions that would be required from partners or ESA in order to implement the partnership.
4.21	Additional information	Any further information deemed relevant to the submission.
	SUBMISSION AUTHOR DETAILS	
4.22	Lead author	
4.23	Organisation & address	
4.24	Company website	
4.25	Email address	
4.26	Contact telephone	
4.27	Co-authors of the submission	
4.28	Background experience of the authors	

5 LUNAR SERVICE CAPABILITIES

The ISRU demonstration mission is foreseen to be implemented through ESA procuring commercial lunar service capabilities for the mission functions

- payload delivery to the lunar surface (incl. lander);
- mission and payload operations.

Related services currently are developed by the European and international private sector and are planned to exist by the mid-2020s. The envisaged approach assumes, for example, that ESA would procure an integrated service for delivering and operating the payload on the lunar surface from a commercial provider. By buying a ticket to the Moon, ESA would become one customer within a growing market for lunar exploration services.

5.1 Submission template

The following template 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 Service Capabilities	
6.1	Service title	Title of the lunar service being proposed.
6.2	Objectives	The objectives of the service capability.
6.3	Target customers/ market	Information on the addressable market size, types of customers, and competitive advantage of the service.
6.4	ISRU mission relevance	Brief description of how the service supports the implementation of the ISRU mission
6.5	Level of service	Description of the service performance and level(s) of service provided (e.g. interfaces with the ISRU payload, feasible landing sites, min/max duration of operations, level of operations support, surface mobility, level of power, data etc.).
6.6	Planned entry into service	First planned commercial demonstration of service
6.7	Estimated service price	Information on service market price. Separately for different levels of service, if applicable.
6.8	Operations	Short description of the concept of operations
6.9	Compatibility with launcher (if applicable)	Launch vehicle(s) envisaged/proposed and information on compatibility, including high level launcher interfaces.



6.10	Heritage, current status and ongoing relevant activities	The current status of the service development, and previous/ ongoing activities.
6.11	Planned service evolution	Information on planned service evolution (e.g. lander evolvable to human scale)
6.12	Current level of support/ funding	Information on current or previous level of support/ funding of service development (public and private)
6.13	Development funding options	Potential sources for development other than direct support from ESA.
6.14	Partnership opportunities	<p>Outline the potential for pursuing a commercial partnership with other providers, or ESA, including the partnership idea, high-level business case, and addressable market;</p> <p>Identify partner(s) to jointly mature proposed service capabilities. Explore potential synergies with other industrial sectors;</p> <p>Suggest contributions that would be required from partners or ESA in order to implement the partnership.</p>
6.15	Major risks	Any major risks associated with the development of the service
6.16	Additional information	Any further information deemed relevant to the submission, with the aim to support future ESA decision making on the implementation of the ISRU Mission.
	SUBMISSION AUTHOR DETAILS	
6.17	Lead author	
6.18	Organisation & address	
6.19	Company website	
6.20	Email address	
6.21	Contact telephone	
6.22	Co-authors of the submission	
6.23	Background experience of the authors	

6 CIS-LUNAR COMMUNICATIONS INFRASTRUCTURE

ESA envisages a strong European role in future lunar exploration, and currently prepares the development of capabilities for a cis-lunar communications infrastructure in support of the ISRU mission and future exploration activities. Capabilities of interest are those that would most effectively enhance ESA's deep space communications network (ESTRACK) and also leverage existing, planned, and new commercial communication services. Furthermore, related technologies, mission architectures, systems and services, are linked to the planned lunar 'Gateway', a lunar-orbit space outpost currently studied by the ISS partners NASA, ESA, Roscosmos, JAXA and CSA for construction in the first half of the 2020's. The Gateway is intended to have a power and propulsion system, a habitat(s) for crew visits, docking capability, crew and scientific airlock, and logistics modules.

In relation to the different mission operations to be supported by the communications infrastructure, the following specific capabilities and considerations apply.

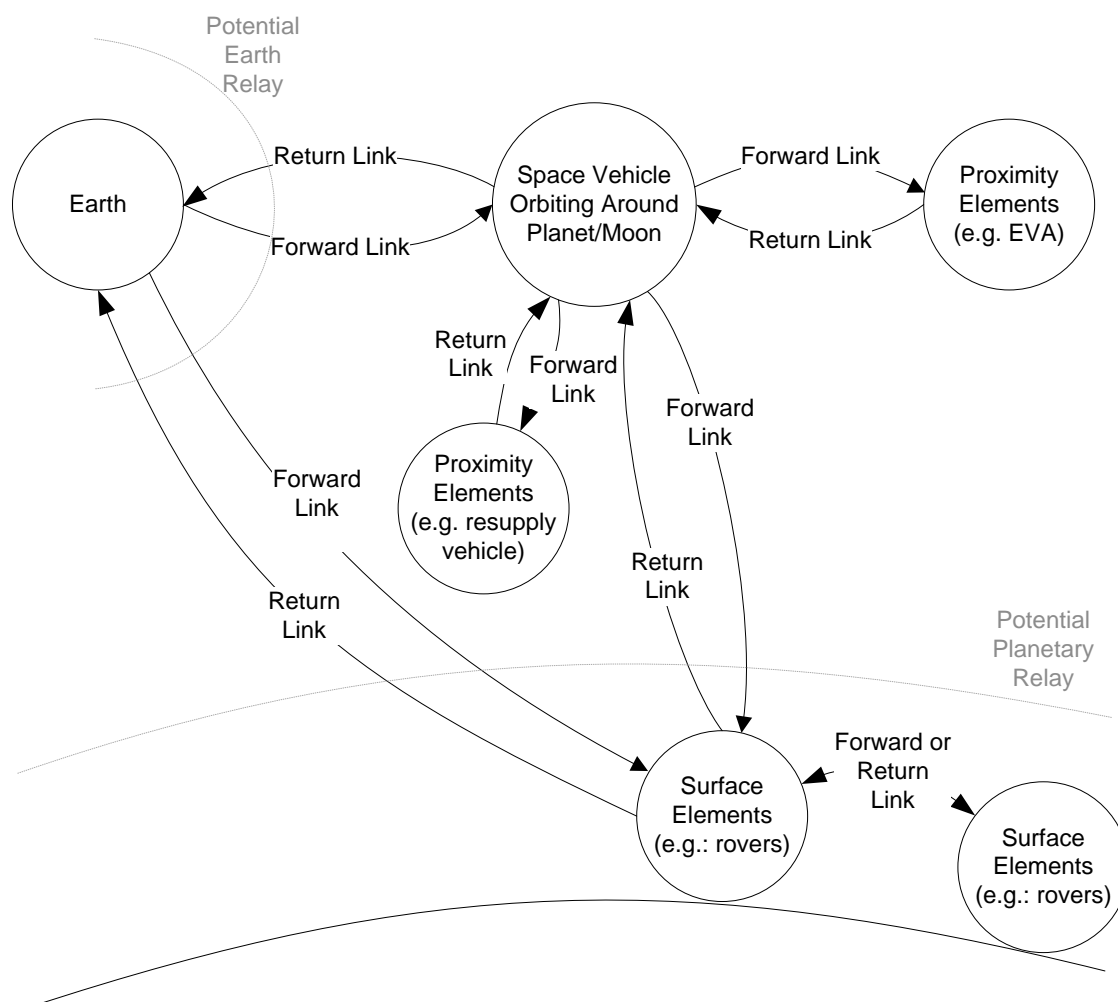


Figure 1 Functional communication paths in cis-lunar space (not necessarily a direct link)

Figure 1 shows the functional communication paths (arrows) between the different entities in the cis-lunar environment, called the communication system. A subsystem is a complete communication system located within one of these entities. A component is an element of a subsystem. Multiple proximity and surface elements could be simultaneously communicating with space vehicle(s) and each other. Additionally, the links defined could operate simultaneously. Any functional communication link elements could be implemented in different ways for example as follows:

- Point-to-point link;
- Intermediate relay between source and destination
 - Ground-based relay (e.g., Ground System Element-to-Space Vehicle);
 - Space-based relay (e.g., Space Element to Space Element);
- Surface Elements may interface with a space communications system that interfaces with a terrestrial telecommunications system.

Respondents are invited to provide alternative architectures as well.

The proposed architecture and service should minimize mass, volume, and power requirements on the space vehicle(s) as well as on the elements on the destination surface. The proposed architecture and service should aim to maximize overall availability. Communications coverage and availability should be maximized for crewed vehicles and elements. Some communication links may need to support radiometric tracking to provide range and range rate information to the navigation system. The system should be able to infuse new technology developments, upgraded protocols, etc. The following Table 1 provides expected use cases. The International Deep Space Interoperability Standards are available at RD8. The Communications Standards defines the functional, interface and performance standards necessary to support interoperable and compatible communications between spacecraft, ground infrastructure, other space and surface vehicles.

Table 1 Comms use cases

<u>Communication Link</u>	<u>Forward Link</u>	<u>Return Link</u>	<u>Availability</u>
Earth to Space Vehicle in Cislunar Orbit	2-10+ Mbps	10-100+ Mbps	~ 80% and no outage greater than 8 consecutive hours
Space Vehicle to Moon Surface Elements	1-10+ Mbps	5- 25+ Mbps	~ 80% and no outage greater than 8 consecutive hours
Element to Element on Surface of Destination	1- 20+ Mbps (two-way comm)		Maximize availability when in line of sight to communication asset
Space Vehicle and Element in proximity of Space Vehicle such as a resupply vehicle or EVA crewmember	up to 1 Mbps	up to 10 Mbps	~98% coverage with no outage greater than ~50 and 120 seconds for separation ranges less than 250 m and 3 km, respectively
Earth and Element on Surface of Moon	at least 16 kbps	at least 256 kbps	

Note: At this stage, the data rates, availability, and outage specifications identified in this table are indicative for nominal links. The data rates could be much less during off nominal conditions and the architecture should be able to accommodate this. The RFI respondents may submit alternative specifications with technical explanation for the alternative and related advantages and disadvantages.

6.1 Submission template

The following template 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.

Cis-lunar Communications		
6.1	Capability Title	Title of the communications capability being proposed.
6.2	Objectives	The objectives of the capability.
6.3	Setup and operations	Short description of the setup incl. ground segment, space segment, launch segment (if applicable) and concept of operations.
6.4	Technical description	See Appendix A (Section 6.2)

6.5	Target customers/ market	Information on the addressable market size, types of customers, and competitive advantage.
6.6	Relevance to lunar Gateway	Brief description of how the capability leverages the planned Gateway in lunar orbits (NRHO, DRO, LLO).
6.7	Capability performance	Description of the performance and level(s) of service provided to assets in cis-lunar space (e.g. data rates, frequency bands, availability, min/max duration of operations, level of operations support, navigation services).
6.8	Planned entry into service	First planned commercial demonstration of capability
6.9	Estimated price	Information on estimated market price. Separately for different levels of service, if applicable.
6.10	Compatibility with launcher (if applicable)	Launch vehicle(s) envisaged/proposed and information on compatibility, including high level launcher interfaces.
6.11	Heritage, current status and ongoing relevant activities	The current status of the service development, and previous/ ongoing activities.
6.12	Planned evolution of capability	Information on planned evolution (e.g. communications coverage in lunar orbit, data rate)
6.13	Current level of support/ funding	Information on current or previous level of support/ funding of development (public and private)
6.14	Development funding options	Potential sources for development other than direct support from ESA.
6.15	Partnership opportunities	<p>Outline the potential for pursuing a commercial partnership with other providers, or ESA, including the partnership idea, high-level business case, and addressable market;</p> <p>Identify partner(s) to jointly mature proposed capabilities. Explore potential synergies with other industrial sectors;</p> <p>Suggest contributions that would be required from partners or ESA in order to implement the partnership.</p>
6.16	Major risks	Any major risks associated with the development of the capability.

6.17	Additional Information	Any further information deemed relevant to the submission, with the aim to support future ESA decision making on the development of cis-lunar communications infrastructure
	SUBMISSION AUTHOR DETAILS	
6.18	Lead author	
6.19	Organisation & address	
6.20	Company website	
6.21	Email address	
6.22	Contact telephone	
6.23	Co-authors of the submission	
6.24	Background experience of the authors	

6.2 Appendix A: Technical Description – requested data

The RFI response on cis-lunar communications infrastructure should include a description of the identified commercial technology, capability, and/or enhancements to current concepts (can include any system/subsystem/component). The respondent is invited to provide information on the following aspects:

Architecture and Concept

- Associated flight and ground segment network architecture;
- Intent to provide flight and/or ground infrastructure (in full or partial) or data and operations service(s);
- Reliance on data relay satellite(s) including description of its orbital position, and/or resources from other commercial-based architecture;
- Description of coverage and availability supported by the architecture;
- Operational concept.

Functional and Performance

- Compatibility with the use cases identified in Table 1;
- Capability to maintain an operational communication link and recover from losses in an automated manner (e.g., rover traversing and keeping active link with orbiting station or Earth);
- Capability to support and/or provide:
 - minimum latency (e.g., real-time video, voice) communications;



- delayed communications using methods such as Disruption Tolerant Networking (DTN) and data storage;
- navigation features (such as ranging);
- concurrent low and high data rates for the purpose of maintaining active communications during critical operations;
- parallel communication with multiple surface elements and space vehicles;
- Expected usage frequencies, data rates, power, mass, volume, link budgets, and reliability (including redundancy concept if applicable), if not covered by answers to points above.

Service(s) and Technology

- Assessments and/or trade-offs of both optical and radio frequency (RF) communication technologies supporting the proposed concept (if applicable);
- Any asset(s) from the European Space Agency or its Member States which may be beneficial for the responder's approach to support Moon Human Exploration Communications;
- Description of service (e.g. data, operations) if the responder's proposal does not include flight or ground infrastructure