

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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Introduction (1)



- 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



- To link more explicitly with the overall Terra Novae strategy.
- To propose a prioritisation of the Lunar Pathways, with justification.
- To go one level deeper in each Programmatic Line and identify new possible concrete flight development activities under CS#3 non-Argonaut to be approved and initiated in the coming months.
- Through the open and informal exchanges at this workshop, the Executive would like to determine Member States' views with respect to:
 - Priorities regarding capabilities and technologies to be advanced and / or maintained;
 - Priorities regarding scientific payloads and supporting capabilities;
 - The relative importance of the different lines;
 - The balance between working with NASA on Artemis, enabling other possible partnerships and acting autonomously;
 - The extent to which co-funding may be envisaged;
 - Where there is consensus among Member States and where there is not.

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



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 <u>10 years;</u>
- 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





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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



1:1 Mockup presented at SRW , April 2023

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 Recall of the current E3P budgetary situation to initiate <u>new</u> flight development activities in Period 3 (CS#3 – Non-Argonaut)

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 (industrial + ESA)	40 MEuros

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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 fist stage considering short Artemis stays Link with crew transportation

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Prioritisation of the Lunar Pathways: Summary



- All the Lunar Pathways have been introduced to NASA during the M2M (complemented by others) and will be discussed; we expect discussions at rather high level in the coming months.
- Considering the very limited budget currently available in P3 and the need for timely availability in the global landscape, it is proposed to focus the investment and initiate the first activities end 2023/beginning 2024 in the Category 1 Lunar Pathways: Energy Management and Science: environment characterisation and monitoring, volatiles characterisation, return of new lunar samples.
- In principle, The Transportation Path is considered covered with Argonaut, as well as the Communications & Navigation Pathway with Lunar Pathfinder and Moonlight; certain Technology Payloads may be considered later in P3 if the need arises.
- Due to its nature, the Small Mission Line, while answering to E3P lunar exploration objectives, may not follow this prioritisation.



Rationales

- 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.

Line 4: Small-Class Opportunity Payloads

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

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

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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







Line 5: Medium-Class Strategic Payload for Artemis Missions

Surface Deployed Lunar Environment and Weather Station 2028 timeframe

- Selection and funding:
 - Instruments to be selected following a dedicated AO, to be agreed with NASA
 - Instruments nationally funded or in co-funding;
 - ESA as payload integrator

Past relevant activities: E3P P2 studies

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.

SCIENCE Cat 1.1: environment characterisation & monitoring

ENERGY MANAGEMENT

COMMUNICATIONS



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





Key Questions (general)



- 1. What is your overall feedback on the suggested ESA ambitions for lunar surface Science and Technology in the next 10 years, considering affordability aspects?
- 2. What should be the priority among the candidate activities?
 - \rightarrow Which line(s) are a must?
 - \rightarrow Are there lines that shall be deleted?
- 3. What should be the share between Science and Techno Payloads (noting that this distinction is often blurred)?
- 4. To which extent should ESA implement activities for Science and Technology on the Moon independent from NASA?

Key Questions (per line(s))



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- Should ESA ensure a minimum European utilisation of every Argonaut mission, including the first three missions that are assumed to be driven by a NASA Artemis payload? – Line 1
- 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,
- 6. Is there consensus to invest in flight hardware for the Energy Path? Line 5 and others
- Is it important to 'bridge the gap' between the last of the six already approved lunar payloads (2026 launch) and Argonaut Mission #1? – Lines 4, 5 and 6

Key Questions (per line(s), co-funding)



- 8. Should we plan to have access to the lunar surface with transportation means other than NASA's HLS and Argonaut? For which timeframe? And role of commercial service providers ?
- 9. Should we support a more European landing/mobility service provider ? Line 4 and 6
- 10. When should we plan a first ESA-driven Argonaut mission (Mission #4 is assumed in the document) Line 3
- 11. Is co-funding with other ESA programmes (GSTP, Prodex, others) to be considered ? What are the advantages (other than budgetary)? What are the drawbacks?
- 12. Is national funding for payloads to be used (qv Science Programme; ExoMars etc.)? Advantages (other than budgetary)? Drawbacks?