

Draft 10-year Plan (Roadmap) for Science and Technology on the Moon ESA/PB-HME(2023)11

Inputs to the Workshop

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- **ESA/PB-HME(2023)11**: paper providing axes of reflection to take decisions on which **science/technology surface activities, i.e. development of systems for flight** ESA will invest, at which scale and in which target timeframe.
- Jan 2023 EUB/PB version: overall context and Lunar Pathways.

Lunar Pathways (Annex 2 of ESA/PB-HME(2023)11)	Exploration Capabilities common to Moon and Mars (Annex p10 of ESA/PB-HME(2023)20)
Science	CAP-12: Surface Science
Transportation	CAP-7: Precision Entry, Descent and Landing
Communications and Navigation	CAP-6: Communications and Navigation
Energy Management	CAP-5: Power
ISRU	CAP-9: ISRU and ISM
Surface Mobility	CAP-1: Mobility
Crew and Habitation	CAP-10: Crew Elements
Robotics	CAP-3: Drilling, CAP-4: Robotics

- May 2023 May EUB/PB version:
 - lines of activities (with various programmatic frames and various timeframes) and associated budgets;
 - 3 scenarios across the lines and overall budget projections;
 - refinement of the Lunar Pathways;
 - 12 key questions presented during the PB.

Programmatic Lines of Development for Flight and Operations on the Moon

Line 1: European Payload for Argonaut #1, #2 and #3

Line 2: Astronaut Tools and Equipment for Lunar Surface Campaigns

Line 3: Large Surface Facilities/ Infrastructure(s)

Line 4: Small-class Opportunity Payloads

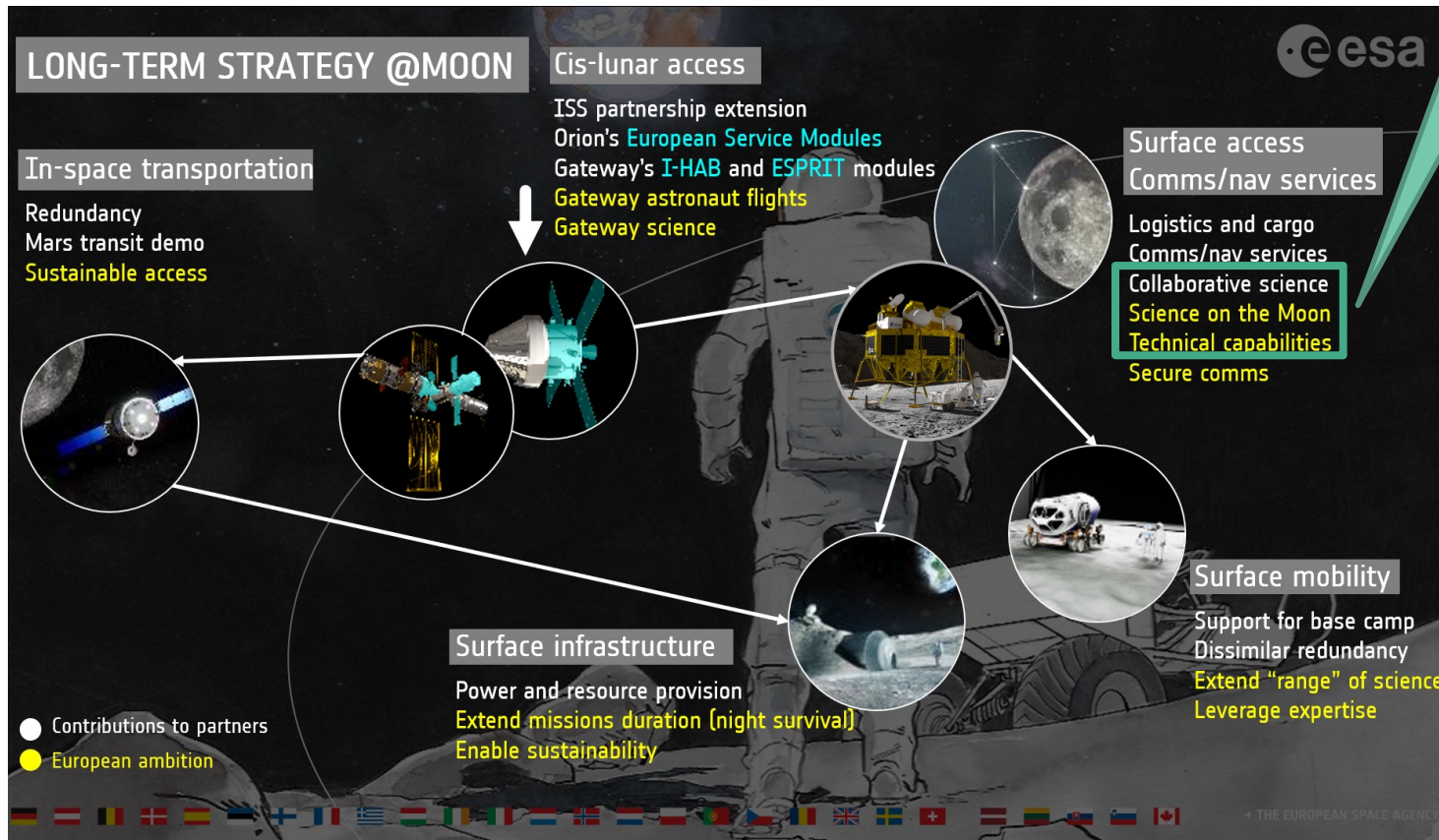
Line 5: Medium-class Strategic Payload for Artemis Missions

Line 6: Small Lunar Mission

- See also the May PB-HME questions (in Annex).

Terrae Novae & the 10-year Roadmap

Roles and benefits enabled by the Terrae Novae Moon strategy, through a stepwise build-up of capabilities in cis-lunar space and on the Moon surface.



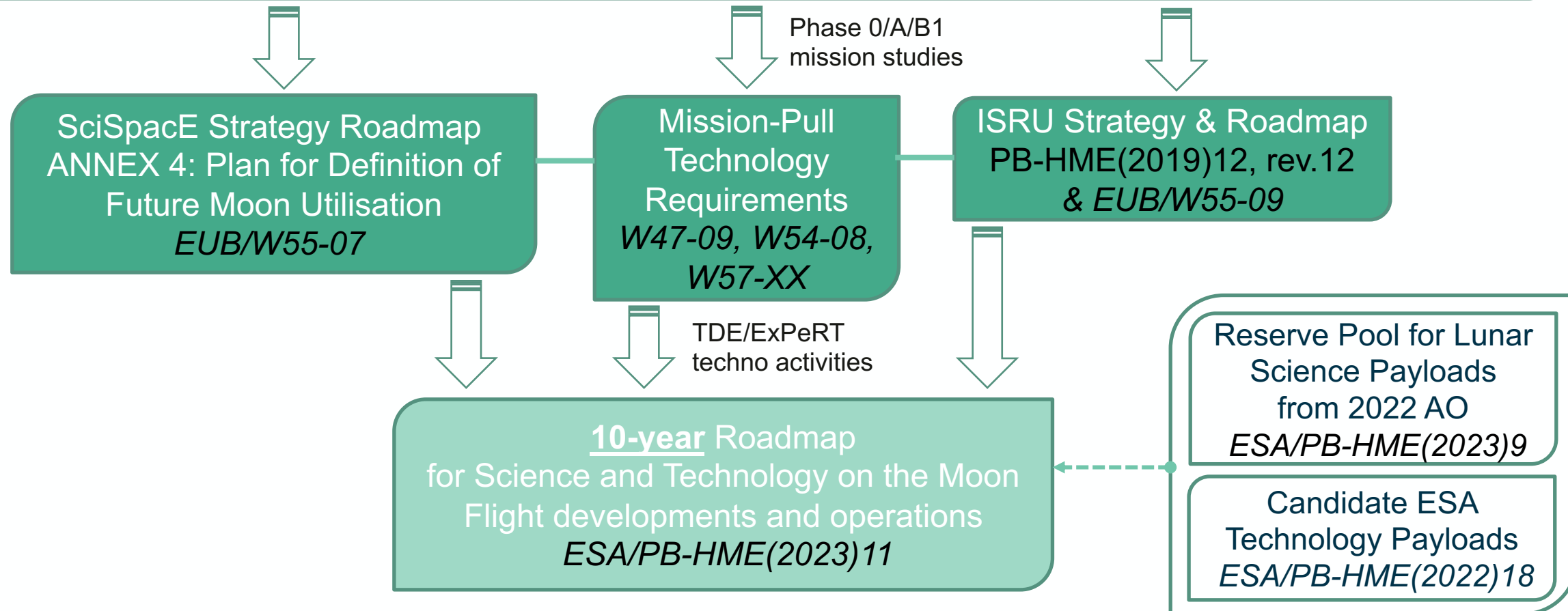
The 10-year Plan (Roadmap) for Science and Technology on the Moon supports:

- prioritising and establishing a few targeted domains of European excellence on the lunar surface for the next 10 years;
- continuing gathering knowledge about the Moon;
- preparing incrementally full-scale capabilities/larger missions;
- participating to a crewed campaign on the surface of the Moon;

based on current budgetary constraints and projections.

The 10-year Roadmap and the other high-level HRE documents

Terrae Novae 2030+ Strategy Roadmap (LEO, Moon & Mars) *ESA/C(2022)108*



Interface with NASA: Status of Argonaut Discussions

Argonaut LDE in ITT process

Argonaut Missions in support to Artemis Programme

Current candidates for Argonaut mission #1 under study with NASA are:

- Utility rover (CSA)
- Logistic cargo

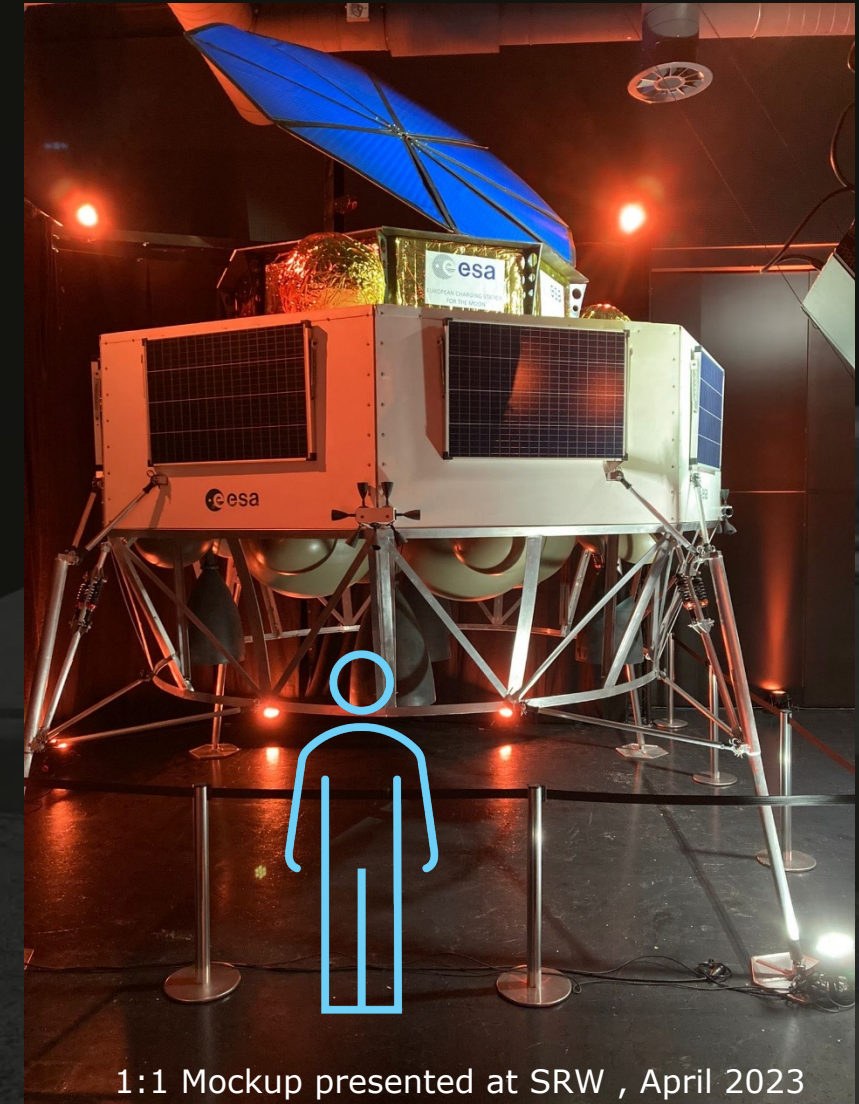
+ 'hitchhiker' ESA science/technology

Next TIM (#2) in July 19-21 in ESRIN (also with a trilateral with CSA). Main topics:

- IRD (from ESA)
- P/L description (From CSA)
- ConOps (all, Deployment mechanism)

Argonaut Mission #1 PrePhaseA ITT in Sept 23, MDR in Q1/2 2024, NASA MCR in Feb 24 (condition to be included in M2M ADD/ACR)

Argonaut Mission #1 Phase A/B1 in 2024/2025



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|--|------------------|
| Budget released from PILOT cancellation (E3P1) | + 25 MEuros |
| New budget from E3P3 CM22 | + 9 MEuros |
| E3P3 ISRU activities pre-allocation | - 5 MEuros |
| Allocation for existing (approved) payloads | - 3 MEuros |
| Assumption for new budget available in 2024 (release of contingency) | + 14 MEuros |
| TOTAL (<u>industrial + ESA</u>) | 40 MEuros |

Proposed Prioritisation of the Lunar Pathways:

Cat. 1 – highest priority

Lunar Pathways	Description	ESA flight development	Remarks
Energy Management	- Power generation, energy storage, thermal control solutions - To be advanced now with a) surface demonstrators b) a first flight system enabling night survival for science - Power Plant as a medium-term goal	ENDURE (Moon & Mars) <i>Note:</i> ExPeRT techno activities: RFCS, flexible solar array	- Key to gain more European autonomy in exploration in general - A must for a sustainable exploration of the Moon and return on investment - Potential for services at a later stage
Science	- To be continued with a priority on: Cat. 1.1: environment characterisation and monitoring Cat. 1.2: volatiles characterisation (in support to ISRU) Cat. 1.3: return of new lunar samples - To be complemented later by biology and human health and performance research	Cat. 1.1: ISS, Gateway, NILS and Mars Cat.1.2: PROSPECT EMS-CLPS EMS-LUPEX Cat. 1.3: Apollo, MSR	- Cat. 1.1: understanding the environments and both their impacts on our activities and our impacts on those environments - Cat. 1.2: understand the resources we find there and how they can be used - Cat. 1.3: role in sample return connects science, technology, and astronaut activity - All timely meaningful if prioritised now

Proposed Prioritisation of the Lunar Pathways:

Cat. 2 – medium priority

Lunar Pathways	Description	ESA flight development	Remarks
ISRU	- To be advanced in P3 at technology / study level (covered by ExPeRT, e.g. ISRU-DM study), with surface demonstration as a medium-term goal. - ISRU Plant as a long-term goal	PROSPECT	- Potential game changer - Unique European competences - Resources at the Moon still uncertain and unknown (see Science priority Cat. 1.2 - ISRU at the end of the chain of capabilities on the surface - Potential for services at a later stage
Surface Mobility	- To be advanced in P3 at technology / study level (covered by ExPeRT, e.g. European Moon Rover Systems). - Long-range mobility for science, mobility for PSRs access as a medium-term / long-term goal	Rosalind Franklin (Mars)	- Utility rover, Pressurised rover and Lunar Terrain vehicle for Artemis already led by other agencies
Robotics	- To be advanced in P3 at technology / study level (covered by ExPeRT, e.g. Robotic Manipulator) - Capability supporting other pathways: Science, ISRU, Surface Mobility	STA (Mars)	- Robotic arms and other types of manipulators - Drilling and other extraction systems

Proposed Prioritisation of the Lunar Pathways: Cat. 3 – lowest priority

Lunar Pathways	Description	ESA flight development	Remarks
Crew and Habitation	Focus on Life Support Systems. - To be advanced in P3 at technology/study level (covered by ExPeRT, e.g. Mars Transit Habitat CDF, LLS technos/MELiSSA). - Contributions to a habitat as a long-term goal.	ACLS (ISS) Anita-2 (ISS)	- Physical-chemical processes expected in a first stage considering short Artemis stays - Link with crew transportation

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- Gain experience in developing for and operating in lunar conditions
- Continue gathering lunar knowledge and data (both scientific and technical) feeding on-going developments and preparing for future larger ESA capabilities
- Create partnerships with different agencies (e.g. JAXA, CNSA, UAE....)
- Opens opportunities for commercial delivery to the Moon
- Keeps ESA present on the Moon between last payload delivery from E3P P2 in 2026 and Argonaut #1
- Addresses capabilities priorities in an incremental manner, allowing for demonstration
- Addresses scientific priorities in a timely way
 - HESAC feedback on the Moon annex to the SciSpace Strategy Roadmap is that resource exploration is not sufficiently addressed after PROSPECT (as a larger Polar Explorer mission is pushed in the longer term)

Line 4: Small-Class Opportunity Payloads

Ad-hoc Science Payloads on Partner Missions

2025-2028 timeframe

Selection and funding:

- Opportunities identified on the go (“first one – first served”)
- Instruments selected from the 2022 Lunar Science AO pool, privileging Science Priority Cat. 1.1 and Cat. 1.2, but also based on partner’s interest.
- ESA-funded instruments or in co-funding.
- Transportation and mobility (if needed) provided by partner at no cost to ESA

Concrete discussions on-going with UAE for an instrument
onboard their next generation polar rover (RX2, launch 2026 tbd)

SCIENCE Cat. 1.2:
volatiles characterisation

Next step: Pending conclusive discussions with UAE and with the potential European PI/payload provider, a fiche will be proposed for approval at the September or November PB.

Option 3: Technology Payloads

2026-2029 timeframe

Selection and funding:

- Selected from a Lunar Technology Payload Call to industry to be organised in autumn 2023; proposed to focus on Fuel Cells subsystem(s), possibly Flexible Solar Array (mid TRL)
- <20 kg class
- Payload ESA-funded (participation of GSTP/ScaleUp tbd) and/or co-funded with industry
- ESA procurement of transportation services to the lunar surface OR industry procurement OR co-funding

ENERGY MANAGEMENT

Relevant ExPeRT/TDE activities: RFCS, Flexible Solar Array

Next step: More details about the Call will be presented at the September PB, with a fiche for approval at the September or November PB

Line 5: Medium-Class Strategic Payload for Artemis Missions

Surface Deployed Lunar Environment and Weather Station 2028 timeframe

Rationales:

- Objective: monitor and characterize the integrated lunar environment including dust, plasma, radiation, exosphere, electric and magnetic fields over a period of multiple lunar days and ideally several years;
- Serves science and operations needs
- Includes self-contained power and communications package to support long duration operations of the instruments as a step on the Energy Pathway and as a possible customer for MoonLight
- Activity for crew on the lunar surface, connection with European astronaut missions
- Interest from NASA for recurring power and comm units for payloads from Artemis IV onwards
- Scalable (for other missions , e.g. Argonaut), evolutions possible (with RHUs, with other instruments)

SCIENCE Cat 1.1: environment characterisation & monitoring

ENERGY
MANAGEMENT

COMMUNICATIONS

SCIENCE Cat 1.1: environment characterisation & monitoring

ENERGY MANAGEMENT

- ## COMMUNICATIONS

Next step: Pending preliminary technical consolidation, a fiche in synergy with Line 1 (European complementary payload onboard Argonaut) will be proposed for approval at the September or November PB.

Line 1: European Complementary Payload Onboard Argonaut Missions

Assumption: The first Argonaut missions are contributions to Artemis and have a NASA Core Payload. It will be complemented by a European payload in the order of 100-150kg (TBC).

Proposed candidates for Argonaut #1:

- Opt. 1: Surface Deployed Lunar Environment and Weather Station

Selection and funding: instruments to be selected following a dedicated AO; instruments nationally funded (or in co-funding); ESA as payload integrator

- Opt. 2: Mobility with piggyback science, and possibly charging demonstration
- Opt. 3: Science Payloads from the Reserve Pool / Technology Payloads selected from a Call

depending on more consolidated mass allocation and its associated definition.

Next step: Pending preliminary technical consolidation, a fiche for Opt. 1 in synergy with Line 5 (payload for Artemis missions) will be proposed for approval at the September or November PB.

Possible candidates for Argonaut#2 and Argonaut#3: active biology lab, ISRU demonstrator, fuel cell demonstrator

Summary of Proposed Way Forward



- Line 1:** European Payload Onboard Argonaut Missions #1, (#2 and #3)

Line 5: Medium-Class Strategic Payload for Artemis Missions

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Lunar environment and weather station,
with long-duration operations

ENV. SCIENCE

ENERGY
(high TRL, operational)

COMMS
- Line 4:** Small-Class Opportunity Payloads

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| TBC one science payload, cooperation with UAE

VOLATILES SCIENCE

| Focused Call for one technology payload, commercial flight

ENERGY (mid TRL, demo)
- Line 6:** Small Lunar Mission

➤

Separate discussion in this workshop
- Line 2:** Astronaut Tools and Equipment For Lunar Surface Campaigns

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In discussion with NASA for mid-term
- Line 3:** Large ESA Facilities/Infrastructures

➤

In discussion with NASA for longer term

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- ➡ recognising that the available mass for such payloads may vary from one mission to the other.
- ➡ The document currently plans for the approval of one new payload at each period: it will be revised and aligned with the 2-year flight cadence of Argonaut,

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