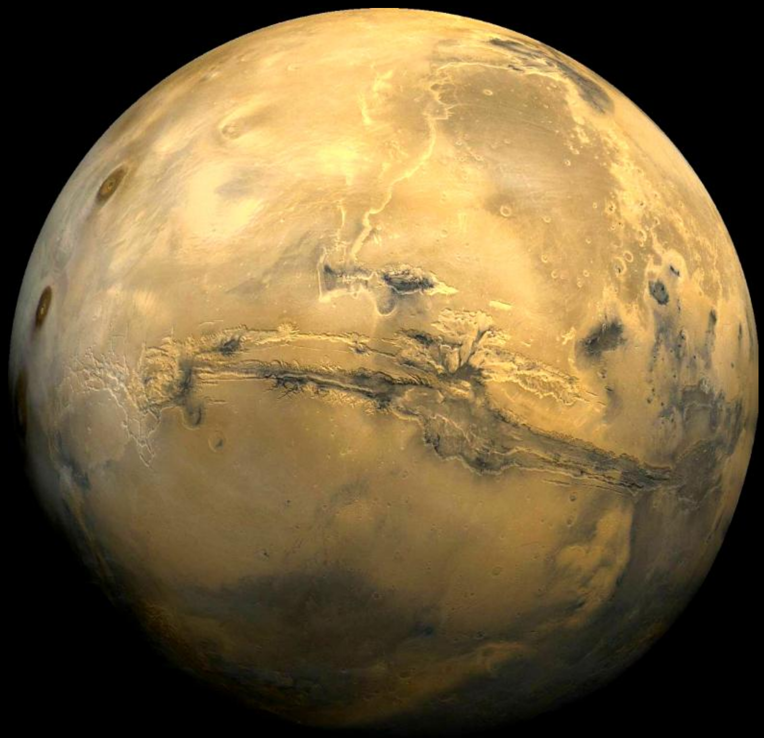
European Robotic Exploration Programme (EREP)



What is EREP Programme?

Objective: Develop Europe leadership in planetary robotic exploration

- ***Through a series of top-class missions to Mars following ExoMars***
- ***By developing long term enabling technologies***
- ***Build on ExoMars and MREP achievements***

What is proposed in EREP-1 at CMIN(2012):

- Prepare two missions for 2022 & 2024 launch opportunities.

  INSPIRE: Mars Network science mission

  PHOOTPRINT: Sample return from Phobos moon of Mars
- Develop Propulsion Engines and Nuclear Power Systems to TRL 5

Very positive recommendations on EREP from Human Spaceflight and Exploration Science Advisory Committee (HESAC) and Science System and Exploration Working Group (SSEWG)

HESAC & SSEWG recommendations on EREP

Extracts from HESAC recommendations

“ The HESAC Committee considers that both missions are not only desirable but necessary to ensure the success of MSR.(…) These missions are logical steps on the path to MSR”

“The Committee considers that the long-term enabling technology content of the Programme, in particular nuclear power sources, advanced propulsion, throttleable engines, and entry, descent and landing elements, is strategic for Europe and fully in line with future exploration missions, independent of their destinations and objectives.”

“ The Committee’s evaluation of the EREP Programme is very positive; it considers the programme to be well balanced between science and technology. The programme enables Europe to play a major role on the road towards a MSR mission, building on knowledge and expertise acquired in a stepwise approach.”

Extracts from SSEWG recommendations

“Both mission candidates were deemed very important scientifically and suitable for EREP first opportunities. Public outreach for both missions will be high.”

“ The SSEWG stresses that the long-term enabling technologies of the EREP Programme, in particular nuclear power sources, advanced propulsion, capability for landing on a distant body, sampling and handling mechanisms, and re-launch and re-entry technologies are critical to establish the desired European leadership in planetary space exploration.”

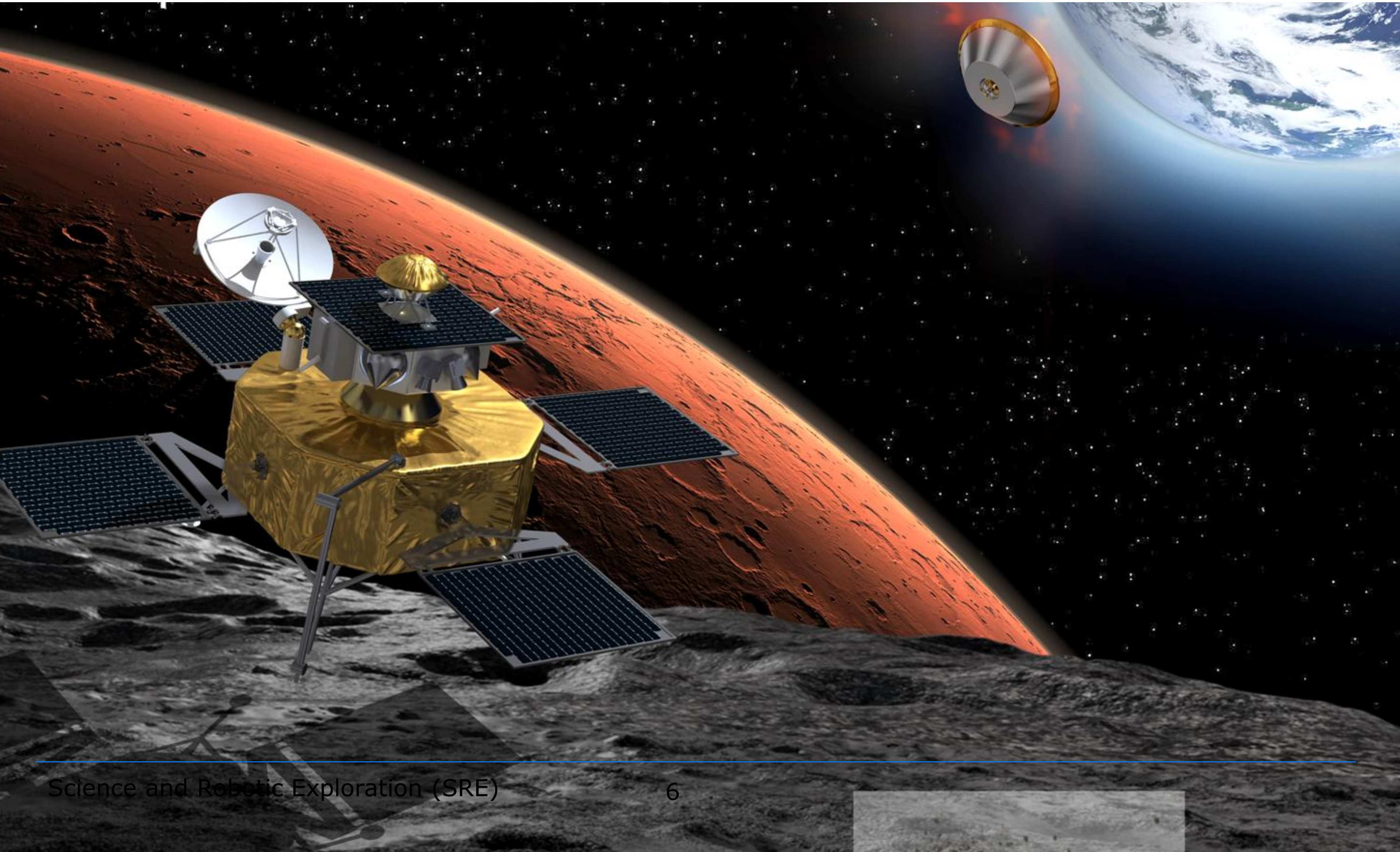
International Landscape and Potential Collaboration

- **NASA Mars programme in re-planning mode**
- **Russia/Roscosmos interested on ExoMars and for long-term collaboration with ESA**
- **International collaboration will be investigated while preserving EREP objectives and implementation**
    - First mission is proposed to be Europe-led
    - International collaboration can help for enabling a mission at each opportunity (e.g. scheme 80%-20% for mission #1, 20%-80% for mission #2)
    - Re-discuss the international Mars Sample Return mission as long term objective with major partners (NASA, Russia, others)

EREP Technical Approach for Mission Definition and Preparation

- **Stepped approach for missions and long term developments**
  - Realistic expenditure capabilities, mission cost ~ 750 M€
  - Doable missions, although challenging
  - MSR as medium/long term objective
- **Implement missions with mastered risks**
  - Reach TRL 5/6 for enabling implementation decision at CMIN(2015) with a reliable development schedule.
- **Pre-developments (TRL 6) for critical sub-systems for ensuring 2022 launch opportunity for at least one of the proposed missions**

PHOOTPRINT
Sample return from PHOBOS



PHOOTPRINT key features

- Build the enabling capability to **return a sample** from interplanetary space,
- **Robust, mature and low-risk mission** concept that is unique, challenging and exciting for the public, the science community and industry,
- **Make best use of synergies with other programmes**, e.g. navigation camera developed for the lunar lander, GNC development for MarcoPolo-R, etc.,
- Demonstrate key technologies required for the challenging **Mars Sample Return** mission,
- **Huge potential for public engagement** based on the first exploration of a Martian moon and the first return of a sample from an extra-terrestrial body by Europe.

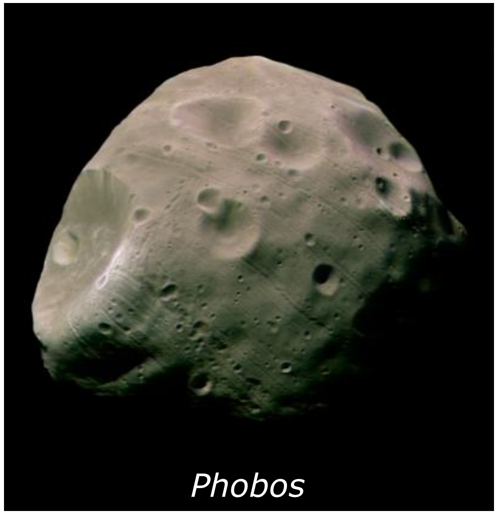
PHOOTPRINT
Science and Payload

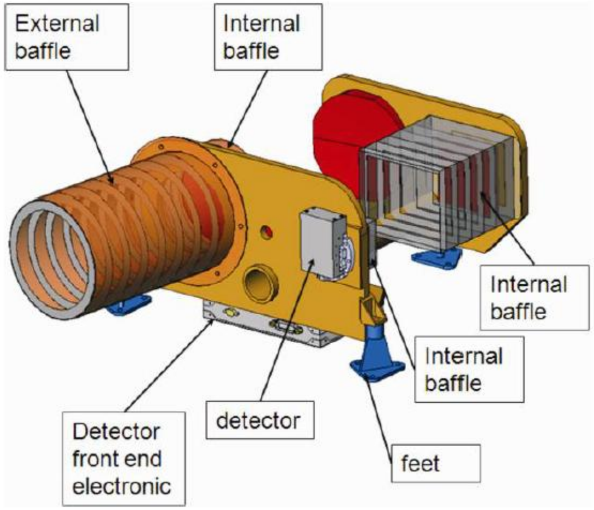
Science Case

- To determine which process was most likely to be responsible for the formation of the Martian moons:
  - Co-formation with Mars
  - Capture of objects coming close to Mars
  - Impact of a large body onto Mars and formation from the impact ejecta
- To put constraints on the evolution of the solar system

Payload of 30 kg

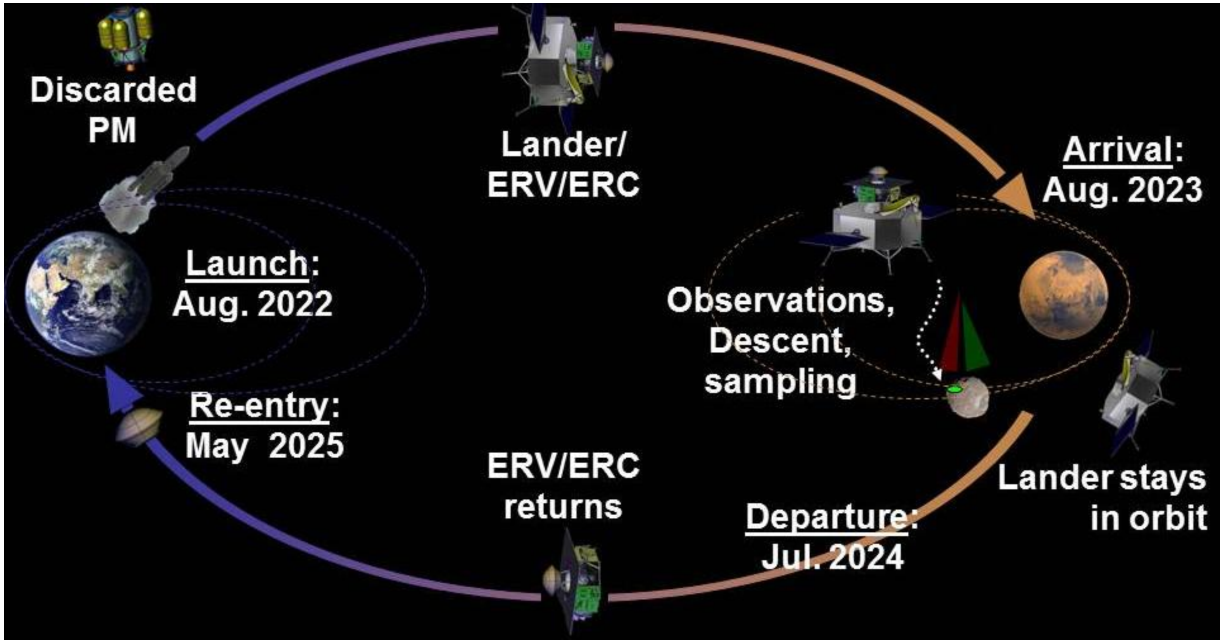
- Wide, narrow-angle & close-up cameras
- Visible/NIR spectrometer
- Mid-IR spectrometer
- Radio science (part of the lander TT&C)


Phobos



Conceptual drawing of the narrow-angle camera

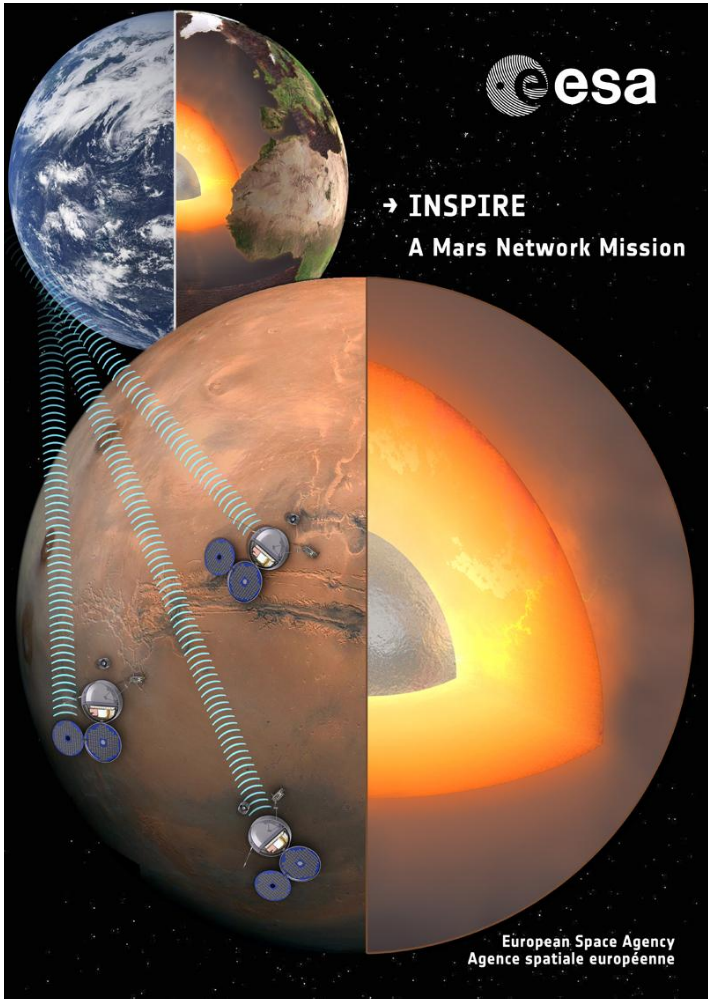
Mission Profile



- **Ariane 5** launch Aug 2022 from Kourou
- Escape to Mars, arrival at Mars in Aug 2023. Return to Earth in May 2025 < 3 years mission
- 12 months around Phobos/Mars dedicated to science observations and sampling.
- Staged Space segment: Propulsion Module, Lander/Orbiter, Earth Return Vehicle, Re-entry Capsule.
- Sample curation in receiving facility and investigating analytical laboratories.

INSPIRE
Network Science Missions

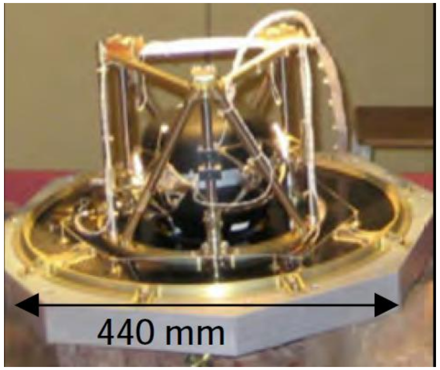
- **Carrier spacecraft with 3 landers.**
- **Launched with Soyuz Fregat** from Kourou into GTO (3180 kg spacecraft composite incl adapter)
- Carrier releases in sequence **3 landers** at Mars arrival, then breaks up and burns up in Mars atmosphere (Planetary Protection compliant).
- Each lander performs ballistic **entry, descent and airbag landing**.
- Surface platform of 119 kg deployed on the Martian surface with **Direct to Earth comms**.
- Deployment of instrumentation with **a robotic arm**.
- **Long duration operations** (goal >1 full Martian year) on the Martian surface.



Science and Payload

Science Case

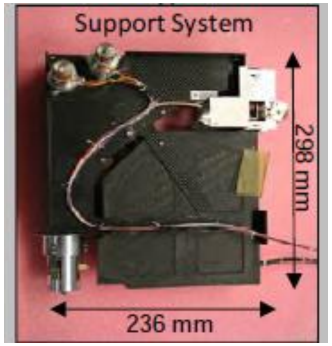
- Determine the <u>interior structure of Mars</u>, its rotational parameters and its atmospheric dynamics
- Provides unique and critical information about the fundamental processes of <u>terrestrial planetary formation and evolution</u>



SEIS sphere and levelling mechanism

Payload of 15 kg including robotic arm

- Seismometer
- Mole with Heat Flow and Physical Properties Probe
- Meteorological Boom
- Radio-Science, potentially part of lander TT&C
- Camera



HP3 support system and MOLE

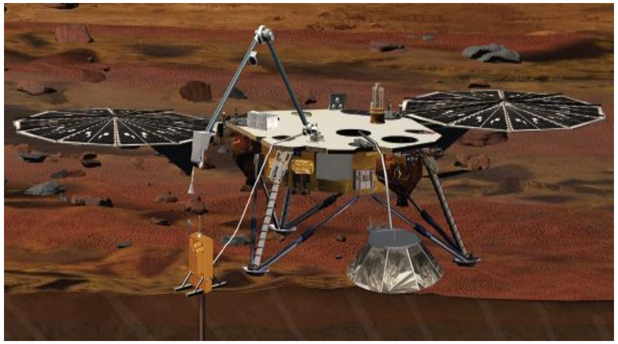
Mature Payload

- Derived from ExoMars Humboldt
- Planned for 2016 NASA InSight

Link to other missions

ExoMars

- INSPIRE represents the **second generation of landers** (the first being EDM) with a higher payload to entry mass ratio.
- Relying on EDM technology developments, complemented by dedicated activities (airbags, altimeter, European IMU and miniaturisation): mission doable in 2022
- Trace Gas Orbiter could be used for data relay and coupled orbital measurements



InSight NASA Mission

- Discovery Programme, 2016 launch
- Single geophysical station with similar instruments as for INSPIRE

PHOOTPRINT and INSPIRE key technologies

PHOOTPRINT

- Guidance, Navigation and Control,
- Sampling mechanism, sample transfer and conditioning,
- Earth re-entry vehicle at high speed (12 km/s) using crushable material developed for ExoMars,
- Sample receiving facility

INSPIRE

- EDL based on ExoMars EDM technologies, but with airbags
- Miniaturisation of electronics, mass efficiency
- Communications
- Robotic arm and instrument deployment
- Surface operations

Enabling technologies : Propulsion

Work being done in MREP

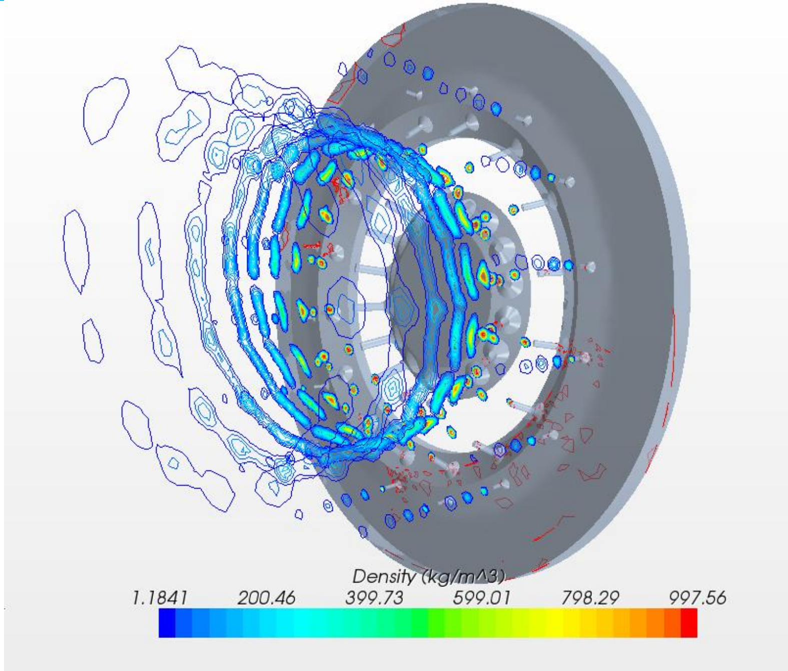
- 1000N bi-prop engine design to TRL3
- Throttleable mono-prop engine development to TRL4

Potential applications

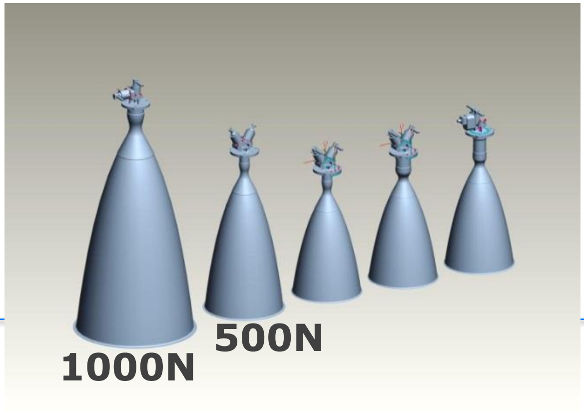
- Mars orbiters, MSR-Orbiter
- Planetary soft/precision landers

Next steps

- EM of high-thrust engine
- Breadboard and testing of throttleable engine



Simulation of injector flow



High-thrust engine size comparison

Enabling technologies: Nuclear Power Systems (NPS)

Objective

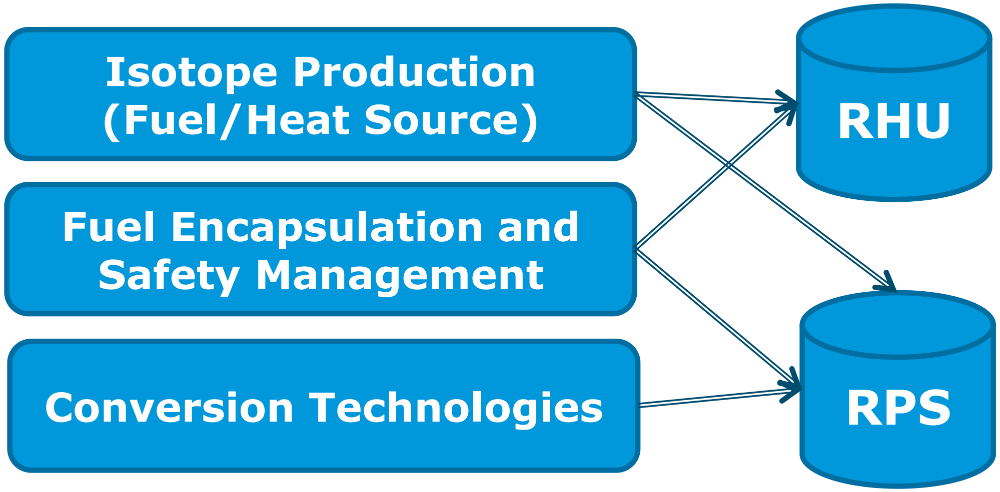
Europe to develop a Radioisotope Heating Unit (RHU) and Radioisotope Power Source (RPS) in support of Mars and all exploration missions

Work being done in MREP

Initiation of activities for major NPS subsystems

Next steps

- Reach TRL 5 for critical subsystems
- Converge on launch safety procedures & requirements
- Decision on NPS fuel facility development by 2015



NPS Enabling technology: Radio-isotope Production

Work being done in MREP

- Feasibility Studies selected ^{241}Am as European fuel/heat source baseline
- Re-processing of nuclear waste from power production plants
- Beginning isotope production (full process laboratory scale)

Potential applications

- Mars and planetary exploration missions

Next steps

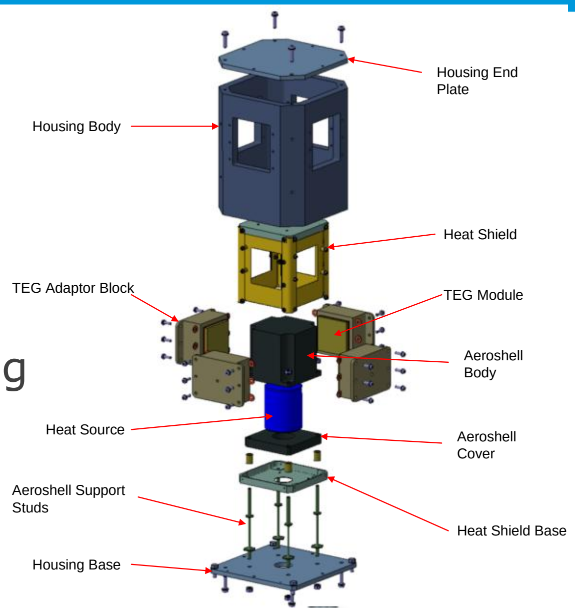
- TRL5 for fuel production
- Full-scale production plant, including safety provisions

The Sellafield Nuclear Site, England

NPS Enabling technology: Encapsulation and conversion systems

Work being done in MREP

- Fuel encapsulation (TRL 3/4)
- End to End Safety management
- Design, breadboarding and testing (TRL 3/4) of
  - Small-scale RTG (1-50W_e) excluding nuclear heat source
  - Stirling based Radioisotope Generator System (≈100We) excluding nuclear heat source

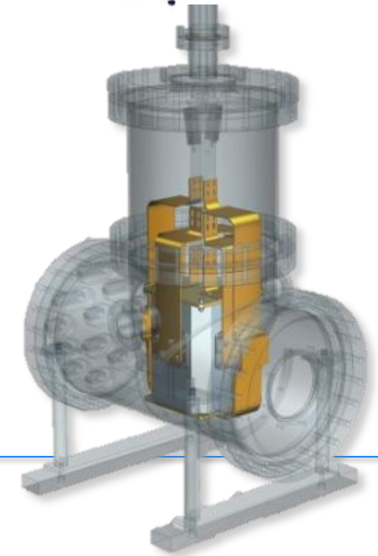


Potential applications

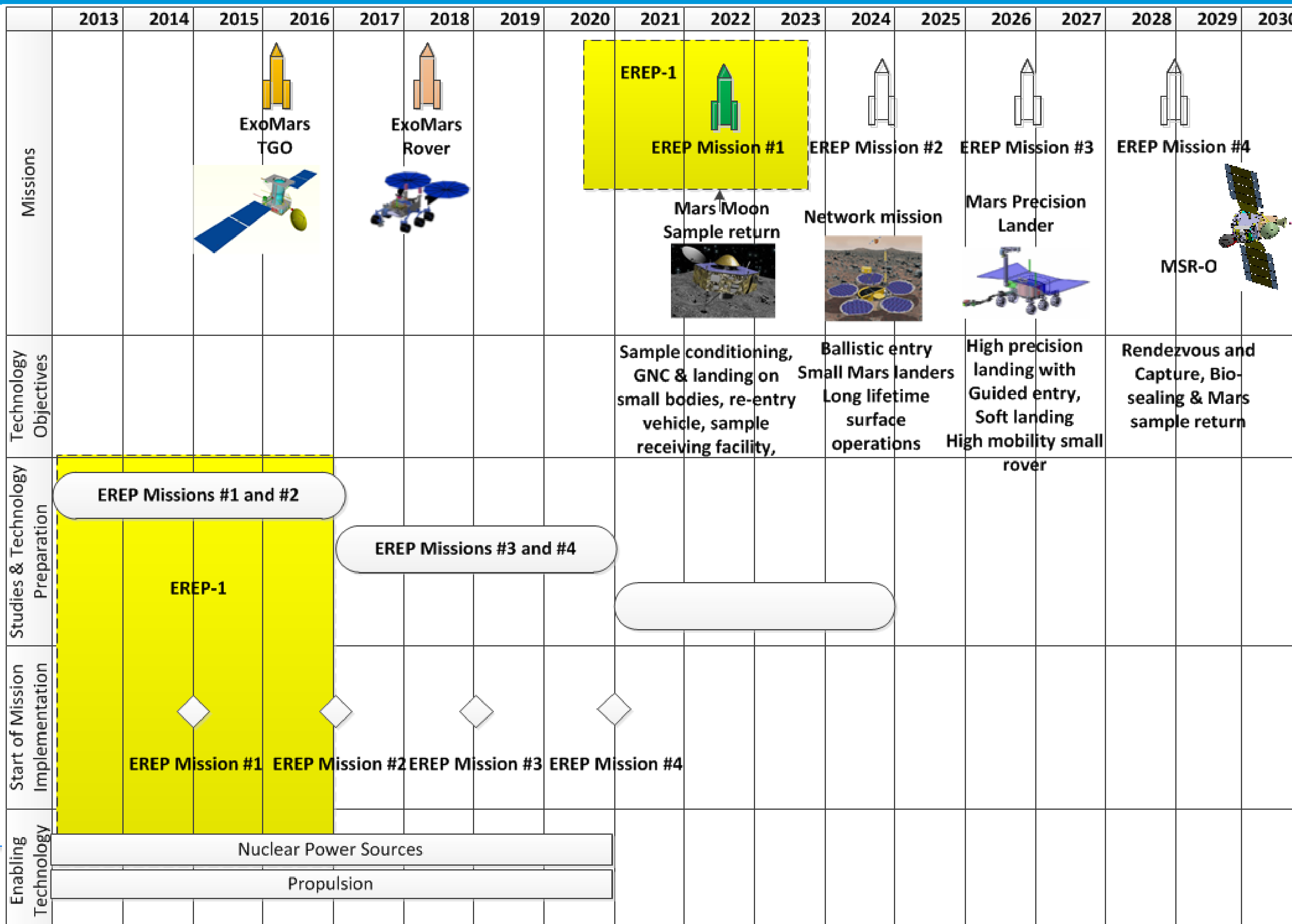
- Mars and all exploration missions

Next steps

- Raise technology to TRL 5
- Converge on launch safety procedures and requirements



EREP roadmap



EREP Financial Envelope for C-MIN 2012 and schedule elements

- **Total financial envelope (M€, e.c. 2012): 115 M€**

Mission studies and technology preparation (TRL5):	44
Pre-developments (TRL 6) for 2022 mission:	24
NPS	35
Propulsion:	12

- **Schedule elements**

First technology work plan:	Q2 2013
Selection of 2022 mission:	Q3 2014
Go-ahead on NPS development:	Q1 2015

The End

Surface Platform

Configuration	• 1.15 m diameter clamshell lander • Solar panel deployed from lander lid
Landing Site	• Latitude: -15 to +20 degrees • Altitude: < 0 km MOLA • Accuracy: ~100 km
Lifetime	• Goal >1 Martian year
Data Handling	• Based on “Tailored On-Board Computer for planetary landers” MREP development • ~5 Gbits of mass memory to store data during solar conjunctions
Thermal	• Warm electronics box (WEB) with aerogel insulation up to 10 cm • Potential use of RHU to enhance mission lifetime • Loop heat pipe connecting WEB to radiators
Power	• Solar array of ~2 m^2 sized for 550 Wh/sol at optical depth of 2 • 6.2 kg Li-ion battery sized to deliver 550 Wh with 60% DoD • Dust removal system to extend lifetime
Communications	• MREP development of dual UHF-X band transponder • X-band direct to Earth link, 40 cm steerable antenna, >1.4 kbps @2.6AU • Data relay capability compatible with any existing orbiter using proximity-1 protocol
Mechanisms	• Self-rightning hinge • Robotic arm for instrument deployment