# SCIENTIFIC RATIONALE FOR A EUROPEAN MARS EXPLORATION PROGRAMME

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ESLAB-09, ESTEC
15 May 2009

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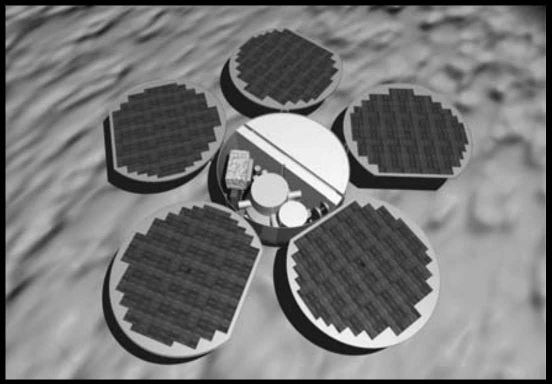
# Europe playing major role in Mars Exploration

2003


2016—2018



2020

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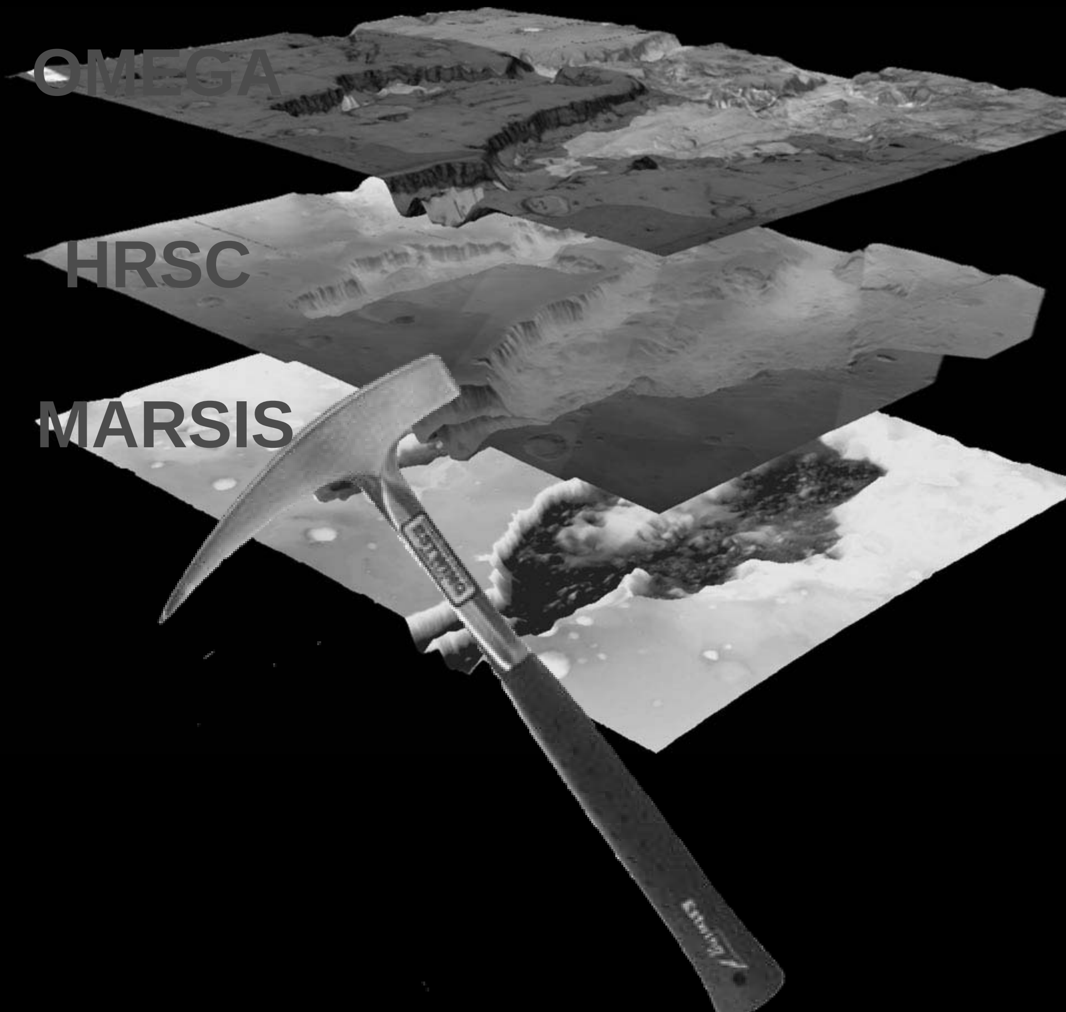
# Building a geoscience model of Mars





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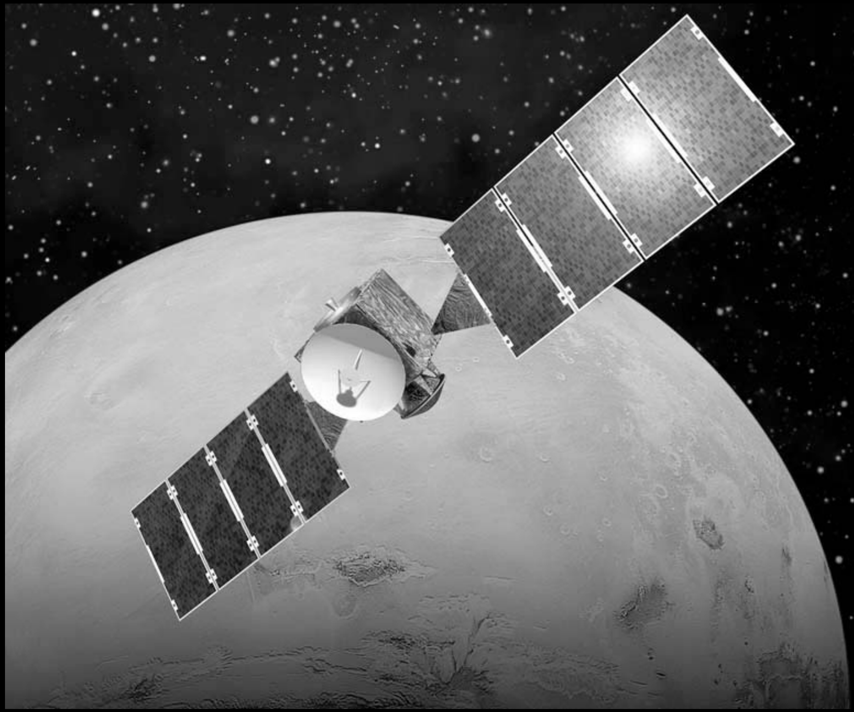
# MEX Science Status

- Completing HRSC global detailed imaging coverage
- To complete MARSIS subsurface sounding (North pole) in 2010-11
- OMEGA mineralogical studies of potential landing sites
- Study variable and seasonal atmospheric phenomena and revisit areas of interest with PFS, SPICAM, ASPERA
- Complete study of gravity anomalies in key areas
- Collaboration with Mars Odyssey, MER, MRO, MSL
- Preparatory science activities for ESA's Exploration Program
- Publications: over 300 so far





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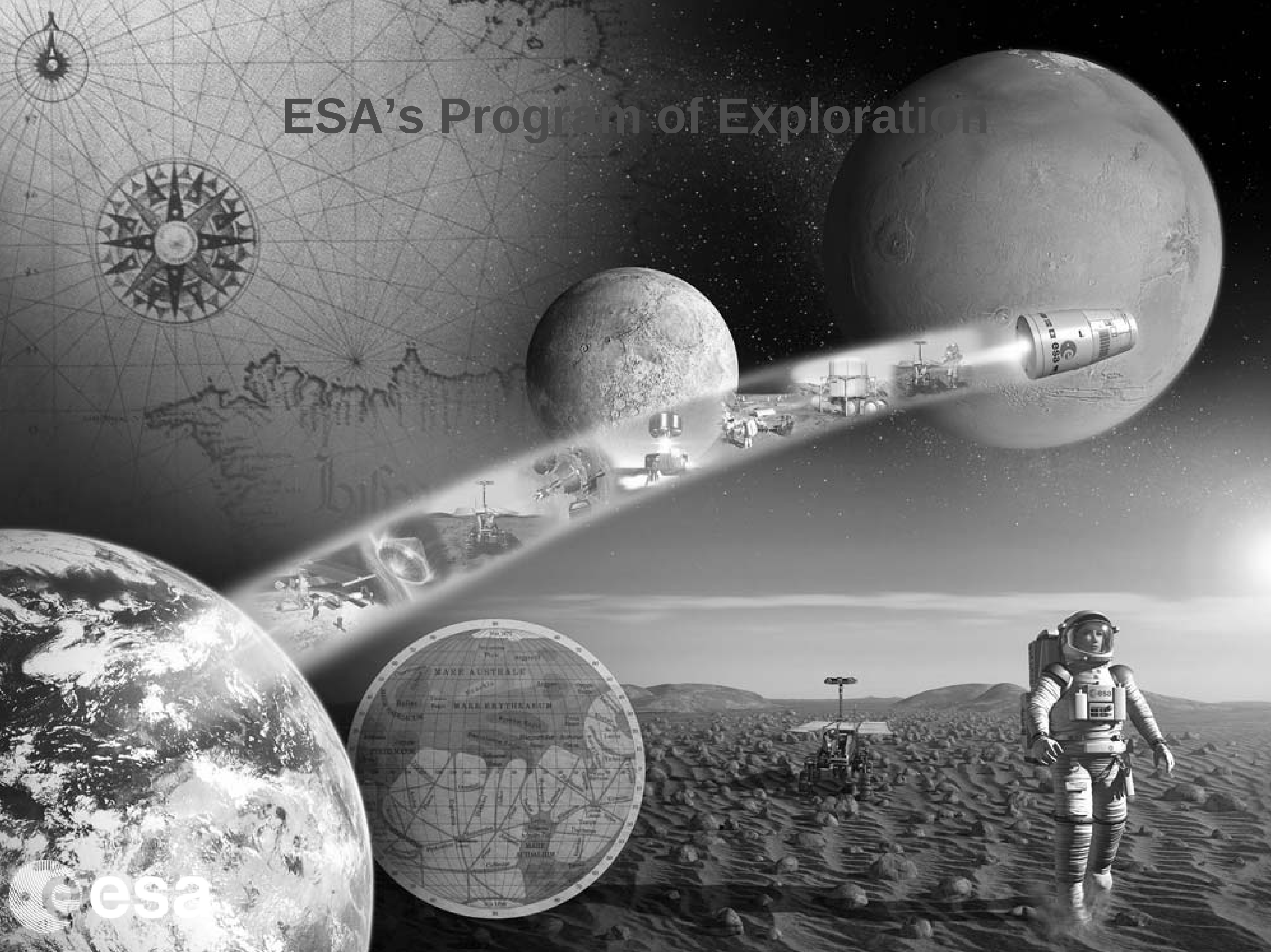
# ESA's Program of Exploration



# The 2016 Opportunity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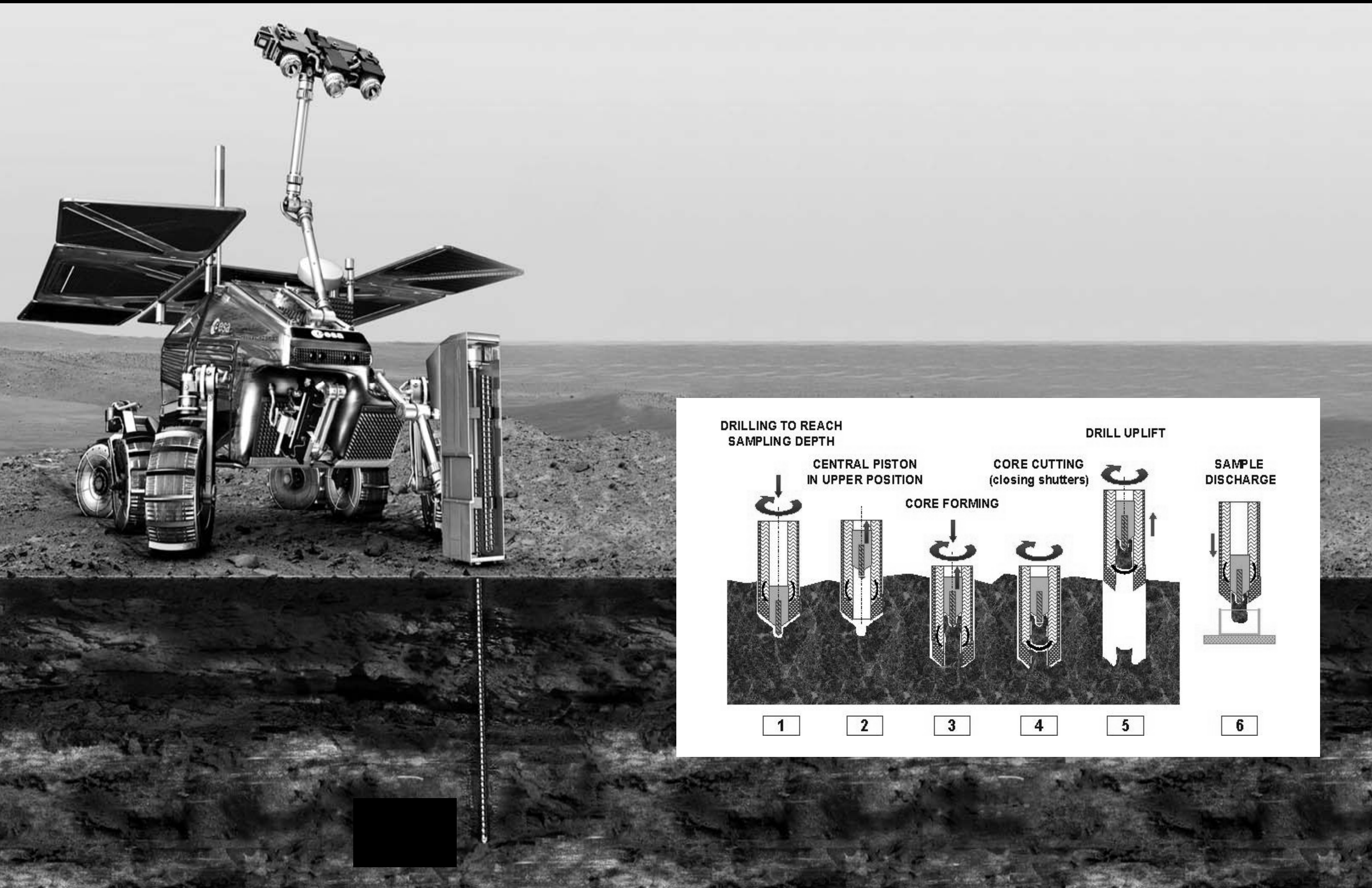
# 2016 Scientific Objectives

- ❑ **Surface Element derived from Exomars**
  - **ESA-led**
  - **Science focus:** habitability and exobiology at and below the Martian surface.
  - **Specific objectives:** search for signs of past and present life on Mars; characterise the water/geochemical environment as a function of depth in shallow subsurface; study surface environment at landing site (including hazards for human activities ?).
  - **Pasteur package instrumentation being re-evaluated by Peer Review Panel.**
  - **ExoMars original objectives could be spread over three launch opportunities.**
  - **Link to next mission:** initial exobiological investigations, to be completed in 2018.
  - If no Humboldt package, TBC: objectives to be fulfilled in 2018-20.

- ❑ **Orbiter-Carrier to deliver the Surface Element**
  - **ESA-led**
  - **Science focus:** complement habitability and exobiology findings of surface element, in particular trace gases in the atmosphere (e.g., methane); hi-res imaging
  - **Specific objectives:** determine regional sources and seasonal variations of trace gases ($H_2O$, $HO_2$, $NO_2$, $N_2O$, $CH_4$, $C_2H_2$, $C_2H_4$, $C_2H_6$, $H_2CO$, HCN, $H_2S$, OCS, $SO_2$, HCl, CO, $O_3$) with high sensitivity, as well as dust variations and isotopic fractionation.
  - **ESA and NASA to provide science instrumentation**
  - **Link to next mission:** determine area of interest (methane source) for landing in 2018.

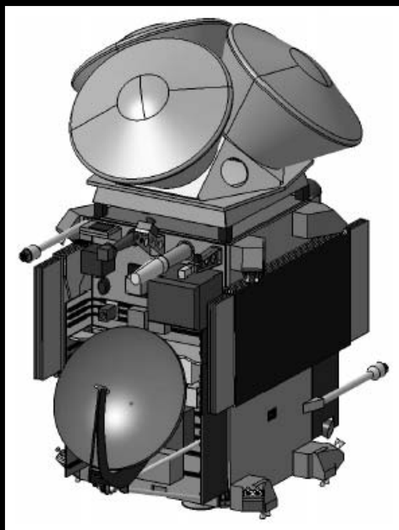
# The 2018 Opportunity

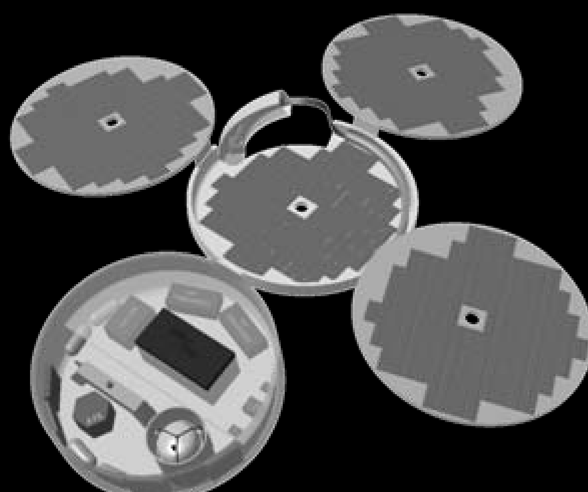


# 2018 Scientific Objectives

- **Surface Element derived from Exomars and new ESA surface package**
  - **NASA-led**
  - **Science focus:** in-depth exobiological investigations on Mars.
  - **Specific objectives:** subsurface organics, life and oxidant detection.
  - **Additional 200-300 kg ESA package on the surface:** possible surface, subsurface or aerial elements to be discussed later at this workshop.
  - **Additional objectives:** e.g., imaging of vertical structures (layering), detailed studies of surface magnetic anomalies and dust storms, complex operations and miniaturised sampling.
  - **NASA and ESA to provide science instrumentation.**
  - **Link to next mission:** investigate habitability & exobiology in full before global perspective; possible “pathfinder” small lander as precursor to Network stations in 2020.

# The 2020 Opportunity





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# 2020 Scientific Objectives

- **Surface Network of Stations derived from MarsNEXT**
  - **ESA-led**
  - **Science focus:** simultaneous surface investigations, not possible by other means.
  - **Specific objectives:** deep internal structure, geodesy and rotation, global atmospheric dynamics and composition, geological characterization of each of the landing sites.
  - **ESA and NASA to provide 3-6 surface stations and science instrumentation. JAXA also very interested. Other agencies (Russia, China) may join.**
  - **Link to previous mission:** provide global view to place habitability & exobiology results in perspective.

- **Orbiter to work in tandem with the Network of Stations**
  - **ESA-led, provision TBD.**
  - **Science focus:** science complementing the Network (low orbit, global weather forecast).
  - **Specific objectives:** mapping of crustal magnetic anomalies, accurate rotational parameters and implications for climate evolution, global understanding of Mars geological evolution together with surface stations to place results of other missions in perspective.
  - **Link to next mission:** necessary precursor to Mars Sample Return (together with Network).

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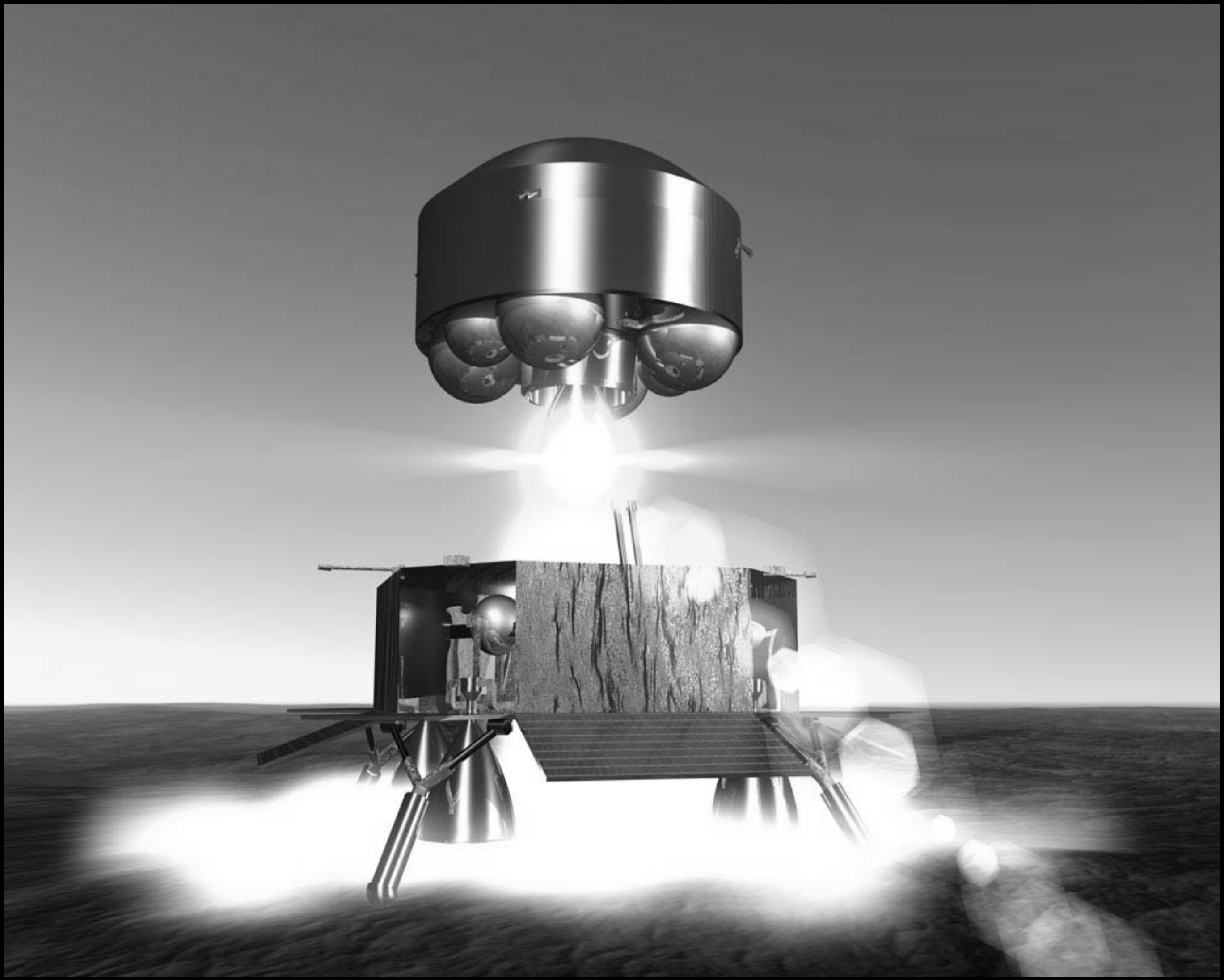
# Mars Sample Return



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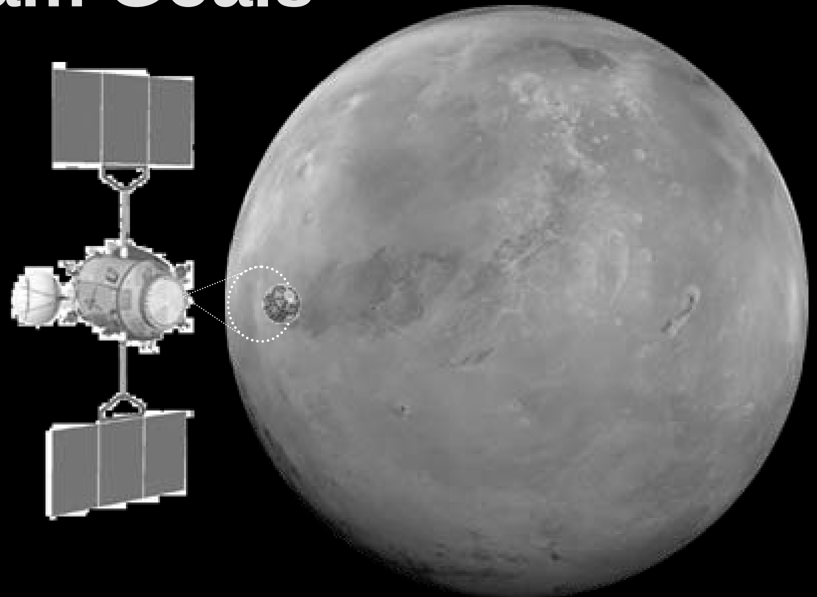
# Network Program Goals



*Overarching Goal:* ***Preparation for MSR***

❑ ***Technological:***

- *Rendez-vous & capture*
- *Aerobraking*
- *X-band proximity link*

❑ ***Scientific:***

- *Global understanding of Mars via Network of stations*
- *Global context to interpret MSR results*
- *Unique science opportunities (e.g., low altitude orbit)*

❑ ***Operational Support for MSR***

- *Initial command and data relay for MSR lander*

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# International Mars Exploration

In orbit: Mars Odyssey, MRO & MEX

On the surface: MER rovers and Phoenix

Under development: ExoMars and MSR

- What is missing ?
- Ionosphere: link atmospheric loss to magnetic fields
- Atmosphere: atmospheric dynamics and global circulation
- Surface: systematic studies of key landing sites
- Subsurface: heat flow monitoring, electromagnetic sounding
- Interior: detailed interior structure, crustal thickness, mantle and core structure, mantle and core dynamics
- Geodesy: rotation parameters such as nutation, precession

**The IMEWG has repeatedly reiterated its strong recommendation for a network mission, as a key element of Mars exploration. Unique opportunity for Europe to do first class science !**

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# 1.5 Year Phase-A Study

- ESTAG Recommendation
  - Following HME's Call for Ideas and evaluation of preliminary study results in Sept. 2007, ESA's Exploration Science and Technology Advisory Group (ESTAG) to the optional Exploration Programme recommended the following: ***A Mars mission launched on a Soyuz, demonstrating rendez-vous and capture in Mars orbit, and delivering a network of surface stations****. The highest science priority for the surface elements is* ***network science****, as extensively studied in Europe in the past. The aerobraking phase will provide opportunities for aeronomy and the mapping of crustal magnetic anomalies.*
- Science Definition Team
  - Pan-European group of leading Mars scientists
    - **Doris Breuer** – *Institute of Planetary Research, DLR, Berlin*
    - **Eric Chassefière** – *Université P. et M. Curie, Paris*
    - **Véronique Dehant** – *Royal Belgian Observatory, Brussels*
    - **Monica Grady** – *Planetary & Space Science Research Inst., Open Univ.*
    - **Patrick Pinet** – *Observatoire Midi-Pyrenees (CNRS), Toulouse*
    - **Angelo Rossi** – *International Space Science Institute, Bern*
  - Translating objectives into payloads and requirements
  - Model payload for landers & orbiter being refined for Phase-A
- Industrial Teams: **1) EADS-Astrium and 2) Thales-Alenia**

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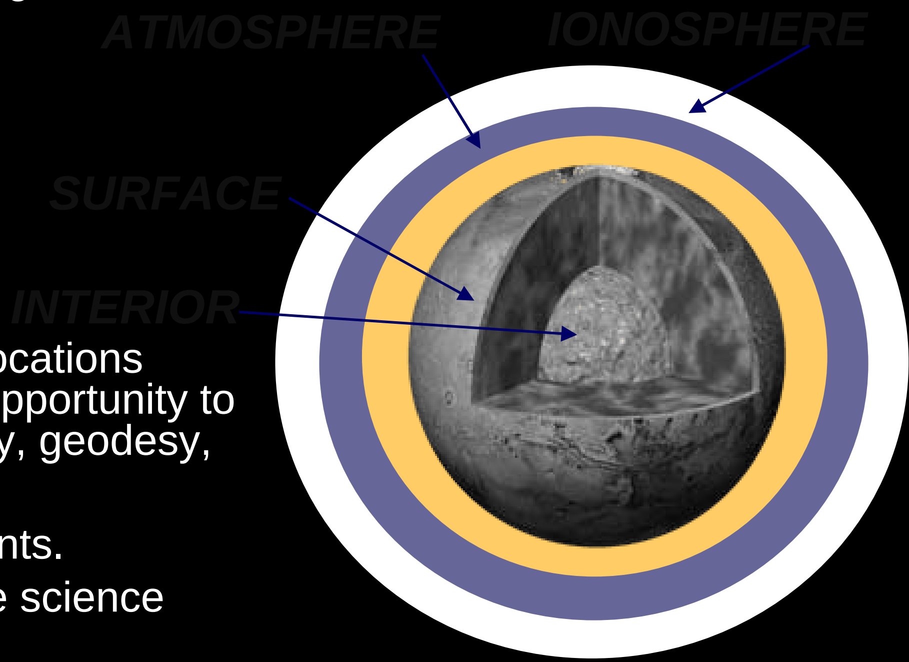
# Network Concept

## ❑Main Science Objectives

- Combined investigations provides unique insight into:
  - Planetary Formation & Interior
  - Atmospheric & Climate Processes
  - Geological Features & Evolution
  - Habitability & Risks for Future Missions

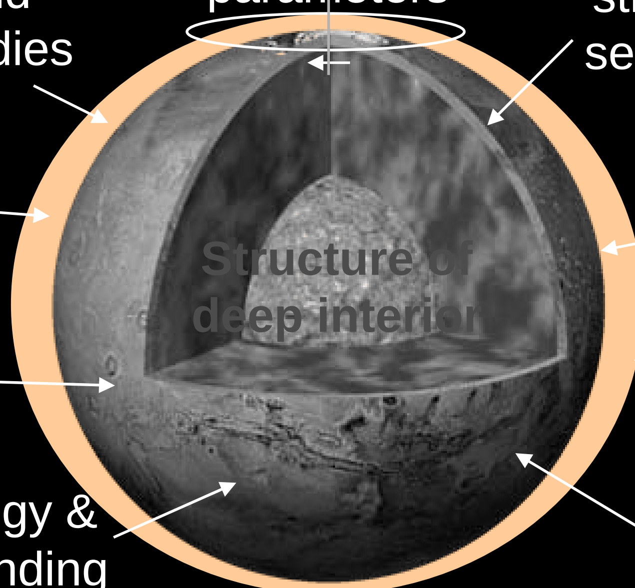



## ❑Network Concept: key to Mars-NEXT

- Simultaneous measurements from multiple locations (Network of science probes) enable unique opportunity to address key scientific issues (e.g. seismology, geodesy, meteorology).
- Coordinating surface and orbital measurements.
- Network Science is of very high priority to the science community in Europe and worldwide.
- The Network concept has a long heritage, including ESA (Marsnet, Intermarsnet), NASA (MESUR) and FMI (MetNet) studies, and even reaching Phase-B with the CNES Netlander mission.
- Significant development history of many instruments from NetLander & Beagle-2 reduces risk for Mars-NEXT implementation.

# Scientific Objectives

A Mars Orbiter mission embarking Network Science probes offers the potential to address a broad range of scientific objectives:




Addressing these ‘global’ science objectives will complement the exobiological objectives of ExoMars, and provide a better understanding of Mars’ evolution.

This is key to placing the following step in the scientific exploration of Mars, i.e. Mars Sample Return, into context.

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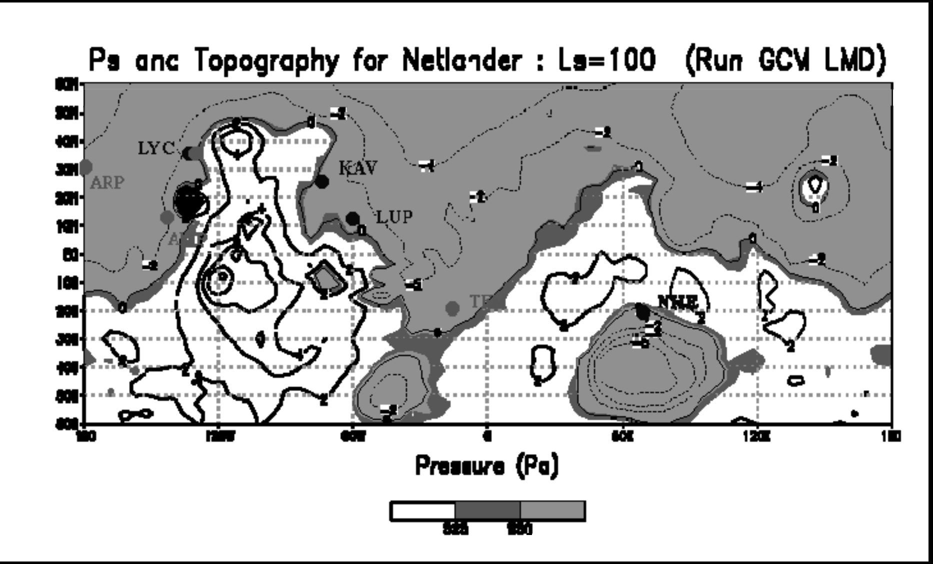
# Network Configuration

- For seismology and meteorology, the scientific return clearly depends on the number of landers:
  1) → basic seismicity level
  2) → quake vertical projection
  3) ***<u>→ 3D quake depth</u>***
  4) → provides redundancy within the Network AND access to the inner core

Phase-A is assessing deployment of **3 probes** → four probes for a purely geophysical Network may also be an option



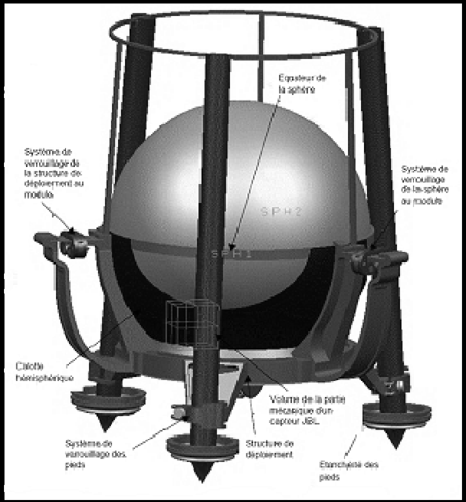

- Examples of Network configurations:
  - Tharsis triangle + antipode
  - Tharsis triangle + Hellas basin

- Aerobraking allows <u>low-altitude elliptical orbits</u> in order to map crustal magnetic anomalies and monitor atmospheric escape and its interaction with the solar wind.

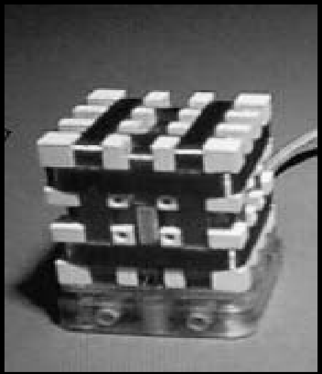
# Network Science

Network science payload suite drawing on existing heritage.

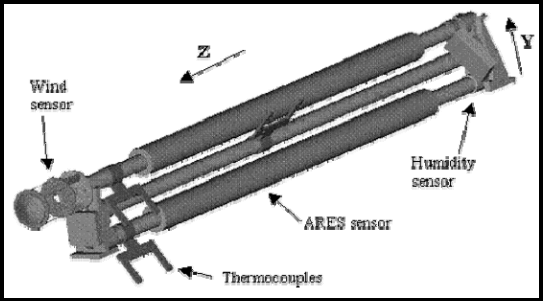
- Seismology: interior structure, crustal thickness
- Geodesy: rotational parameters, $CO_2$ cycles
- Meteorology: climate, global atmospheric circulation



SEISMOMETER

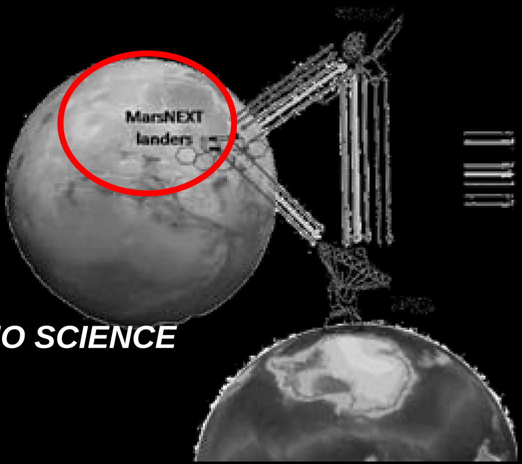


MAGNETOMETER




METEOROLOGICAL BOOM

Reference surface payload = 8kg (incl. margin)




RADIO SCIENCE

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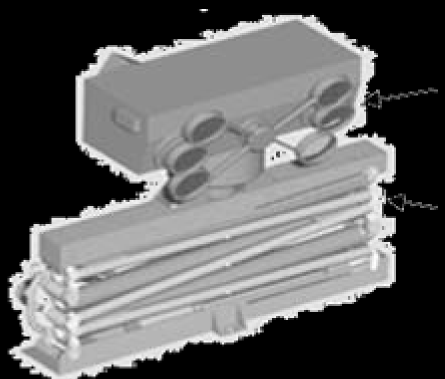
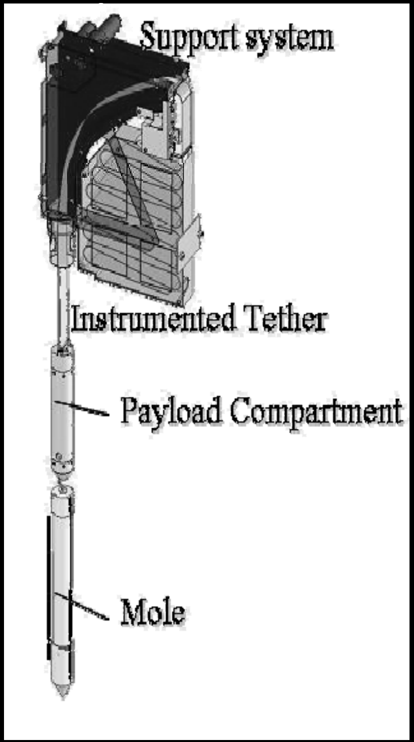
# Landing Site Science

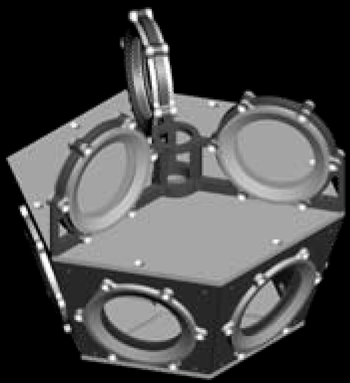
Landing site science instrumentation focuses on investigating the lander vicinity, and draws on existing heritage.

- ❑ Site Characterisation: geology, geochemistry
- ❑ Sub-surface: heat-flow, soil properties, magnetism
- ❑ Surface-Atmosphere interactions: $H_2O$



SITE IMAGING SYSTEM



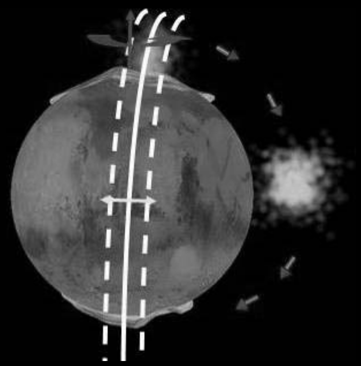



ALPHA- P SENSOR

INSTRUMENTED MOLE

Reference surface payload = 8kg (incl. margin)

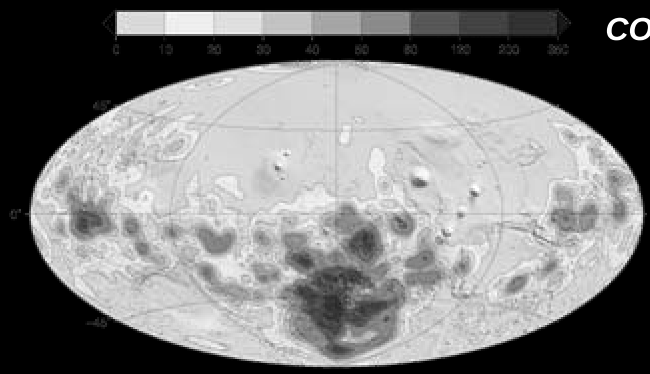
# Orbital Science



*$CO_2$ EXCHANGE*

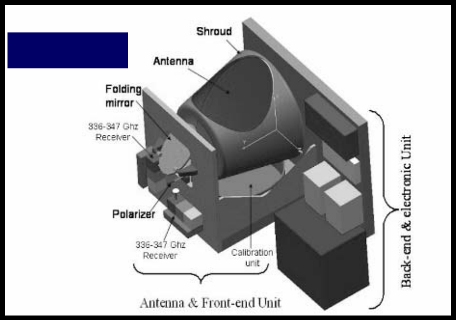
The Orbital Payload aims to maximise use of low altitude orbits

- Geodesy: state, radius & composition of martian core
- Escape: atmospheric evolution, solar-wind interaction
- Magnetism: mapping crustal anomalies in detail
- Atmospheric chemistry: Profiles & interactions

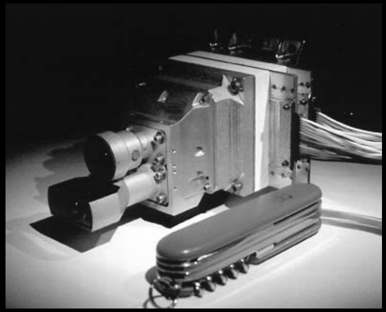


*Magnetic Crustal Anomalies - MGS*

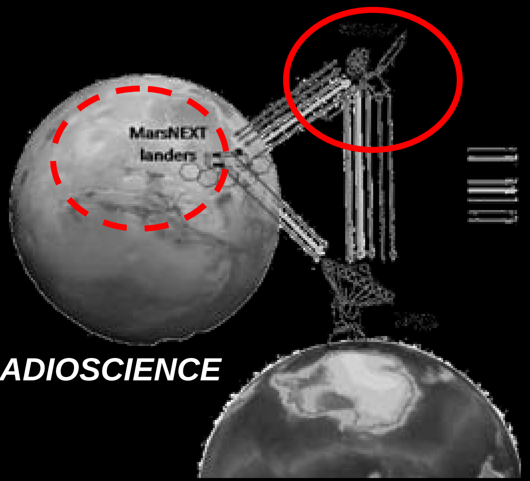
Reference orbital payload = 30kg (incl. margin)




***MICROWAVE SPECTROMETER***



***WIDE ANGLE CAMERA***




***RADIOSCIENCE***

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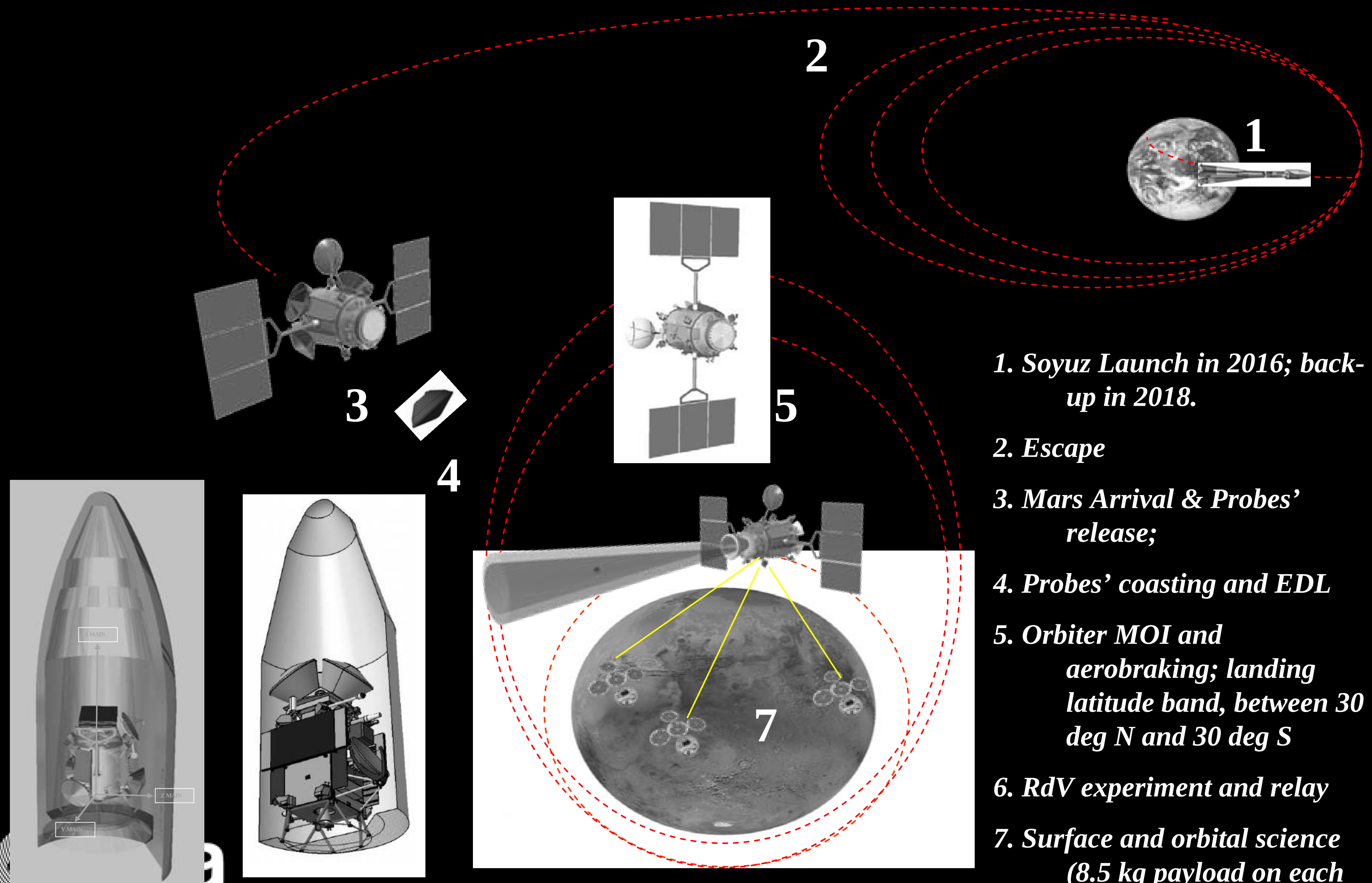
# Mars NEXT Mission Profile




1. *Soyuz Launch in 2016; back-up in 2018.*
2. *Escape*
3. *Mars Arrival & Probes' release;*
4. *Probes' coasting and EDL*
5. *Orbiter MOI and aerobraking; landing latitude band, between 30 deg N and 30 deg S*
6. *RdV experiment and relay*
7. *Surface and orbital science (8.5 kg payload on each lander; 30 kg on orbiter)*

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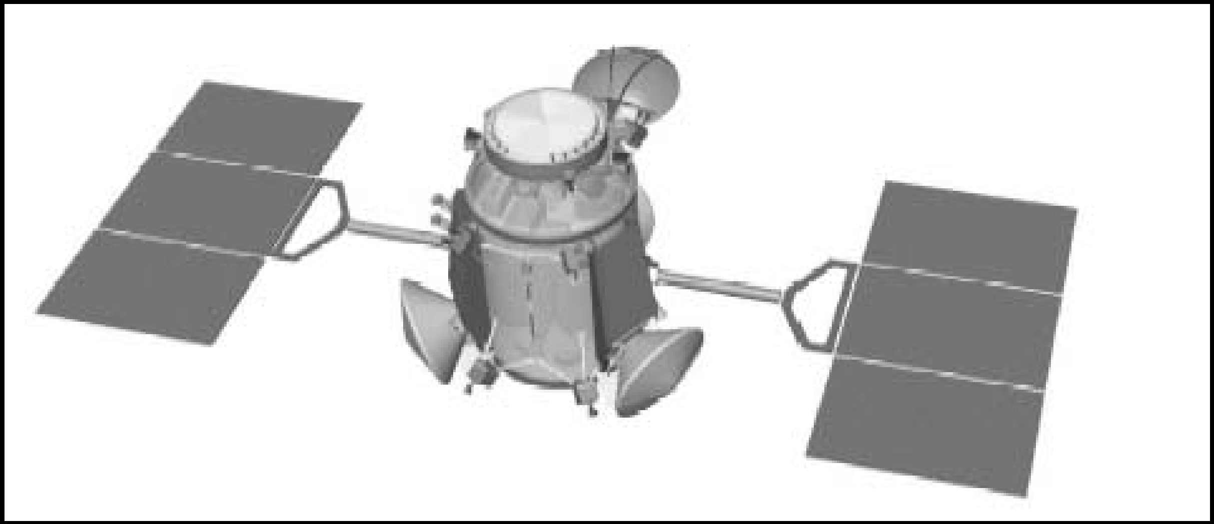
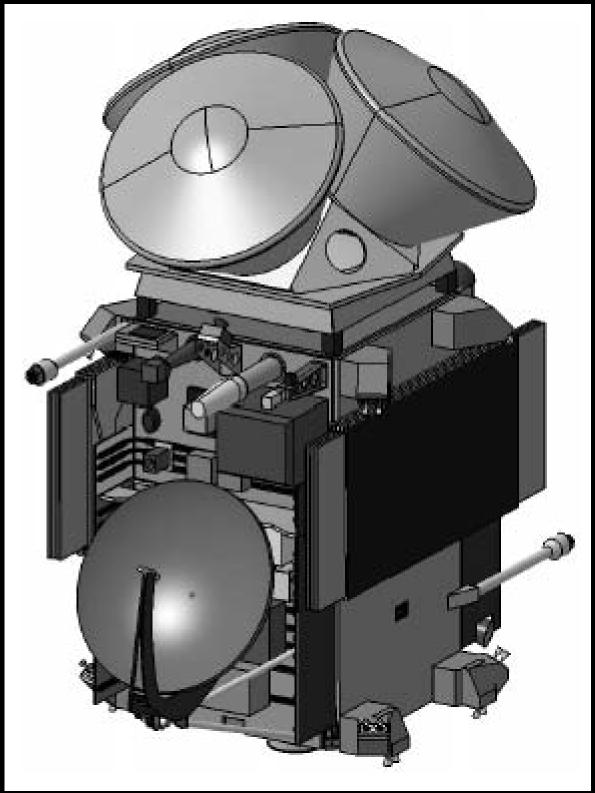
# Orbiter Design





For both contractors:

- Orbiter configuration driven by 4 large propellant tanks
- Complex AOCS architecture to cope with Main engine failure at MOI, Aerobraking, Probe Separation, Rendezvous (24X22 N thrusters)
- "Conventional" Solar Array (max T = 150-170 °C)
- Heritage from Mars Premier, MEX, ExoMars exploited

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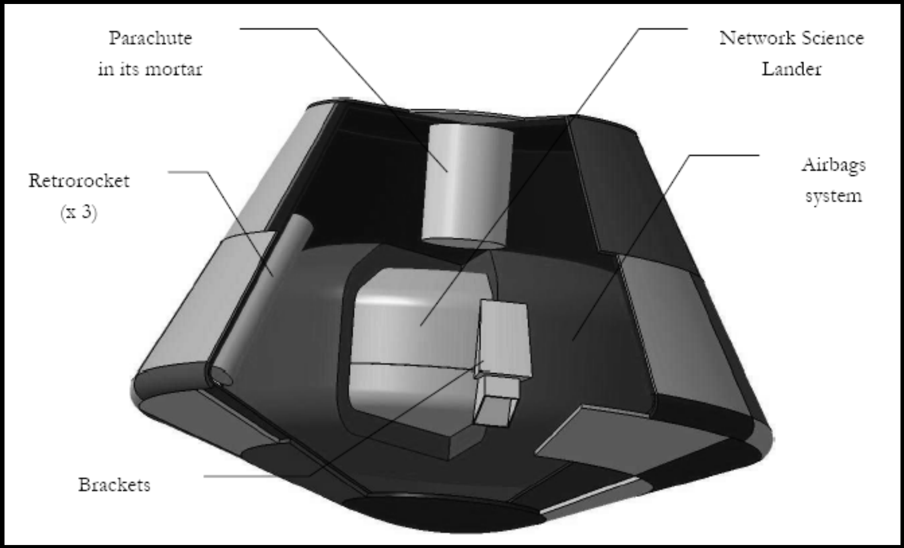
# Probe Design

- Compact capsule based on Viking (and ExoMars) shape with a ∅FS = 1.4 m
- Probe entry mass is 125 kg to 140 kg (depending on the consortium) significantly higher than Netlander/Beagle 2 due to:
  - Inclusion of Beagle 2 recommendations on margins (20% at system level)
  - Inclusion of X-band RF system for tone transmission to Earth during EDL
  - Inclusion of lessons learned from MER on non-vented airbags resistance to shear
  - Inclusion of retro-rockets (TBC) for robustness against density uncertainties

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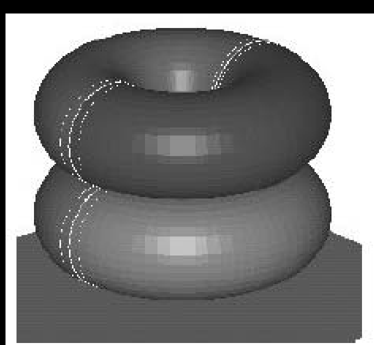
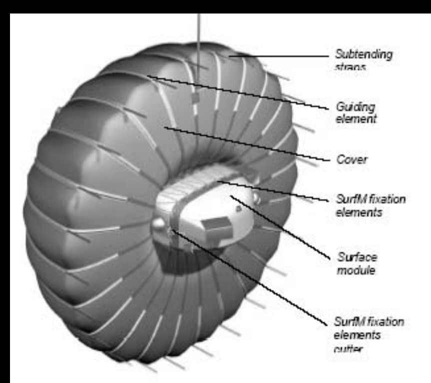
# Entry Descent and Landing

- •Ballistic entry (Ve=5.7 km/s),
- Ablative Aeroshell
- Descent based on parachute and small solid retrorockets (TBC) for nulling-out of vertical velocity
- Landing by bouncing (non-vented) airbags (two options)
- •Due to small mass no need of specific lateral velocity control
- •Capability of landing at MOLA≤0



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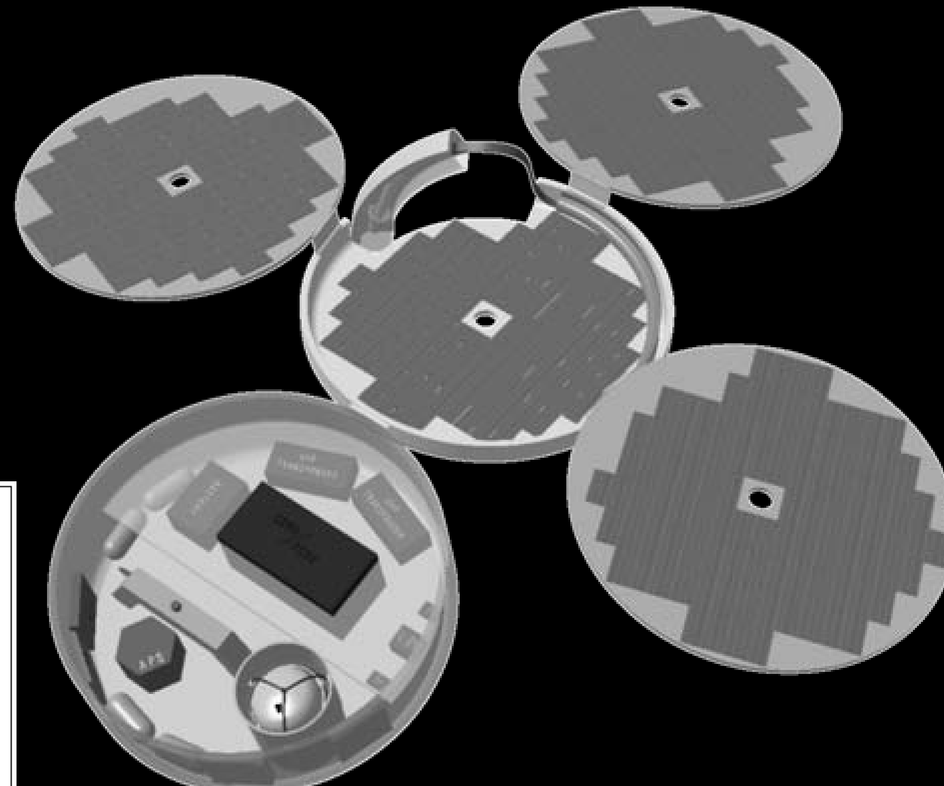
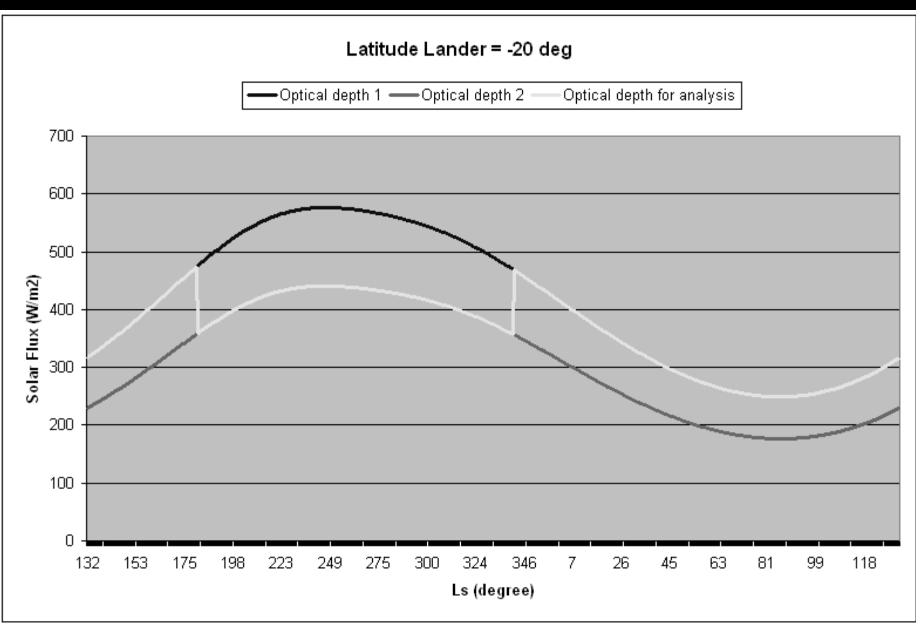
# Surface Mission

- Solar power-based with RHUs
- Landing latitude range: 15 S to 30 N to keep mass down (SA size)
- Configuration Beagle 2-like with self-righting mechanism
- Capability to hibernate during Global Dust Storm Season (τ=2)

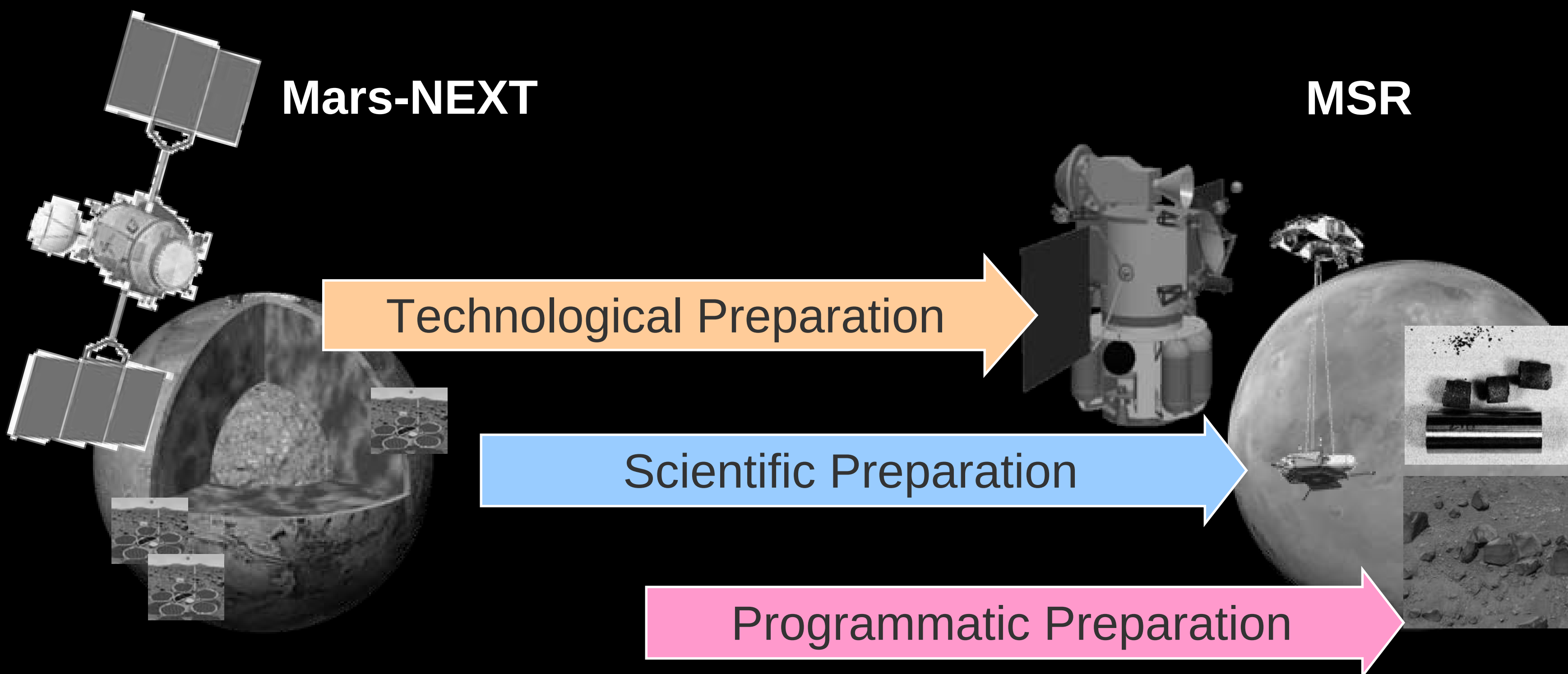





- Payload accommodation the major driver
- Mild electronics integration proposed
- Customised Mole packaging required

# Conclusions 1

## Mars-NEXT represents a fundamental milestone for Europe to prepare for Mars Sample Return




Mars-NEXT to provide pre-operational support to the MSR mission

# Conclusions 2

- Network Science is vital in order to achieve fundamental Mars scientific objectives, such as the study of Mars interior, its rotation and atmospheric dynamics, fully complementary to ongoing Mars missions and MSR.
- The Mars-NEXT Mission represents a timely scientific opportunity, and offers a chance for Europe to lead the field of geophysical exploration, building on the heritage gained by Mars Express (radar sounding).
- The IMEWG has supported the Network concept since its foundation; in addition, very strong interest exists in the scientific community worldwide (and especially in USA, Japan, Russia, Canada & China).
- The Mars-NEXT Mission provides the geological evolution context to interpret the astrobiological findings from other missions, including MSR.

**The Network mission is a unique and powerful tool to provide a global understanding of Mars evolution**

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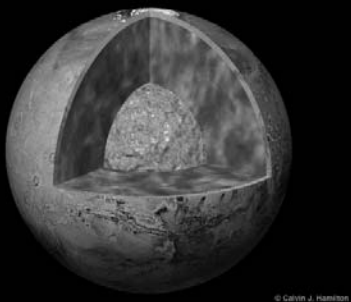
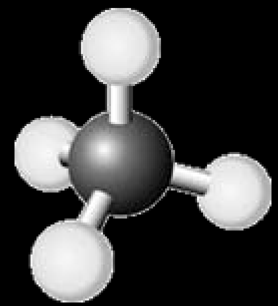
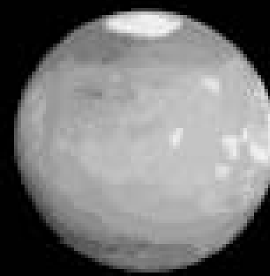
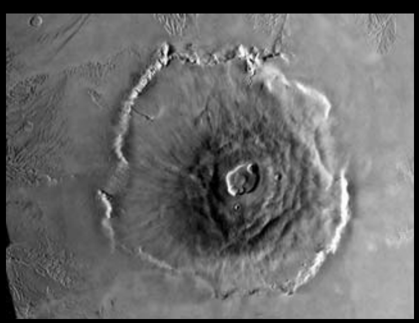
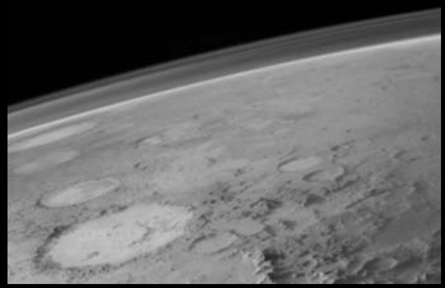
# Workshop on the Origin of Methane on Mars









## 25- 27 November 2009, ESA-ESRIN, Italy

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