Human and Robotic Exploration

ESA – BELSPO CM25 Day

Content

- CM25 Priorities
- LEO
- Moon
- Mars
- Science
- Technology

CM25 Priorities

Strategic resilience in uncertain times

EXPLORE 2040
THE EUROPEAN EXPLORATION STRATEGY

esa

Autonomy in the making. Build Europe's future exploration capabilities.

Reducing risk. Balance autonomous projects with multilateral partnerships.

Partnership diversification. Uncertainty lets Europe step up as a leader in collaboration and innovation.

CM25 priorities

Priority: Valorise past investments, reduce risks and develop autonomy
Perspective: Prepare Europe's future exploration capabilities in diversified partnerships

Continued European astronaut flights to the International Space Station securing the utilisation benefits
Study crewed transportation capability & European-led habitat

Deliver the planned European contributions to Artemis (ESM, Gateway, Argonaut), while delivering on European exploration objectives
Prepare incrementally a European led Lunar base, including Boots on the Moon

Implement ExoMars/Rosalind Franklin
ZefERO new mission (re-oriented from MSR/ERO)

Programme Proposal for Period 4 of Terrae Novae

	Autonomy in the making	Reducing risk	Partnership diversification
LEO	LEO Cargo Return Service Significant crew transportation studies	Non-European Commercial Cargo (CSOC) ESA Institutional Crew mission LCRS demonstration missions continuation	Post-ISS European-led options or significant contribution in commercial or Partner initiative
Moon	Small Missions European Robotic Moon initiative Argonaut mission #1	ESMs batch A focus Gateway continuation for go/no-go readiness	European Robotic Moon initiative
Mars	ERO repurposing	Maximising U.S. contributions to RFM	Advanced EDL Passenger spacecrafts

- Astronaut flights
- Science benefits
- Market access

Political decision level

LEO

Europe's sustained presence in low Earth orbit

Continuation activities
New activities
Autonomy in the Making
Reducing Risk
Diversification of Partnerships

2035

European Crew Transportation tbc

Post-ISS institutional & commercial platforms & utilisation services

LEO Cargo Return Service recurrent use

2030

LEO Cargo Return Service Demonstration (ALADDIN)

Autonomous Robotic Platforms

Astronaut missions

ESA Provided Institutional Crew Mission (EPIC)

CSOC Cargo Commercially Procured Offset (3CPO)

Commercial partnerships

2025

Continued ISS operations and utilisation

Accelerating the use of space

2025 ...

Ground-based and suborbital platforms for exploration preparation and science

2030

Deep space habitation ground demonstrator

Crew Transportation Studies

LEO Cargo Return Service – Overview

LCRS Phase 1 (2024-2026): ongoing with two consortia, led by

- Thales Alenia Space Italy
- The Exploration Company

LCRS Phase 2 (2026 – Execution of the ISS demo mission)

- Tender in Open Competition
- Minimum of 40% co-funding (across Phase 1 and Phase 2, for Phase 1 Contractors)

LEO Cargo Return Service – Evolving context

1) Latest timeframe for the execution of the demonstration mission to the International Space Station is mid-2029
   - After that, docking port will not be available due to permanent presence of US Deorbiting Vehicle

2) Uncertainty in availability of third-party customers in the early 2030s
   - ESA's role as anchor customer essential for viable business case with 40% co-funding
   - ESA demand (4 flights/3 years) insufficient to sustain two providers

LEO Cargo Return Service - ALADDIN

1) To ensure viable business case, ESA proposes to select only ONE Contractor at the end of Phase 1, and commit to purchase a first batch of four flights (2030-2032) upon successful execution of the demonstration mission.

2) There will be a requirement to execute the demonstration mission by mid-2029

3) Ongoing discussions with Member States on a Risk Reduction element in LCRS

Post-ISS transition

Period 4 Objectives

- Post-ISS scenario with increased industrial footprint compared to ISS
- Meeting the E3P high-level requirements (Colorado post-ISS statement)

Proposed thematics

- **Infrastructure studies:**
  - [Scenario 1: No European infrastructure investment]
  - Scenario 2: Limited European infrastructure investment ← Baseline
  - Scenario 3: European initiative for a LEO outpost, with various Partners contributions
- Research and system commodities
- Payload services to crewed platforms and autonomous robotic platforms
- Securing the supply sources for critical components

Post-ISS - Revised NASA CLD Phase 2 acquisition strategy

AIMING TO INCREASE FLEXIBILITY AND ACCELERATE THE TRANSITION TO POST-ISS

Mr. Sean Duffy

- No CLD Phase 2 down-selection; instead, support for U.S. industries will continue under a Space Act Agreement framework.
- Some relaxation of NASA's CLDP requirements is anticipated, particularly regarding how CLD Providers are expected to enable their initial IOC capabilities.
- NASA is expected to present a proposed CLD Certification Plan within ~3 months.
- NASA is expected to move forward promptly with the CLD Phase 2 RfP in the coming weeks
- While the Post-ISS studies with our industrial partners continue, an assessment of how this may impact the transition and full operational capabilities is needed in terms of industrial partners, utilisation, Astronaut missions and LCRS.

➔ Increased importance of Scenario 3 in an ever-changing environment

Moon

Europe's journey to the Moon

Continuation activities
New activities
Autonomy in the Making
Reducing Risk
Diversification of Partnerships

Europeans on surface
?
2033
Argonaut mission #2
Missions of Opportunity
2025
...
IPs &
2030
Argonaut mission #1
Prospect
2027
Small mission #1
2029
Robotic precursor mission

Gateway Lunar View
European on Gateway
2030
Small mission #3
3rd European on Gateway mission / Artemis tbc
Small mission #2
Gateway Lunar I-Hab
European on Gateway

esm-2
ESM-2 (2021)
esm-3
ESM-3 (2024)
esm-4
ESM-4 (2025)
2026
Lunar Pathfinder
ESM-5 (2026)
esm-5
2027
ESM-6 (2027)
esm-6
Gateway Lunar Link
lunar link
GATEWAY
2028
Moonlight

Understand & Demonstrate

Phase 1
2025-2030

Flight proof critical technologies and de-risk Phase 2 in areas such as power (night survivability), surface mobility and dexterity, and PNT

Map potential
landing sites

Characterise Lunar
Environment and resources

Build & initial utilisation

Phase 2
2031-2034

European surface infrastructure, extended to International Partners efforts

Enhanced with
advanced robotics

Live & Operate

Phase 3
2035 and beyond

First Europeans developing research activities

Progressive development of a **lunar economy using in situ resources**

Ultimately, lunar activities serve as springboard for deep space exploration

Delta's -Moon Destination-

1) Argonaut Mission-1 and 2 Payload Candidates under assessment

- ARGONET
- European Moon Surface Rover (mid class, 400-700Kg)
- NovaMoon as additional priority payload, developed by ESA NAV directorate – it requires a night survivability package – feasibility for joint delivery with the Rover to be assessed
- Scientific Payloads

2) Lunar Robotic Precursor Mission:

- Robotics, mobility payload(s), based on a high TRL of main components, potentially sourcing outside space market. Survivability capability as an asset, if possible.
- On-board scientific payloads on mission opportunity basis
- When: deploy the precursor mission to the Moon surface by end 2029

Small Missions to the Moon

- **Objectives:**
  - Shorter cycle missions – targeted 4/5 years Ph.A to launch
  - 50 M€ targeted cost – e.g. cubesat based, piggyback launch
  - Can provide exploration and/or scientific content
  - Programmatic opportunity for E3P small to medium contributing States
- Within Explore2040 implementation plan: contribute to goal of non-dependence; support longer-term major elements of the programme
- Implementation of min 2 Phase A/B1 missions proposed in P4, as well as min 2 mission for implementation Phase B2CD1
- New call proposed early 2026 pending CMIN25 confirmation

Mars

Consolidating Europe's Exploration of Mars

Horizon goal Europeans part of the first Mars expedition

2040

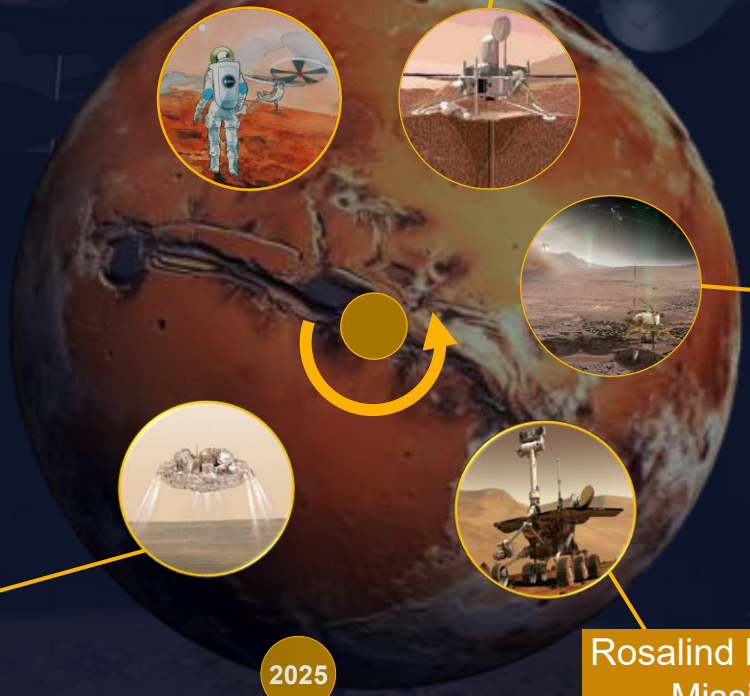
Advanced EDL-2 & surface science

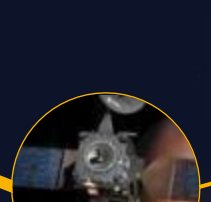
2037

ESA LightShip

2035

Advanced EDL & surface science





Mars Express

Schiaparelli Trace Gas Orbiter

2025

Rosalind Franklin Mission

2028

2032

ZefERO – repurposed ERO mission

Continuation activities
New activities
Autonomy in the Making
Reducing Risk
Diversification of Partnerships

ZefERO: ESA's alternative mission for ERO

Mission Strategic Shift

ZefERO pivots from ESA's Earth Return Orbiter to a dedicated European Mars science mission to be executed by 2032

Scientific Objectives

Focus on atmospheric dynamics, Martian winds, dust transport, and geological studies with state-of-the-art payloads. CubeSats and technology demonstrator payloads are being studied.

Communications

To meet the scientific and strategic needs of ZefERO and Explore2040 programme as a whole an upgraded S-, K-, X-band communications capability is being studied.

Industry Collaboration Opportunities

Industry can contribute to payload development, communications systems, CubeSats and technology demonstrators.

Focused Technology Areas for ExPeRT in P4

Demonstration missions driving technologies derisking

GNC
Advanced Guidance, Navigation and Control

Advanced Thermal Control Systems

Power pack
High performance batteries + Regenerative Fuel Cells (RFCS) + RHUs

ExPeRT demos derisking

- Lunar night survival <2030
- Lunar mobility <2030
- Crew launch abort system <2030
- Hypervelocity return ~2030
- Heavy landing >2035 (Moon/Mars)

Cryogenic throttleable engine

Thermal Protection Systems

Launch abort technologies

Demos
Technologies
Top priority

Mission concepts driven technologies derisking

esa

Studies
Technologies
TDE/GSTP contribution
Top priority

ExPeRT mission studies

- Post-ISS & crew vehicle derisking
- Deep space habitat simulator
- Lunar mobility / logistics (1t+ class)
- Sample returns
- Lunar base camp (shelter as step 1)
- Mars generic “tug”
- MEDaL (precision EDL & lander)

LSS subsystems + Autonomous system mgmt.

Dust mitigation systems

High thrust & Isp Electric Propulsion

RHU RTG RDG

Miniaturised Instruments and payloads

Advanced locomotion Wheels & suspensions + hopper

Multi - purpose Dexterity

Power system Incl. lunar power pack

Aerial mobility Drones

Gap filler Parachutes, propulsion equipment, human rated batteries

Advanced GNC Hybrid and AI enhanced autonomous navigation

ENDURE (EuropeaN Devices Using Radioisotope Energy)

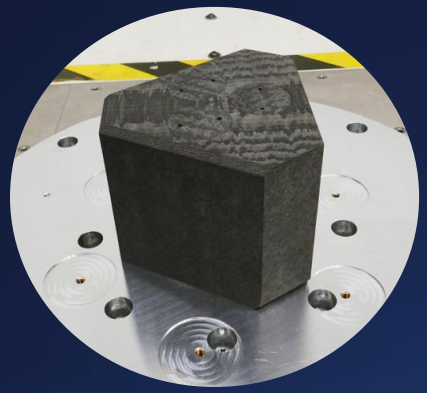
Staged approach:

2028 – 1 RHU → **2031 – RHUs** → **~2035 – ELHS** → **~2038 – RTG / RDG**

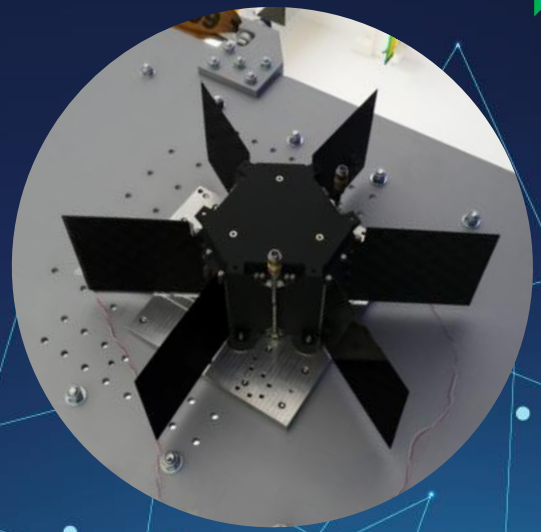
Exploration roadmap

One RHU (3 Wth)
on Mars (EXM-RFM)

A few RHUs (~50 Wth)
on the Moon (Argonaut)



ELHS (~200 Wth)



RTG (a few hundreds Wth + a few tens We)

Main challenges:

- Sourcing of Am-241 radioisotope (achievable, affordable, sustainable)
- Design according to nuclear safety requirements
- Industrial production capacity (achievable, affordable, sustainable)

→ End-to-end European operational capability for RPS:
RPS + spacecraft + launcher (Ariane-6) + launch range (CSG)

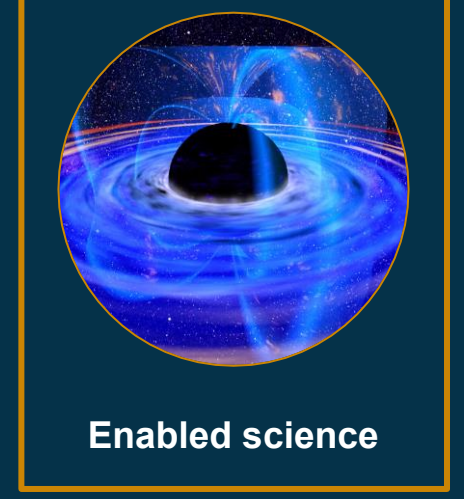
RPS = European americium radioisotope power source
RHU = European americium radioisotope heating unit (3 Wth)
ELHS = European americium radioisotope large heat source (~200 Wth)
RTG = European americium radioisotope thermoelectrical generator (Wth + We)
RDG = European americium radioisotope dynamic generator (Wth + We)

Main Science Elements in P4

Exploration Science: Streams and Priorities

Exploration-focused science

Exploration-enabled science



Uplifting science

Exploration Science

- Exploration-focused science
- Exploration-enabled science → will be excellence based
  → goes via AOs

Core activity → transversal to all destinations

Standardisation
Open Data and Software

CM25: E3P4 priorities with opportunities for LEO

Autonomous platforms

- Mix of activities covering both focused and enabled science that maximise use of autonomous platforms and free flyers.
- Focused on human research (where applicable), biology and physical sciences.

Research commodities and ready to fly payloads

First ITTs planned for Q4 2025

- Standardized capabilities, tools, materials, or elements that enable or support scientific investigations in space and are readily deployable across multiple LEO platforms with minimal adaptation.

Glovebox | Cold stowage | Incubator | Advanced microscopy | Centrifuge microscopy | Sensors and dosimeters | Wearables

End-to-end services for science

Call for proposals released on 3 Sep 2025

- ESA will use commercial LEO providers for end-to-end microgravity research beyond the ISS.
- Missions are planned as of 2026 on commercial platforms.

Study work for dedicated science modules

First opportunities planned for Q4 2025

- Study and preparatory work for future LEO payloads and modules in material sciences, physical sciences and life sciences
- Standardised, modular, and interchangeable approach

CM25: E3P4 priorities with opportunities for Moon

Radiation science

- Characterizing the high-energy space radiation environment—particularly galactic cosmic rays and solar particle events—and assessing its biological and material impacts to inform shielding and mission risk models

Next generation instrumentation & radiation payloads for lunar orbit and surface

Dust, meteoroids and debris - ASTERIA

- Active Sensors for Telemetry of Extraterrestrial Impactors - Development to flight of a payload to measure populations of dust and impactors in the deep space, cis-lunar environment encountered by Gateway. Other flight opportunities being assessed.

Early phases starting now. Flight development intended in P4

Lunar surface environment - OASIS/(Astro)LEAP

- Development to flight of the (Astronaut deployed) Lunar Environment Analysis Package ((Astro)LEAP) & the Outpost for Advanced Scientific Investigation Station (OASIS) surface power and communications support package. Robotic deployment considered. Will allow for comprehensive measurements of the lunar surface environment

Early phases starting now. Flight development intended inP4

Lunar reference models

- Two European reference models for the lunar environment and lunar resources will be developed. These are user-oriented products which are used to support mission planning and design and provide a reference for evolving policy and regulations in these domains.

CM25: E3P4 priorities with opportunities for Mars

ExoMars – Rosalind Franklin

- RFM aims to search for signs of life on Mars by drilling below the surface to analyse subsurface samples for organic molecules and biosignatures.
- Preparing for complex surface operations through joint simulations, field tests, and certifications

ZefERO – repurposed ERO mission

- Using the ERO platform to pioneer Martian wind and dust measurements while advancing geology in line with Explore2040.
- Science strawman payload being elaborated in line with mission constraints, building on LightShip science definition work.

Outlook CM28 Lightship and/or MeDAL

- LightShip: Electric propulsion tug as a transport service to deliver a range of passenger spacecraft around Mars. Communication and navigation services, as well as platform for small exploration and enabled science instruments.
- MeDAL: Focusing on more precise landings with heavier payloads. Further options for surface mobility (ground and/or aerial) and static payloads.

Inspire the current & future generations!

Thank you