Mars Exploration at the European Space Agency

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D/SRE, ESA

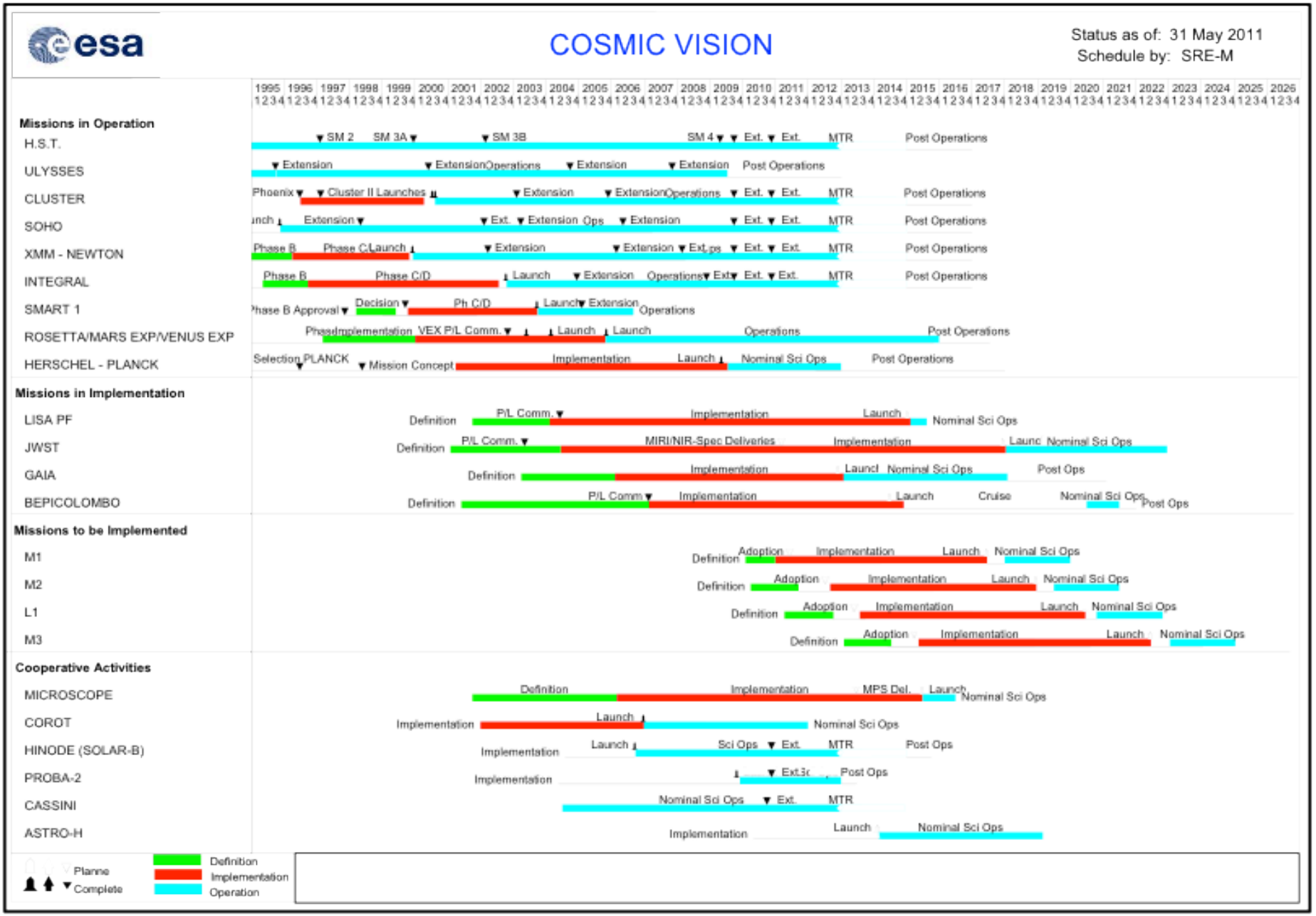
1 July 2011

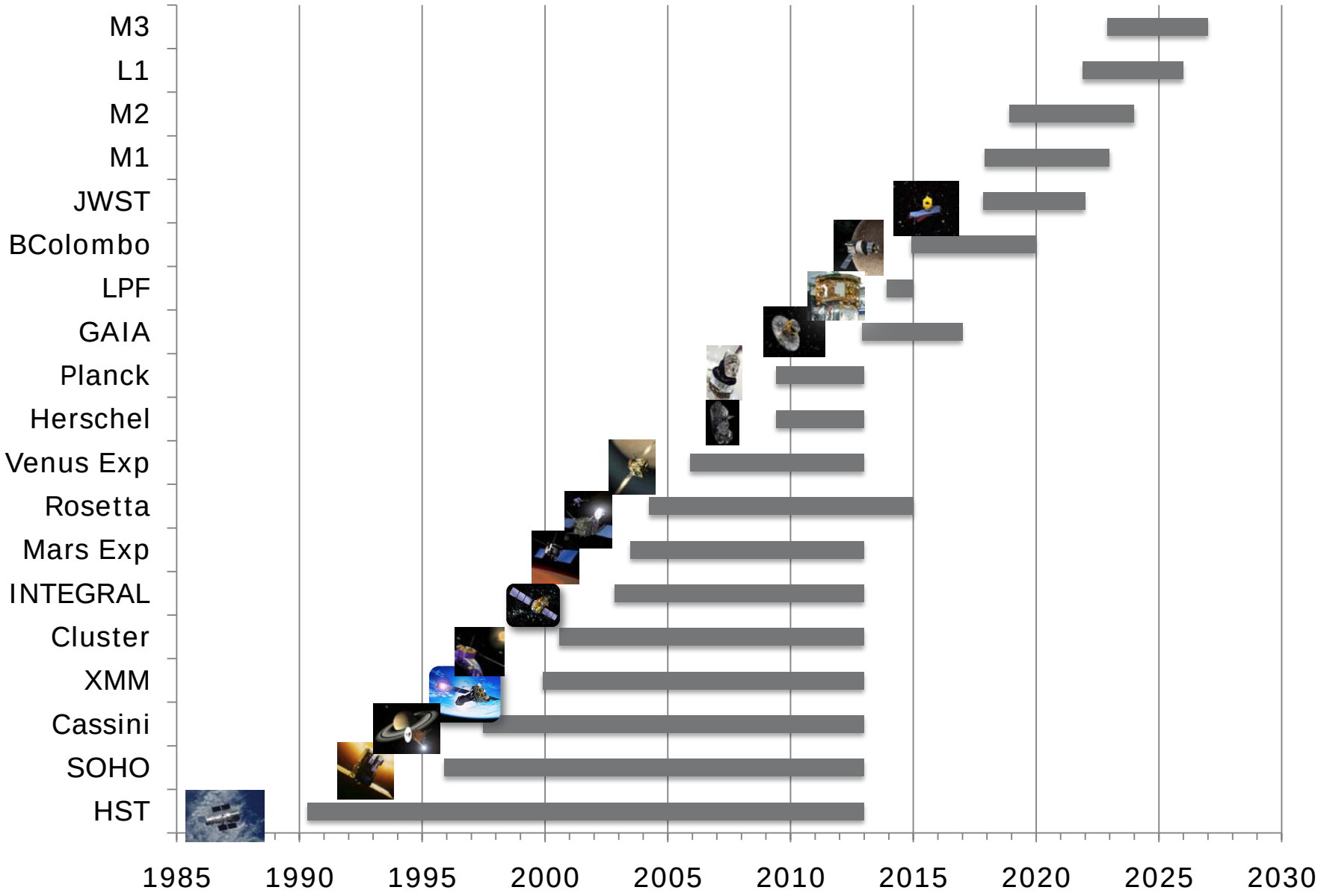
The Science Programme

- ESA's Science Programme is a mandatory programme to which all member states contribute
  - Contribution pro-rata to GNP
- Long-term relative budget stability
- Allows on long-term planning of its scientific goals, in parallel with flexible mission calls
- Typical planning time scale ca. 10 yr
- Both long-term science planning and mission calls are bottom-up processes, relying on broad community input and peer review

COSMIC VISION

Status as of: 31 May 2011
Schedule by: SRE-M



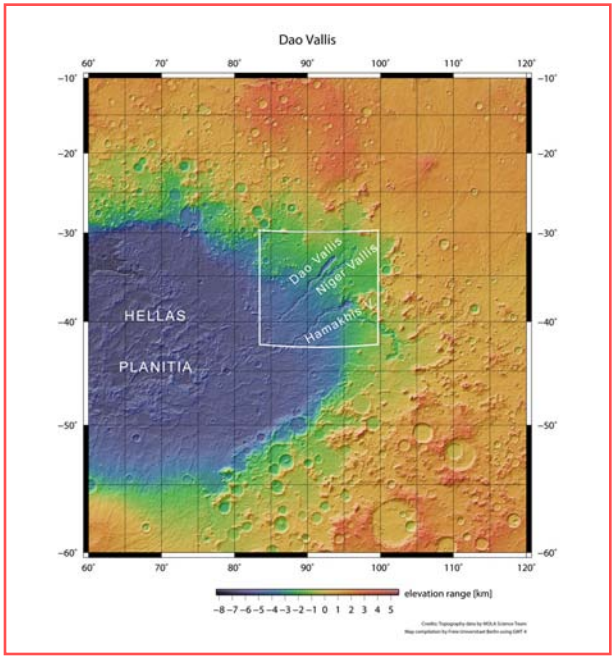

M3
L1
M2
M1
JWST
BColombo
LPF
GAIA
Planck
Herschel
Venus Exp
Rosetta
Mars Exp
INTEGRAL
Cluster
XMM
Cassini
SOHO
HST
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030

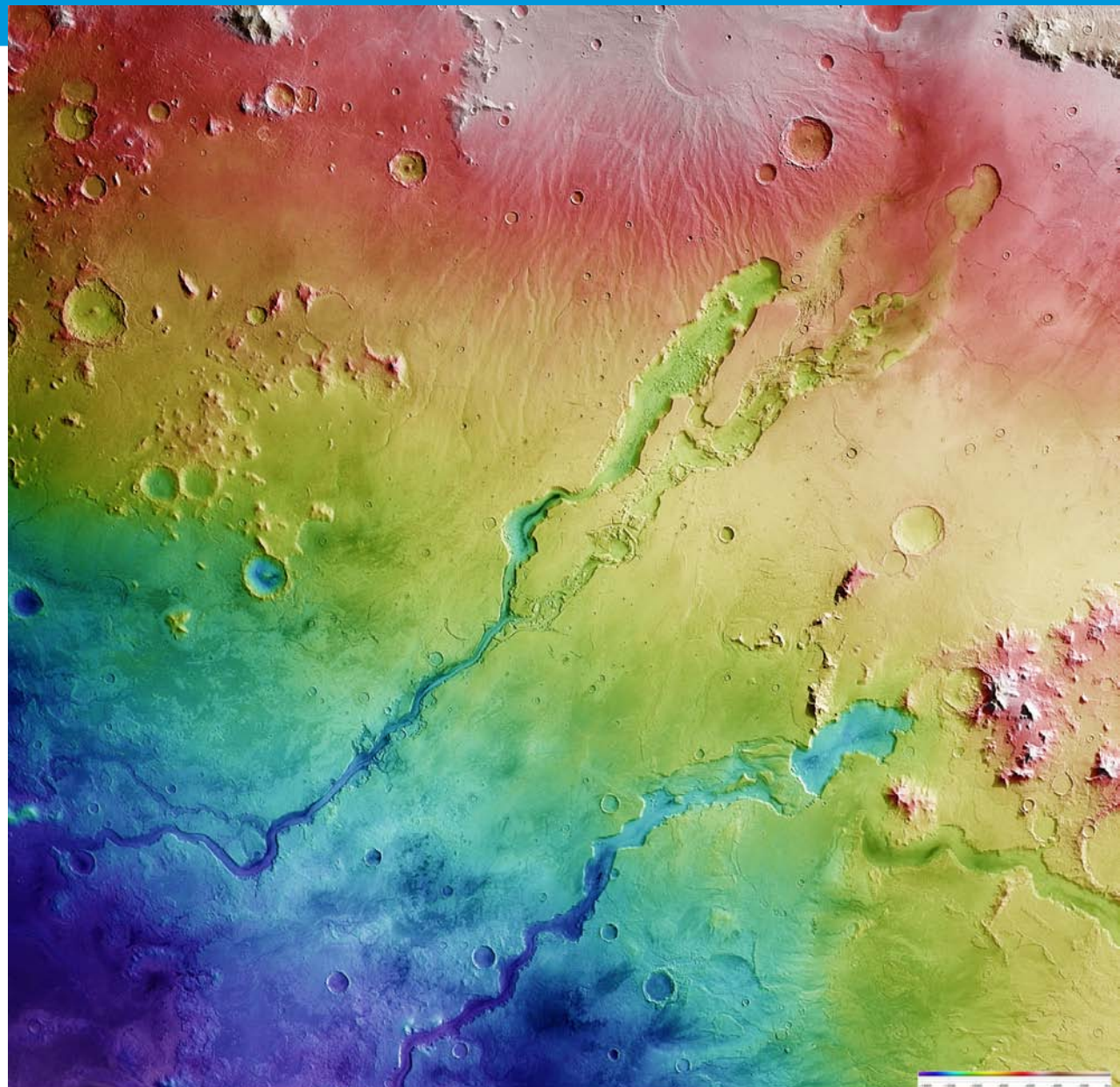
ESA Programme Status:
Mars Express

- 9200+ orbits around the red planet have been completed.
- Scientific achievements in many areas: subsurface, surface, atmosphere, upper atmosphere and Martian moons
- Mission extension until end of 2014, subject to a mid-term review in 2012.
- Payload: overall very good. Loss of the OMEGA C-channel (1-2.5 µm range) end of August 2010.
- Spacecraft: healthy.
- Status of the science data archive: very good.

ESA Programme Status: Mars Express

This HRSC mosaic of Dao and Niger Valles consists of eight single HRSC orbits. It extends over 755 km (N-S) and 770 km (E-W). The resolution is 125 m/pixel. The altitudes are in colour.





ESA Programme Status:
Mars Express

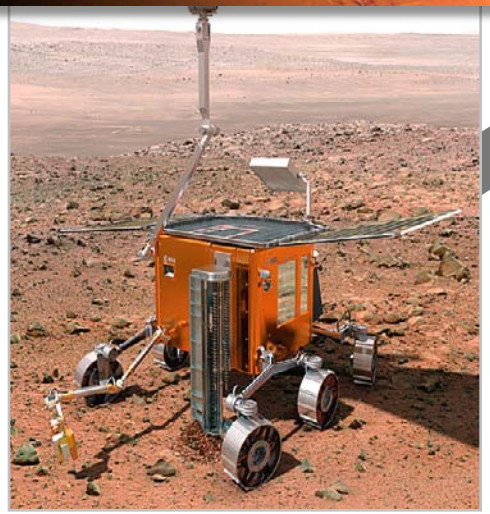
HRSC image of Phobos acquired on 9 Jan 2011, at a distance of ~100 km. This image has been photometrically enhanced to illuminate darker areas. The resolution is 4 m/pixel. Features such as impact craters and grooves can be studied in great detail on this image. A few boulders are also visible. During the same flyby, another image taken with a slightly different geometry allows to characterise the landing site of the Phobos sample return mission.

NASA Programme: MSL

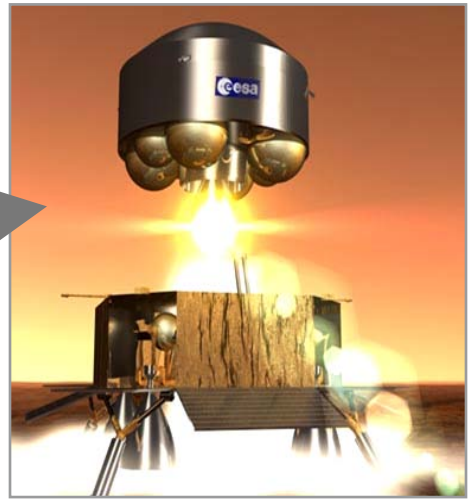
The Robotic Exploration program

- Technology driven and focused on the exploration of Mars
- Optional program
  - Not all Member States participate
  - Individual missions are specifically funded by Member States
  - Based on long-term international cooperation scenario
- Two missions currently approved under the ExoMars single Programme
  - Trace gas orbiter (2016)
  - Exo-biology rover (2018)
- Long-term goal is Mars Sample Return

Mars Robotic Exploration Programme



Mars Robotic Exploration Programme



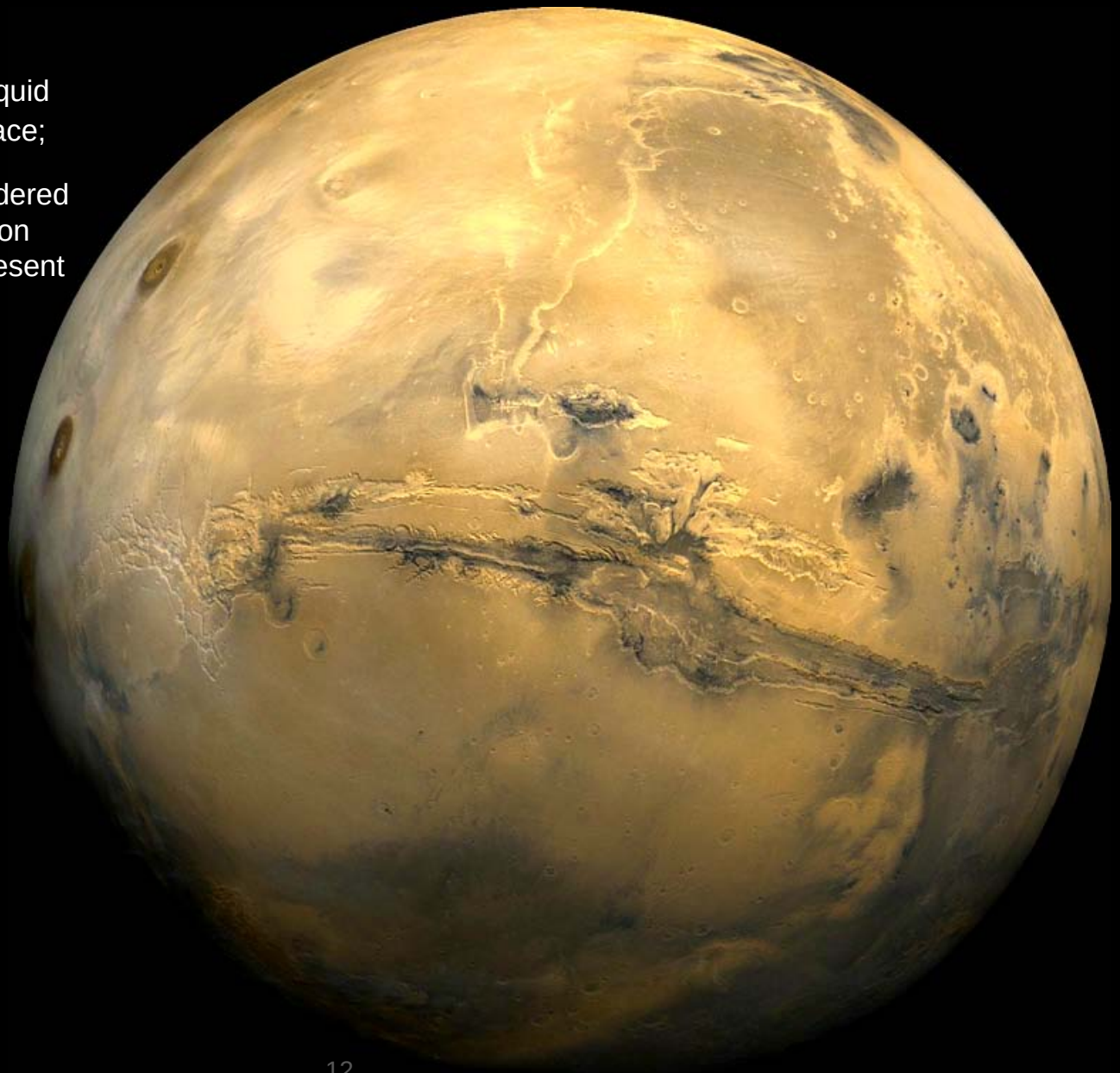
- → Mars Sample Return
- → ...
- → 2020
- → ExoMars 2018 (Rover)
- → ExoMars 2016 (TGO)

Reasons To Explore Mars

1. Many of the key questions in ***solar system science*** can be addressed effectively at Mars:
   - Solar system history
   - Planetary evolution
   - Potential for life
2. Mars provides the opportunity to approach, and possibly answer, origin and evolution of life questions
   - Clear potential for past and possibly present biological activity
3. Mars has a well-preserved record of its climate and geologic evolution exposed at the surface
   - A comparable record of ancient planetary processes, including those possibly leading to the origin of life, exists on no other terrestrial planet, including Earth
4. Mars is the most accessible place in the solar system where these highest-priority science questions can be addressed

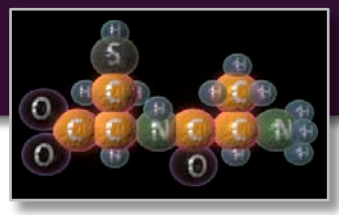
Why Life on Mars ?

- Early in the history of Mars, liquid water was present on its surface;
- Some of the processes considered important for the origin of life on Earth may have also been present on early Mars;
- Establishing if there ever was life on Mars is fundamental for planning future human missions.

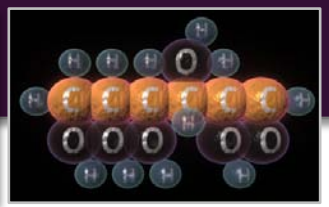


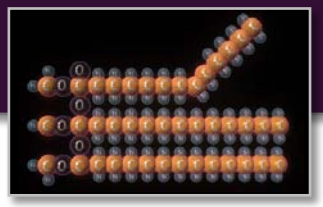
What to search

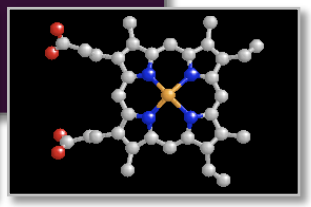
- **PRESENT LIFE:** Biological markers, such as:


Amino acids

Nucleobases


Sugars

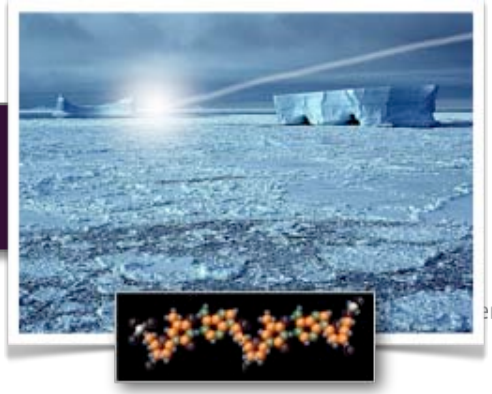

Phospholipids


Pigments

- **PAST LIFE:** Images of fossil organisms and their structure;
(morphological evidence)

Organic residues of biological origin;
(chemical, chiral, spectroscopic, and isotopic info)

- **DELIVERED ORGANICS:** by meteoritic and cometary infall.

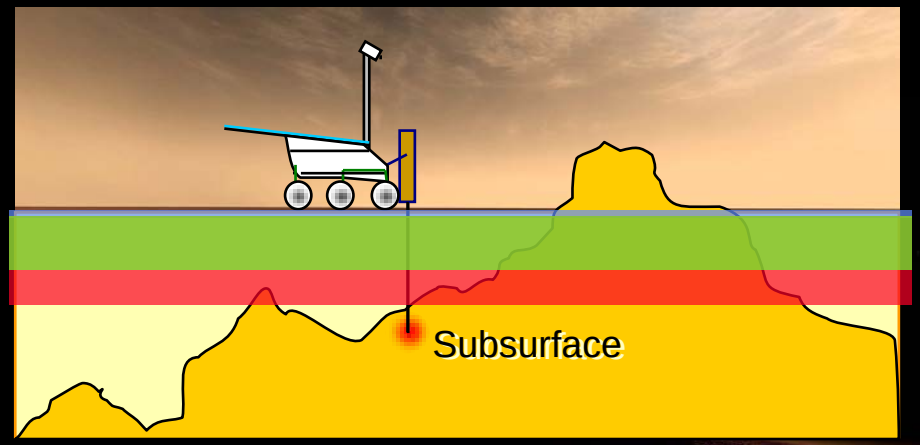


Where to Search

Penetration of organic destructive agents

UV Radiation	~ 1 mm
Oxidants	~ 1 m
Ionising Radiation	~ 1.5 m

Where to Search



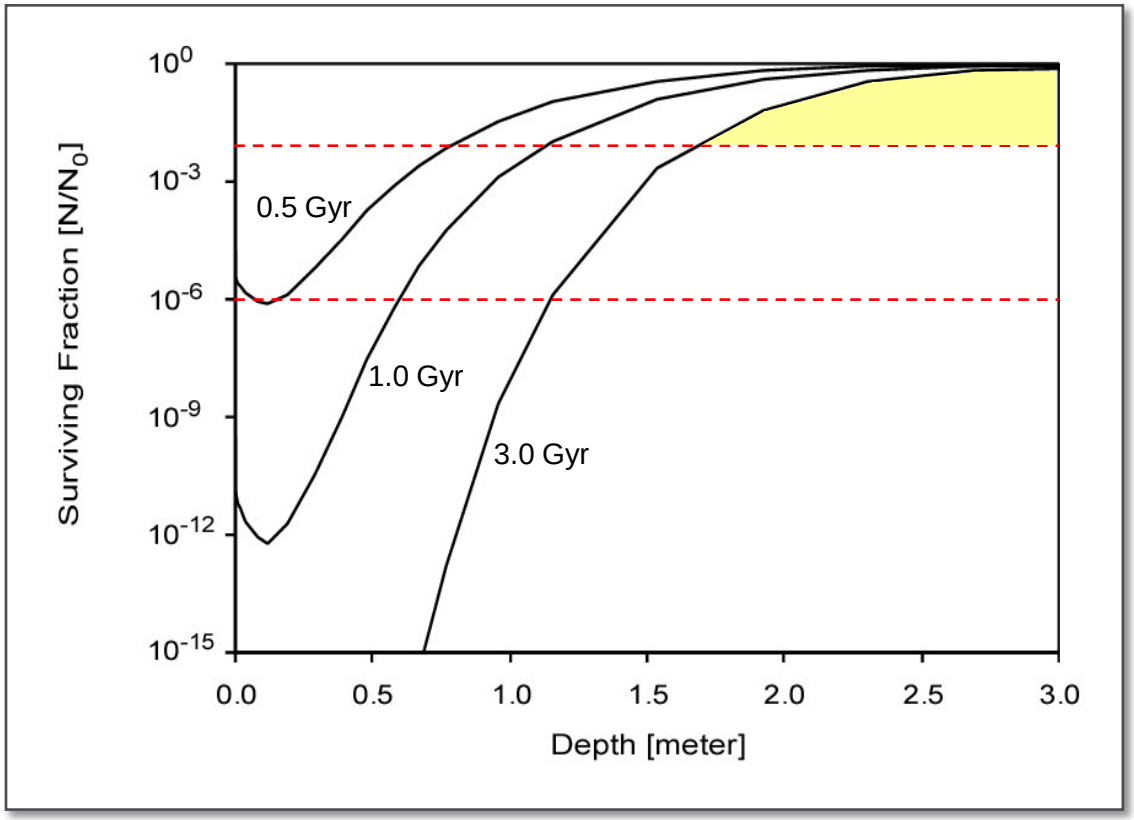
Penetration of organic destructive agents

UV Radiation	~ 1 mm
Oxidants	~ 1 m
Ionising Radiation	~ 1.5 m

ExoMars Strategy:

Collect samples below the degradation horizon

How Deep ?



Adapted from
Kminek and Bada (2006)

Surviving fraction of amino acids versus depth after simulated exposures of 0.5, 1.0, and 3.0 Gyr to ionising radiation in the Martian subsurface. For an initial Earth desert-like cell abundance (10^3 cells/g soil), the present instrument detection limits can tolerate a reduction of 10^{-2} to 10^{-6} (red dashed lines), beyond which amino acid signatures become undetectable.

When searching for biomarkers of Martian life that became extinct more than 3 Gyr ago, it is necessary to access the subsurface in the range of 2 m (yellow area).

ExoMars Programme Objectives

1. Main Technology Demonstration Objectives:
   a. Entry, Descent and Landing (EDL) of a payload on the surface of Mars;
   b. Surface mobility with a Rover;
   c. Access to the sub-surface to acquire samples;
   d. Sample acquisition, preparation, distribution and analysis.

2. Main Scientific Objectives:
   a. To search for signs of past and present life on Mars;
   b. To investigate the water/geochemical environment as a function of depth in the shallow subsurface;
   c. To study Martian atmospheric trace gases and their sources.

ExoMars:
Europe's first time on the surface of Mars

1. 2016: Trace Gas Orbiter with EDL module
2. 2018: joint ESA-NASA Rover in course of definition
3. Cooperative international mission: strategic partnership with NASA

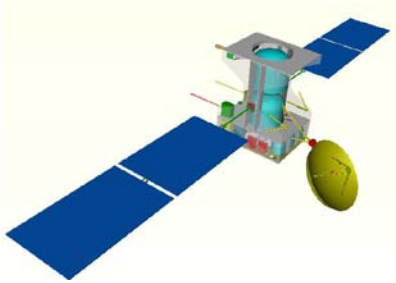
ExoMars Mission Architecture

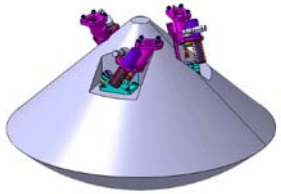
- **ExoMars Programme: *two missions launched in 2016 and 2018 on NASA launchers.***
- **The 2016 mission is ESA lead consisting of a Trace Gas Orbiter and an EDL Demonstrator Module with NASA contributions on Payload and UHF and coms.**
- **The 2018 mission is NASA lead consisting of a joint ESA-NASA Rover accommodated inside a NASA spacecraft and descent module (Sky Crane). NASA also contributes RHUs and part of an instrument (MOMA) in the ESA section of the rover.**

2016

Atlas V Series 4

Trace Gas Orbiter (TGO)





EDL Demonstrator Module (EDM)

+

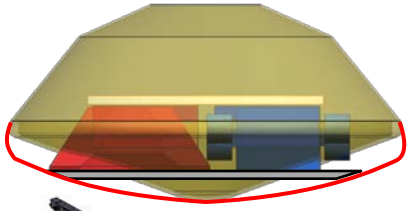
ESA DSN

NASA DSN

2018

Atlas V Series 5

Sky Crane Aeroshell



Joint Rover

European Space Agency

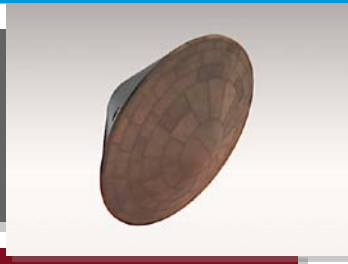
ESA ROCC

2016 ExoMars Trace Gas Orbiter Mission: Overview

2016

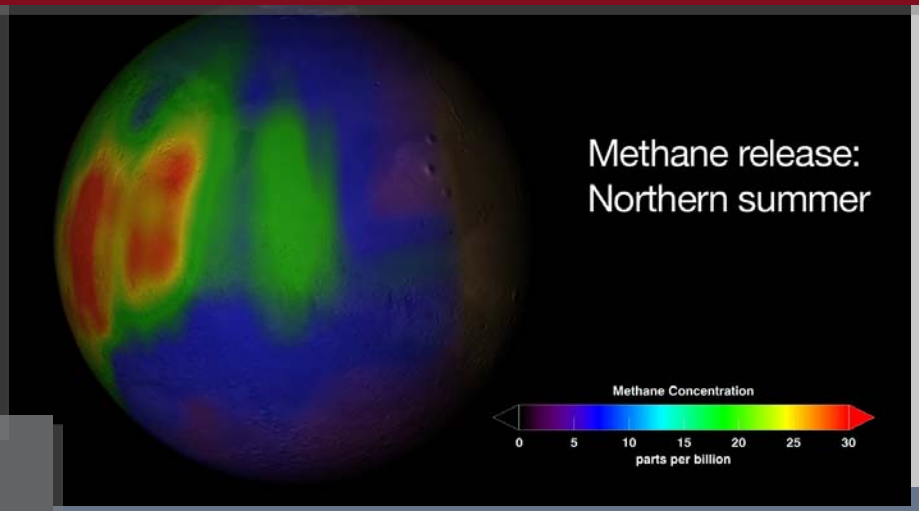
TECHNOLOGY OBJECTIVE

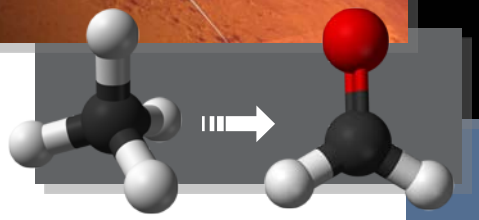
- Entry, Descent, and Landing (EDL) of a payload on the surface of Mars.



SCIENTIFIC OBJECTIVE

- To study Martian atmospheric trace gases and their sources.



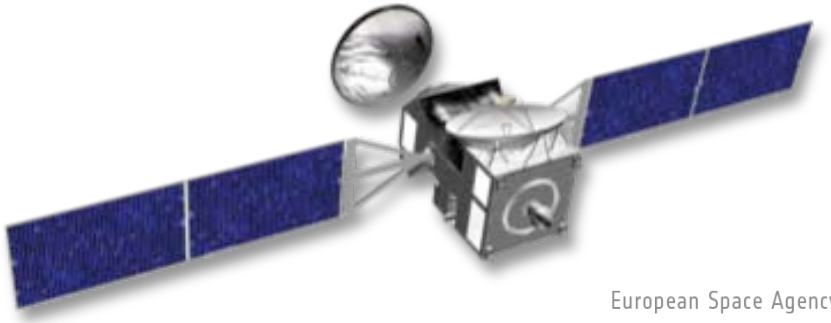


- Provide data relay services for lander missions until 2022.

2016 ExoMars Trace Gas Orbiter Mission

1. Trace Gas Orbiter (TGO) Module design activities proceeding with selected science payload (4 US & 1 European instrument), Launch Vehicle, and Electra

1. Entry Descent and Landing Demonstrator Module (EDM) mass recovery activities have been successful



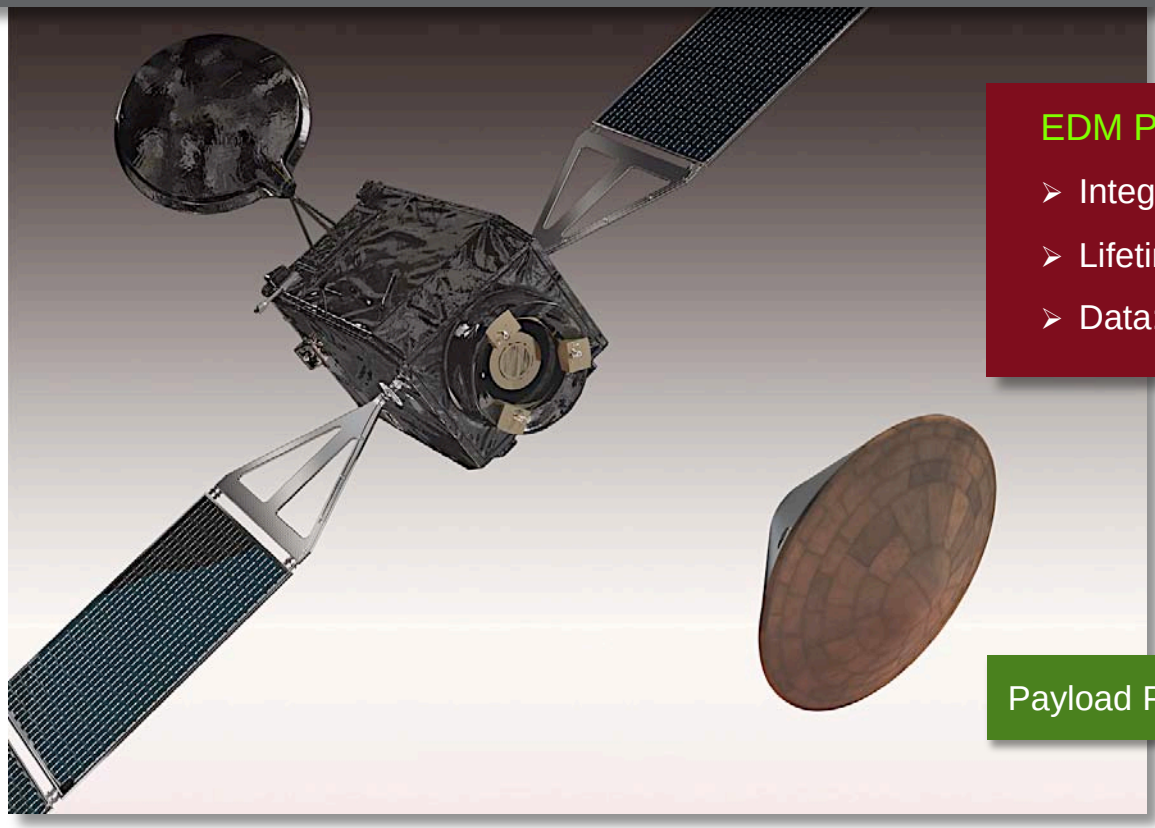
2016 ExoMars Trace Gas Orbiter Mission:
Selected Payload

PRIORITISED GOALS	PAYLOAD	
1. **Detect a broad suite of atmospheric trace gases** and key isotopes with high sensitivity (≤ ppt):	**MATMOS** **(10^{-2} ppt)**	**US**, CAN B, F, RUS
2. **Map their spatial and temporal variability** with high sensitivity (≤ ppb):	**SOIR-NOMAD** **(10^{-1} ppb)**	**B**, E, I, UK USA, CAN
3. **Determine basic atmospheric state** by characterising P, T, winds, dust and water aerosol circulation patterns:	**EMCS** **(P, T, dust, ices, H_2O)**	**USA**, UK F
	MAGIE **(Full hemisphere WAC)**	**USA** B, F, RUS
4. **Image surface features** possibly related to trace gas sources and sinks.	**HiSCI** **(HRC 2 m / pixel)**	**USA**, CH UK, I, D, F

Excellent coverage of high-priority objectives.

EDM

- A European technology demonstrator for landing medium-large payloads on Mars;
- Provides a limited, but useful means to conduct scientific measurements during the dust storm season.



EDM PAYLOAD

- Integrated payload mass estimate: 3 kg;
- Lifetime: 4 sols;
- Data: Single pass of 50 Mbits.

Payload Proposals selected in May 2011

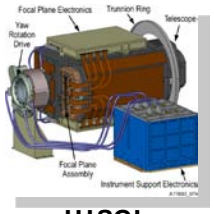
2016 ExoMars Trace Gas Orbiter Mission

NASA Mission Elements

EMCS

MAGIE

Electra



HISCI

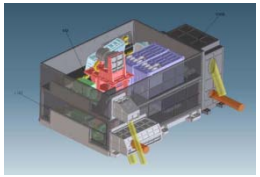
MATMOS

Atlas-V - 431 Class

JPL DSN

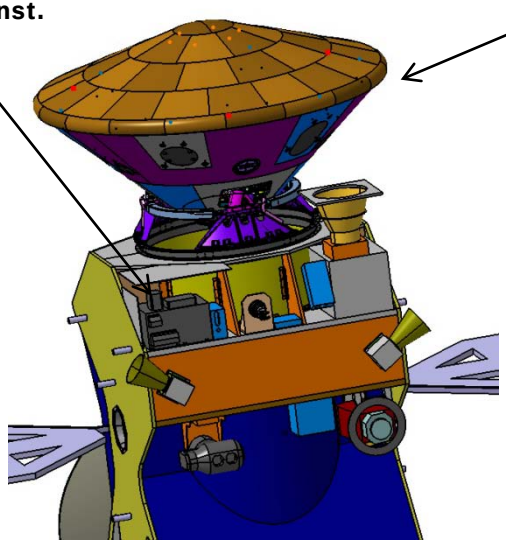
JPL SRA

ESA Mission Elements



NOMAD Inst.

Entry / Descent Module (EDM)



Spacecraft / Orbiter

ESA ESTRACK

ESA ESOC

European Space Agency

2018 Mars Mission: Objectives Overview

SCIENTIFIC OBJECTIVES

- To identify, acquire, document, and cache “outstanding” samples in a manner suitable for collection by a future Mars Sample Return Mission;
- To characterise sequences of geological units of a few km extent, documenting geological and geochemical variations at various scales.

TECHNOLOGY OBJECTIVES

- Sample coring, acquisition, and encapsulation

2018

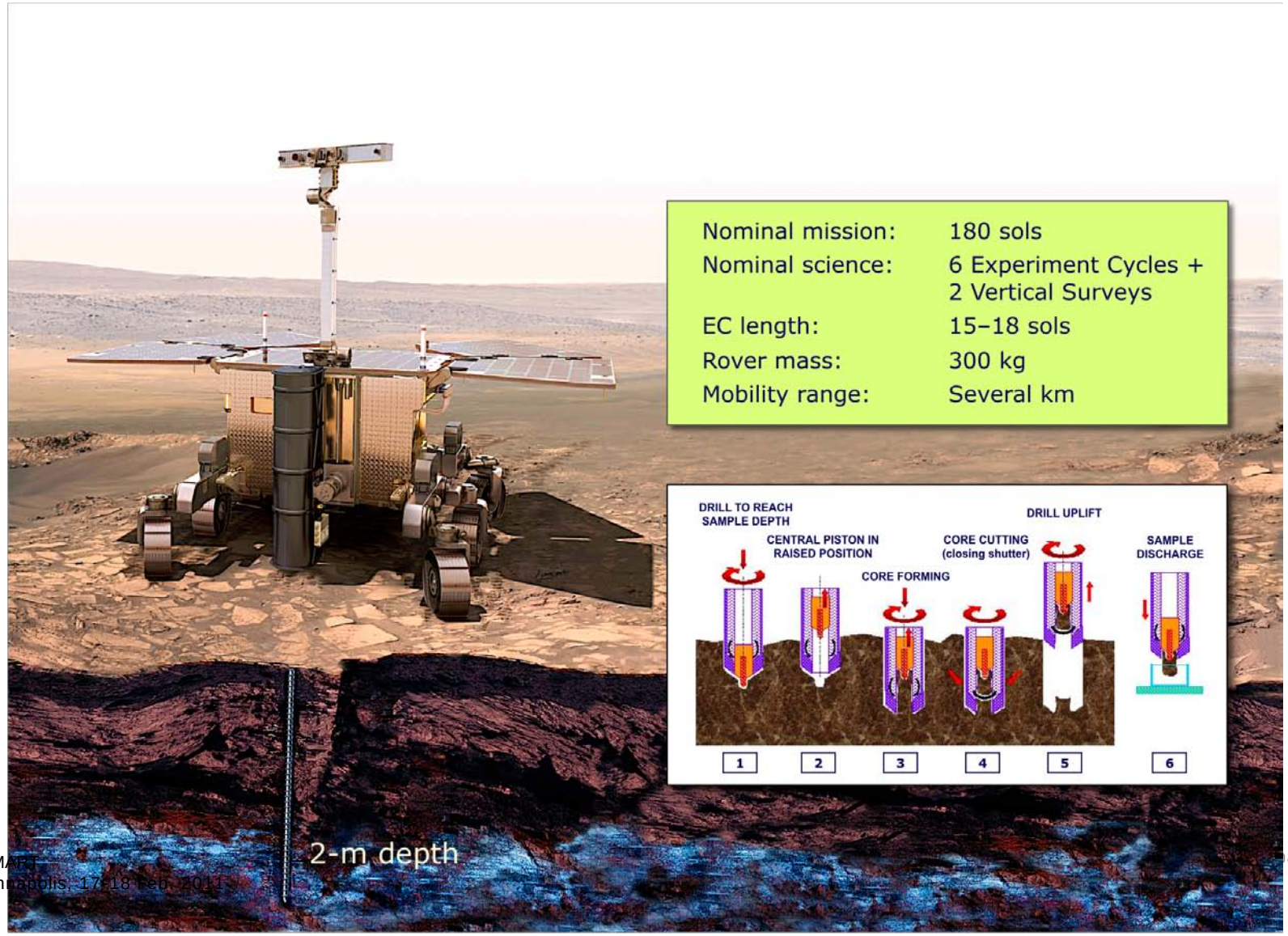
TECHNOLOGY OBJECTIVES

- Surface mobility with a rover (having several kilometres range);
- Access to the subsurface to acquire samples (with drill, down to 2-m depth);
- Sample acquisition, preparation, distribution, and analysis.

SCIENTIFIC OBJECTIVES

- To search for signs of past and present life on Mars;
- To characterise the water/subsurface environment as a function of depth in the shallow subsurface.

ExoMars Rover



Science Exploration Scenario

Determine the rover's geological context:

- Survey site at large scales — **Panoramic Instruments**
- Examine surface outcrops and soils at sub-mm scales — **Close-Up Instruments**

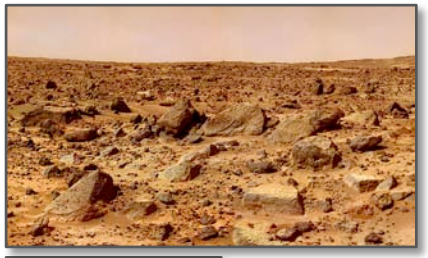
Collect a subsurface (or surface) sample

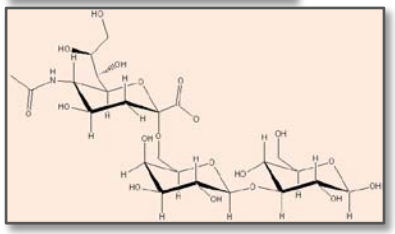
Study sample:

- Survey analysis
- Detailed analysis

Analytical Laboratory

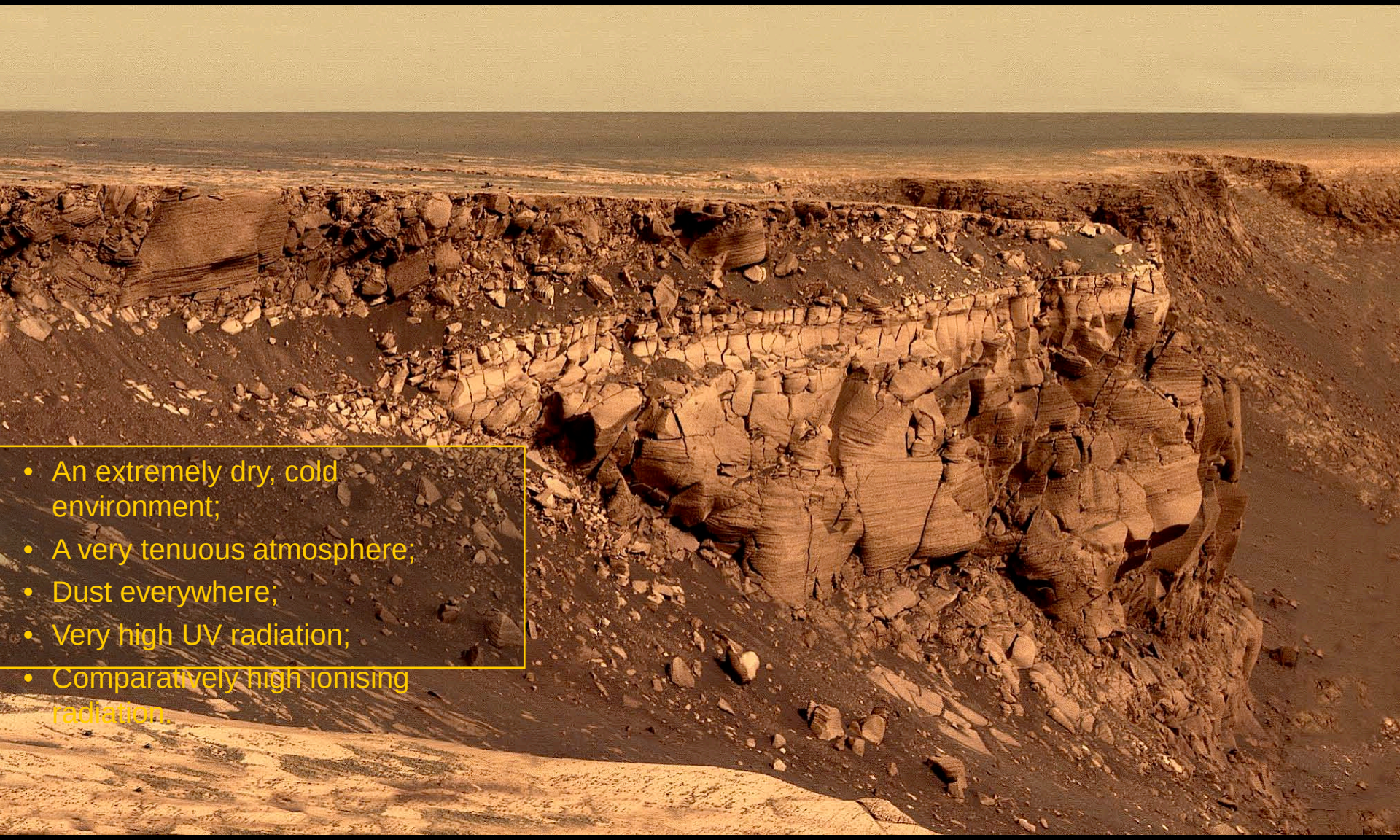
Cache Sample





Scale

Present Surface Conditions



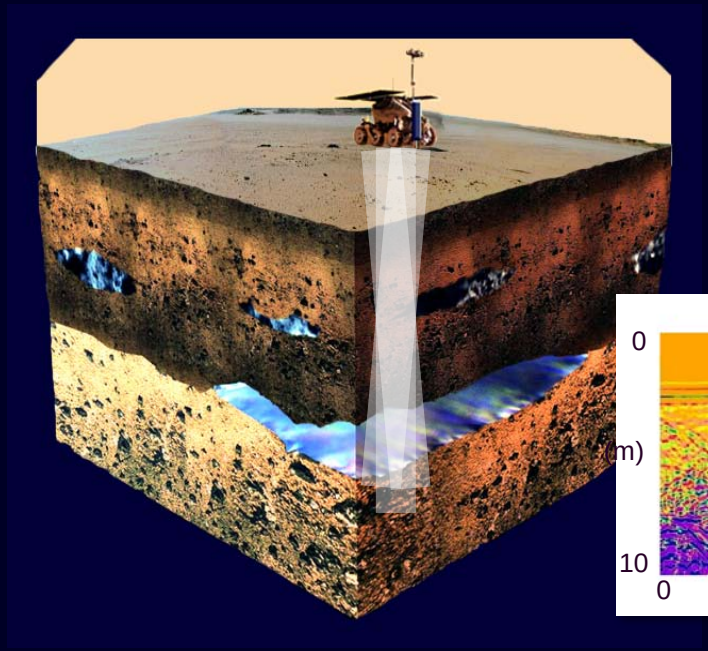
- An extremely dry, cold environment;
- A very tenuous atmosphere;
- Dust everywhere;
- Very high UV radiation;
- Comparatively high ionising radiation.

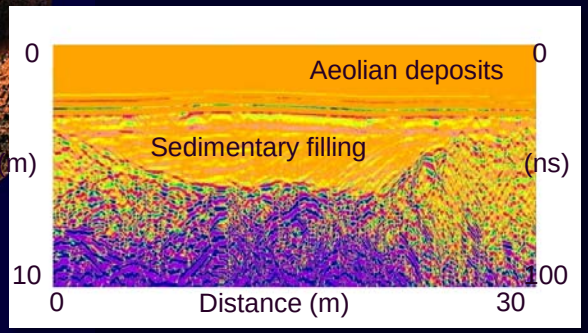
Credit: NASA - Opportunity

Site Characterisation

AT PANORAMIC SCALE: To establish the geological context

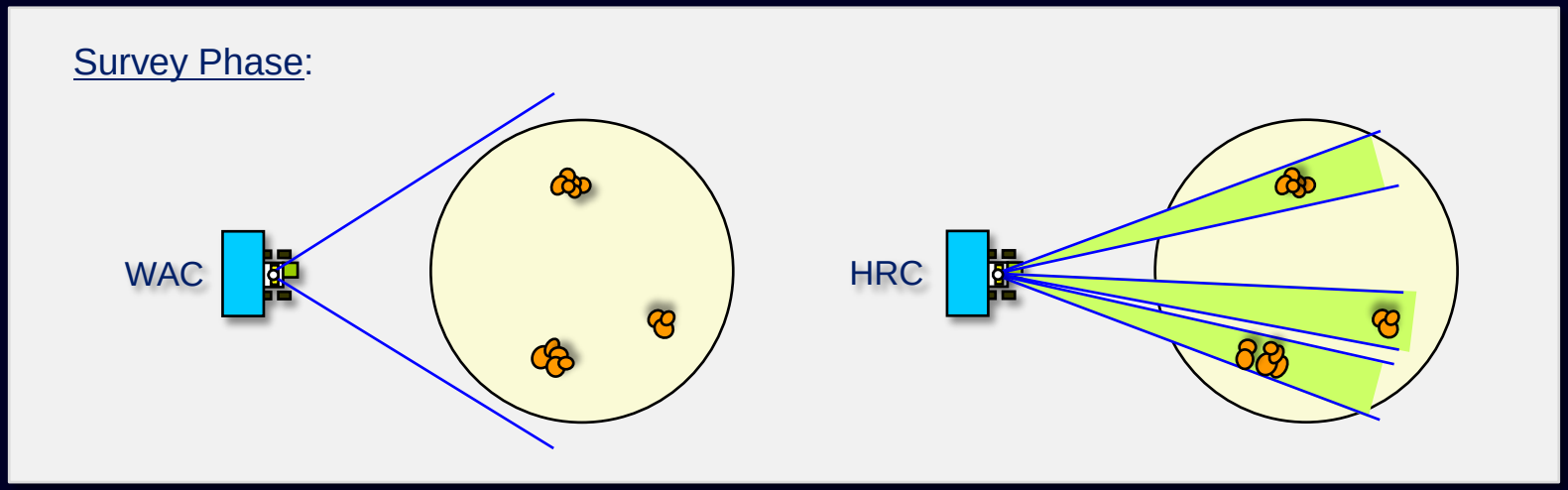
Ground-Penetrating Radar

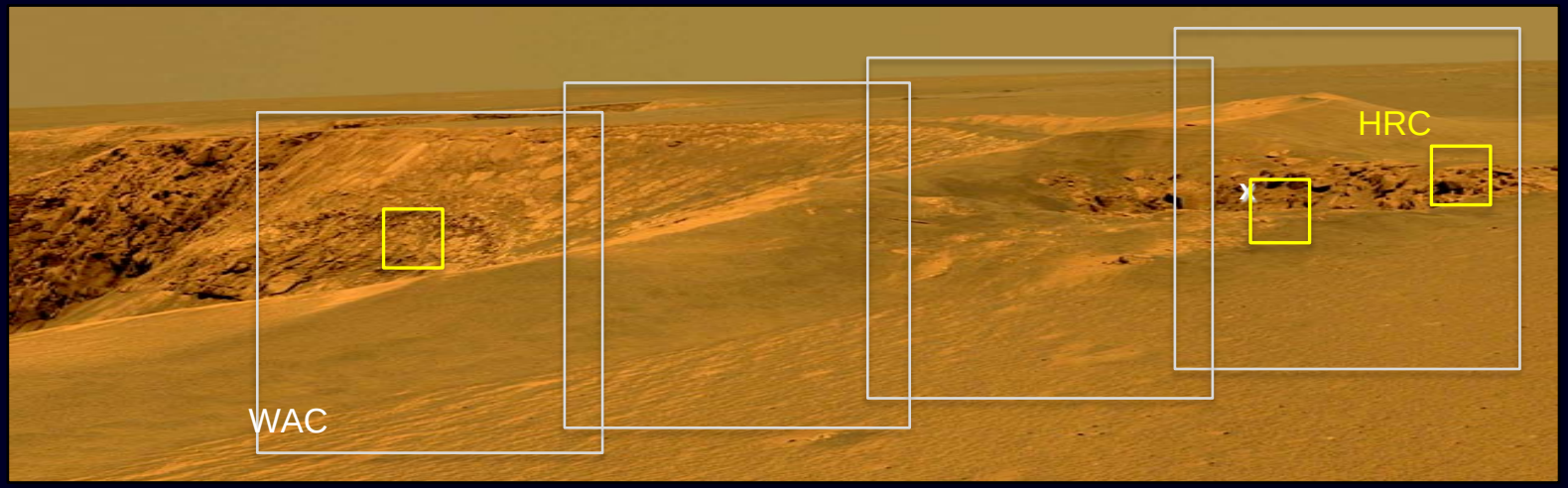




Heggy et al. 2007

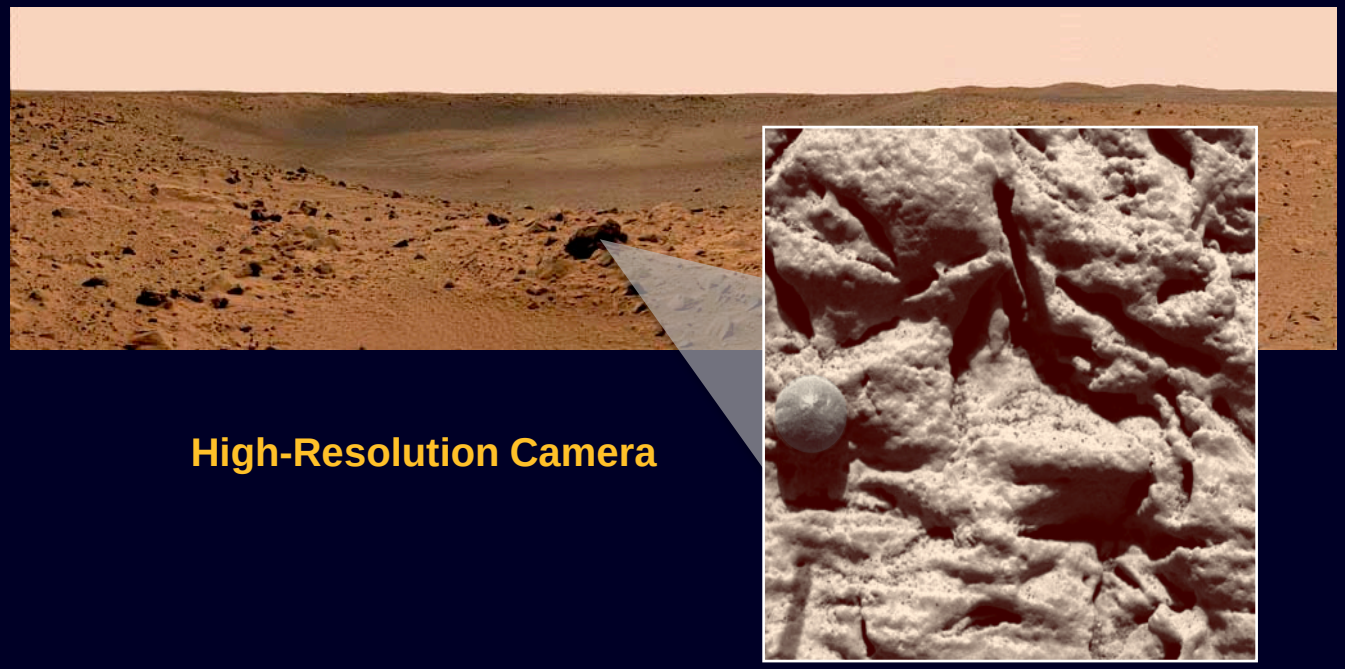
Site Characterisation





Outcrop Characterisation

AT ROCK SCALE: To ascertain the past presence of water
For a more detailed morphological examination



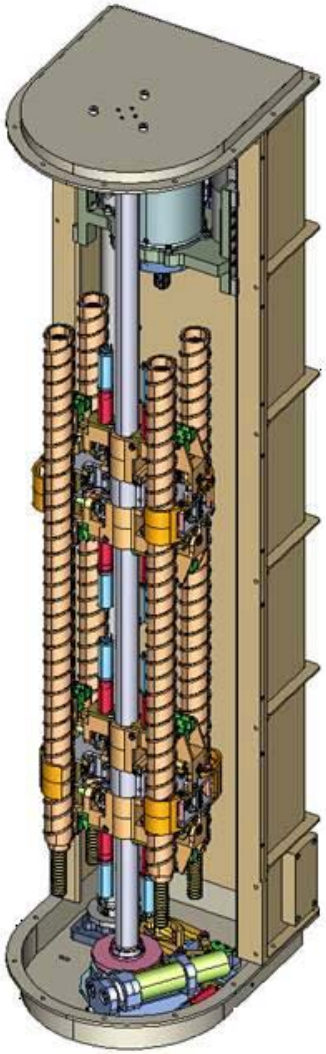
High-Resolution Camera

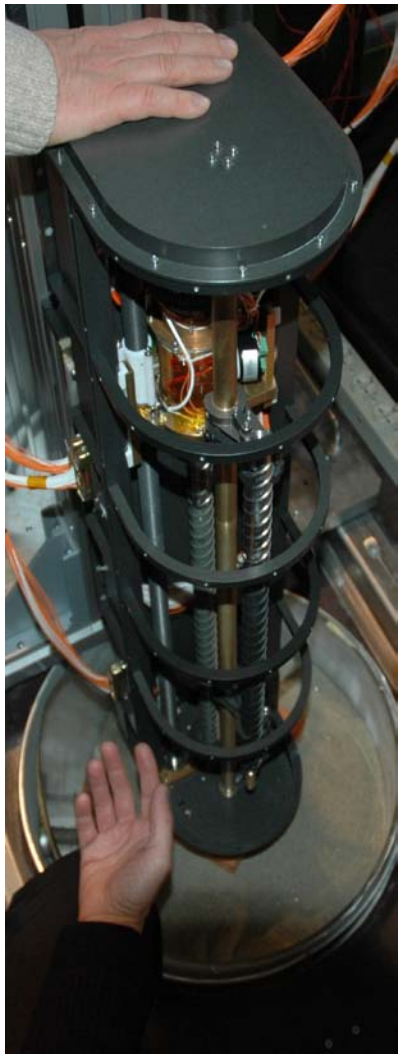
Next step: **ANALYSIS**

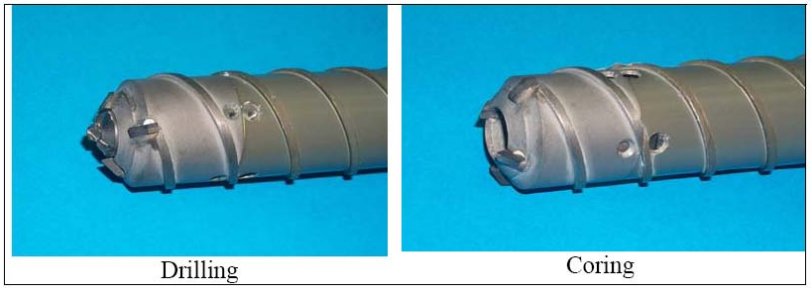
Use the drill to collect a sample

- From an outcrop
- From the subsurface

Drill



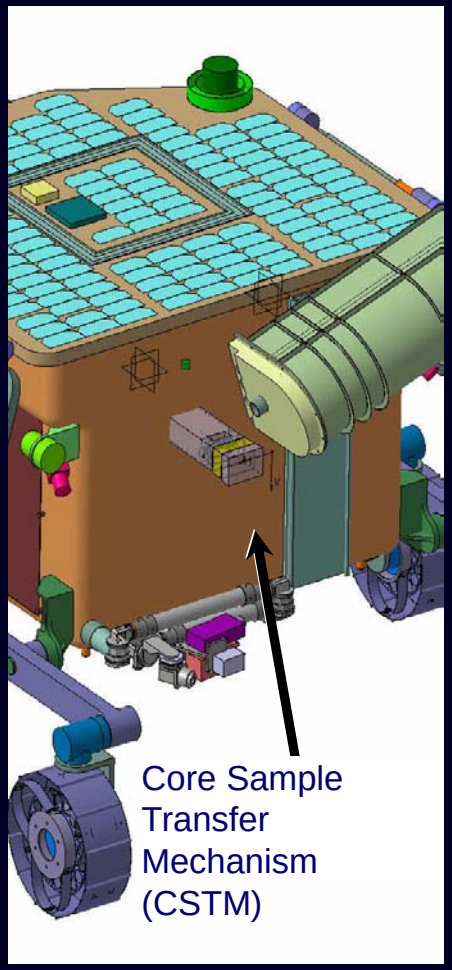


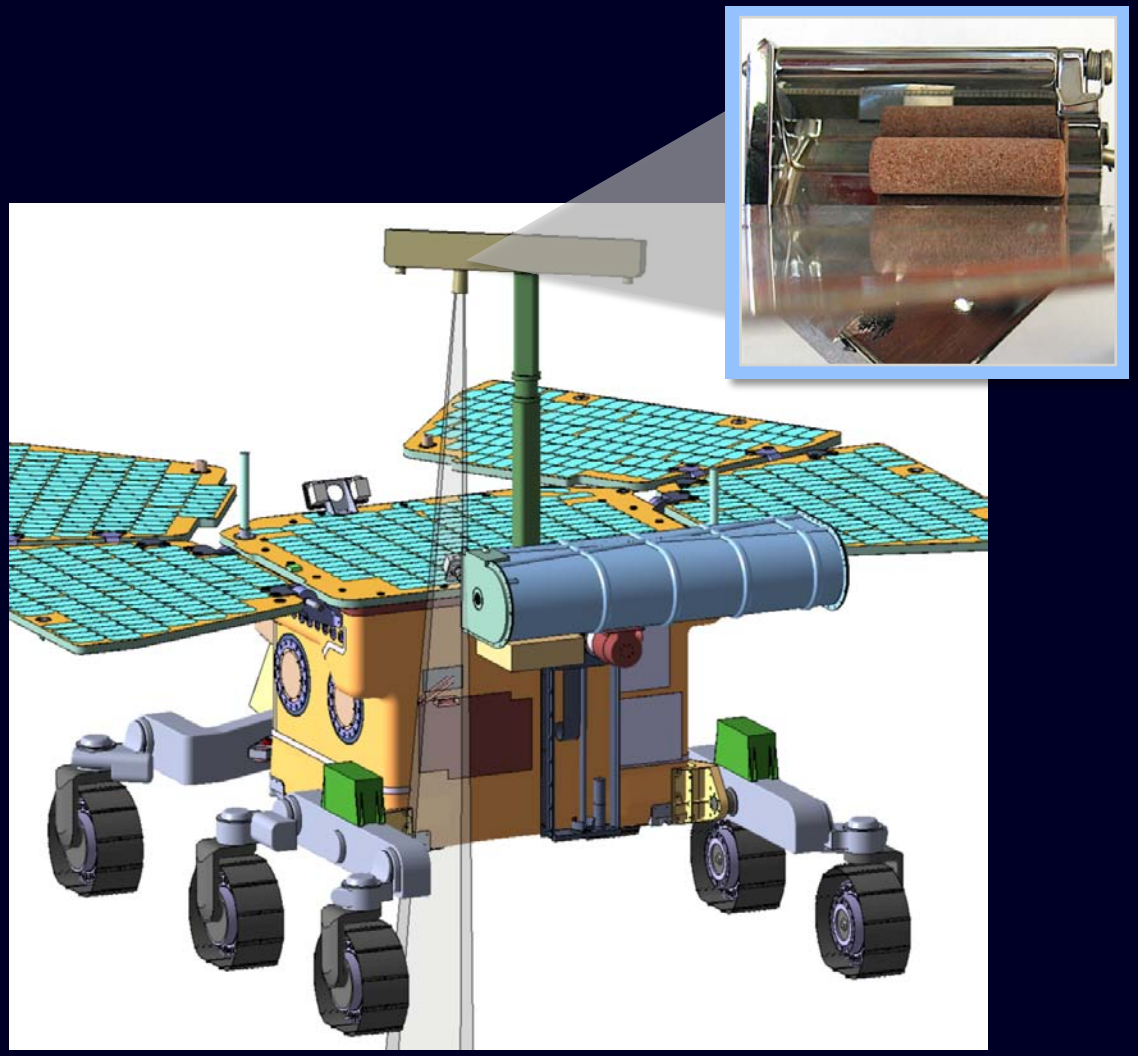


Drill Tool with sample acquisition mechanism

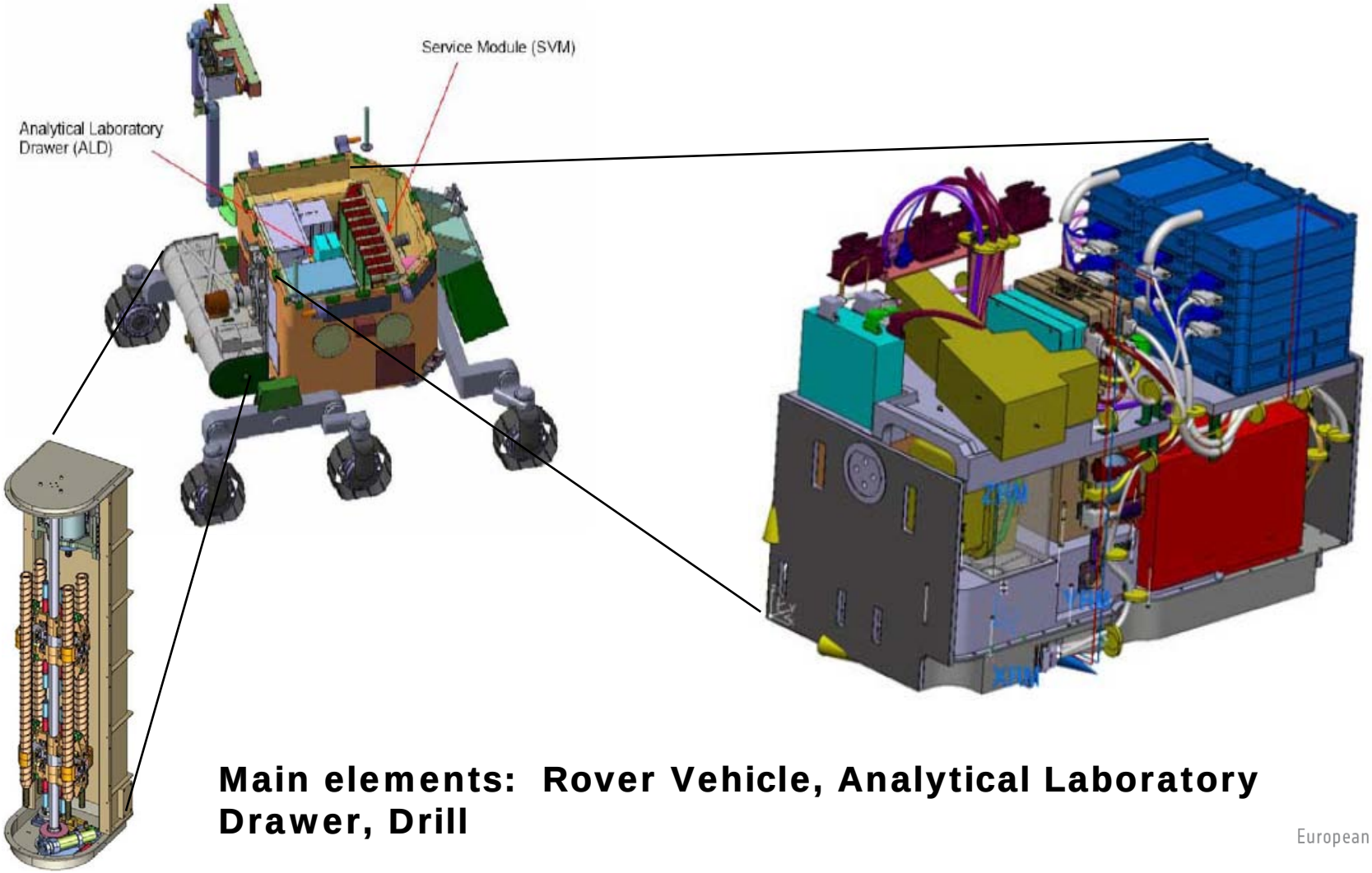
Sample Delivery

DRILL discharges sample into Core Sample Transfer Mechanism (CSTM). PanCam HRC images sample.



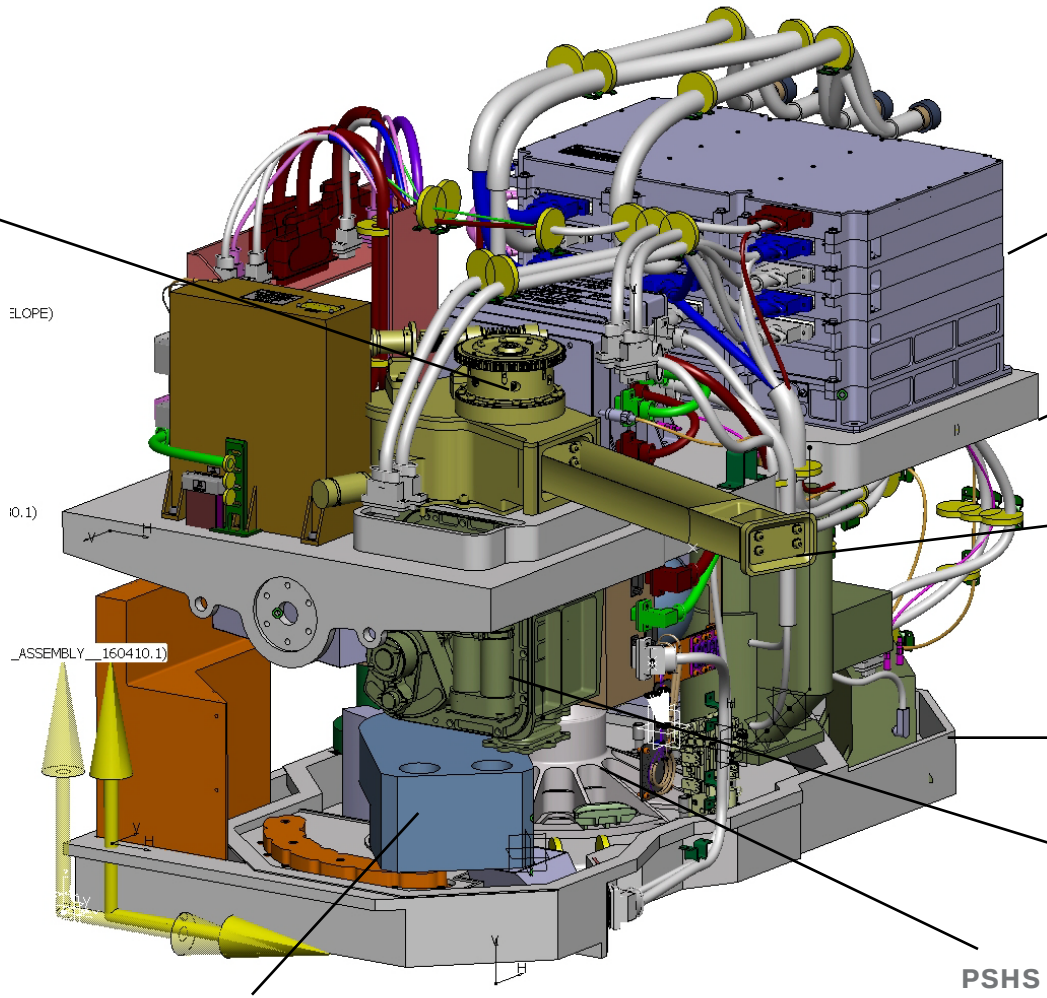


Flight segment: Rover Module



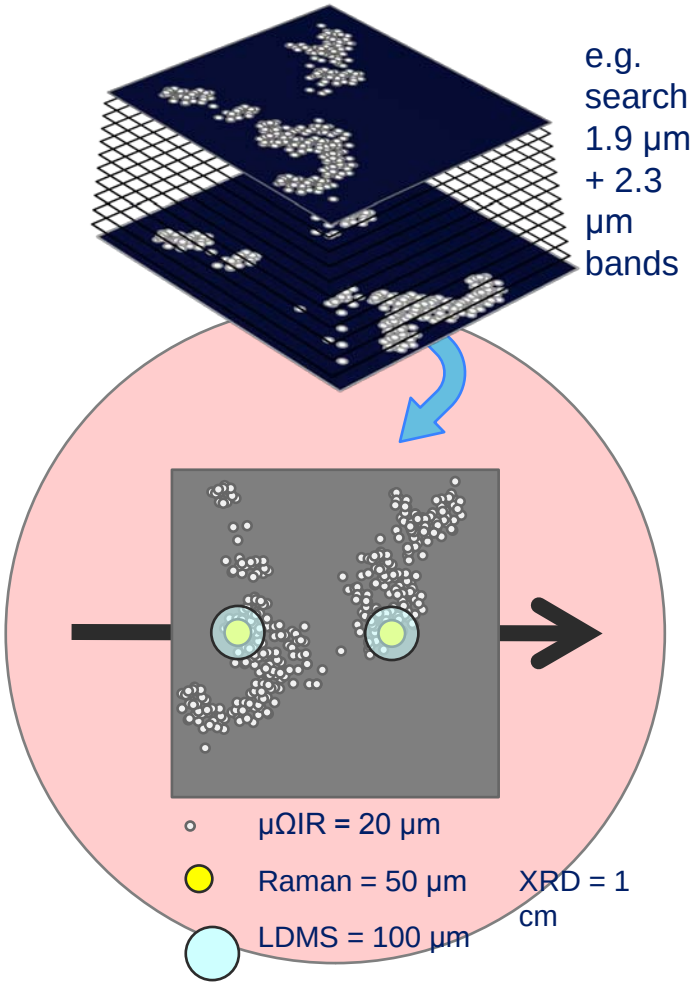
Main elements: Rover Vehicle, Analytical Laboratory Drawer, Drill

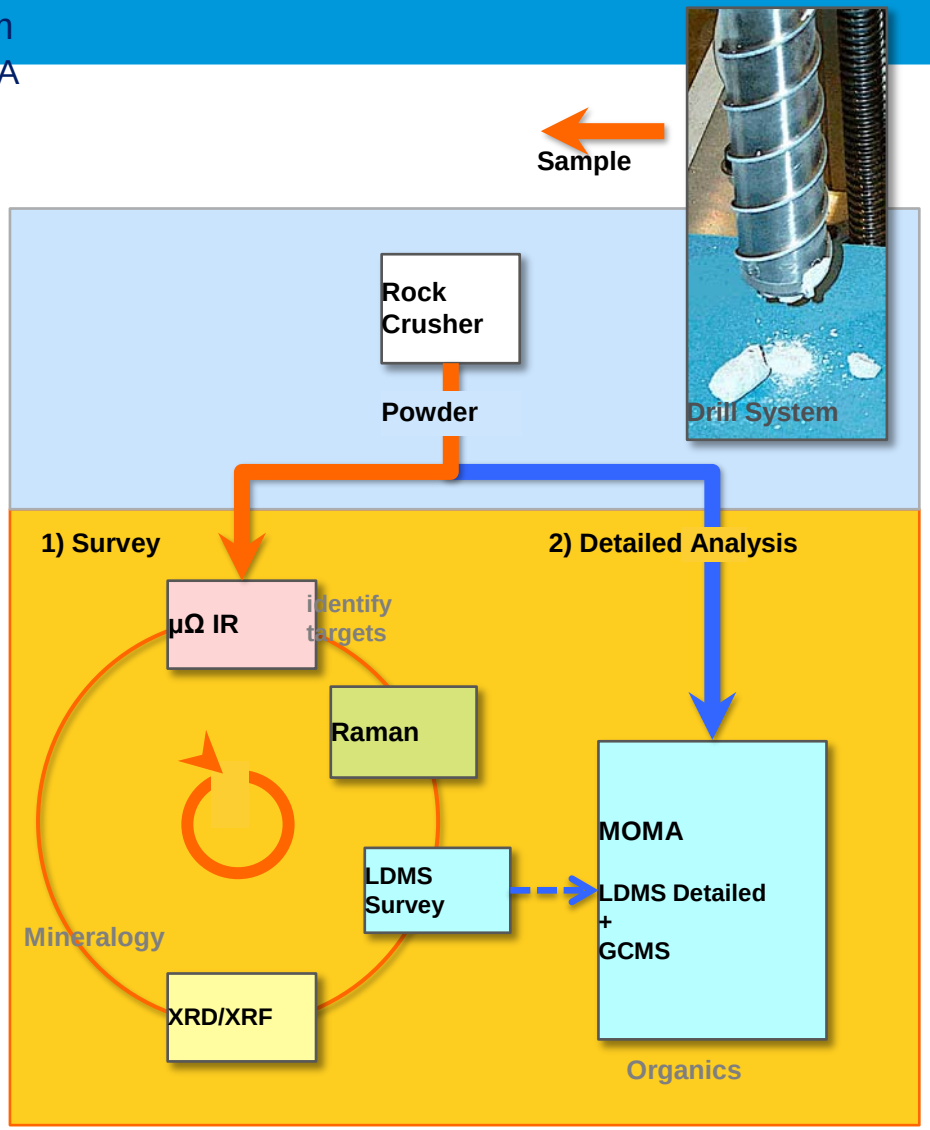
ALD current configuration



Sample Analysis

Use mineralogical + imaging information from μΩIR to identify targets for Raman and MOMA LDMS.





Pasteur Payload

Instrument Name	Description	Mass (kg) including maturity margin
PanCam (WAC + HRC)	Panoramic camera system	1.560
MOMA	LD-MS + Pyr GC-MS for organic molecule characterisation	6.100
MicrOmega IR	IR imaging spectrometer	0.960
Mars-XRD	X-ray diffractometer + X-ray fluorescence	1.480
Raman (internal)	Raman spectrometer	2.260
WISDOM	Shallow ground-penetrating radar	1.380
Ma_Miss included in 2.0-m drill	IR borehole spectrometer	0.650

Why MSR, and not *in situ*?

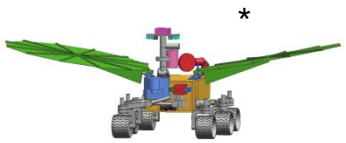
There are three primary reasons why MSR is of such high value compared to in situ alternatives.

1. Complex sample preparation, including sample-related decision-making

2. Many critical lab-based instruments are large/complex

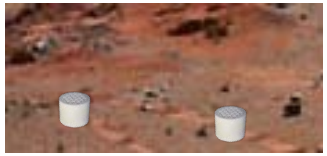
3. Instrument diversity. Investigation pathways are not hypothesis-constrained

Functional Steps Required to Return a Scientifically Selected Sample to Earth – Mapped to a 4-*Element* Architecture



Sample Caching Rover (MAX-C) *

Launch from Earth/Land on Mars → Select Samples → Acquire/Cache Samples



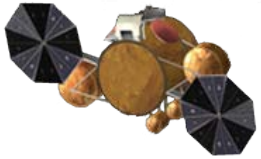
Sample Canisters On Mars Surface *

** *

Mars Sample Return Lander

Retrieve/Package Samples on Mars → Launch Samples to Mars Orbit

Orbiting Sample (OS) in Mars Orbit *

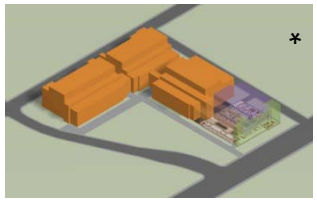


** *

Mars Sample Return Orbiter

Capture and Isolate Sample Container → Return to Earth → Land on Earth

Orbiting Sample (OS) On Earth



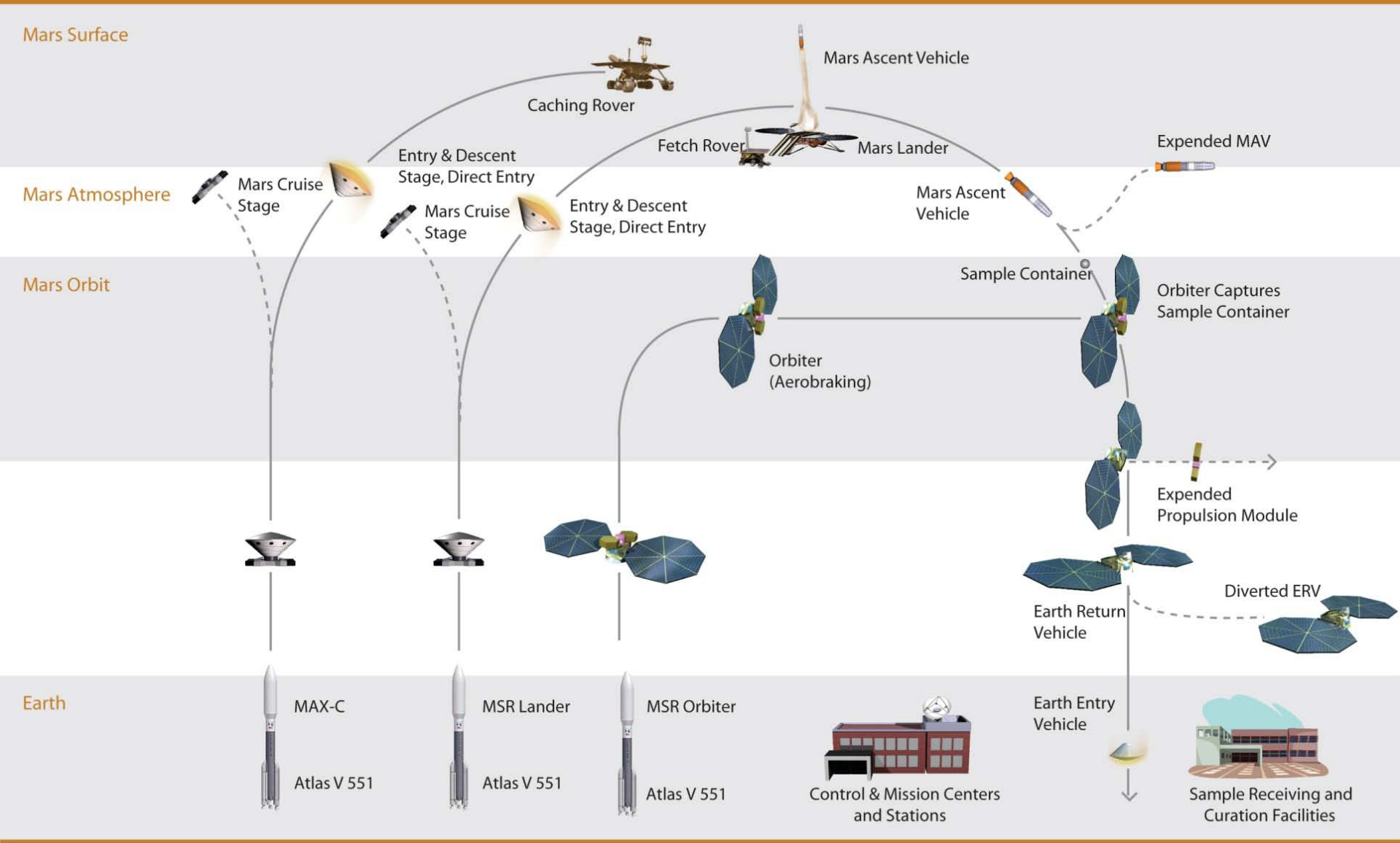
Mars Returned Sample Handling (MRSH) Facility *

Retrieve/Quarantine and Preserve Samples on Earth → Assess Hazards → Sample Science

Sample Science

**Note: Launch sequence of MSR-L/MSR-L can be switched: launching MSR-O first can provide telecom relay support for EDL/surface operation/MAV launch

Three-Opportunity MSR Campaign



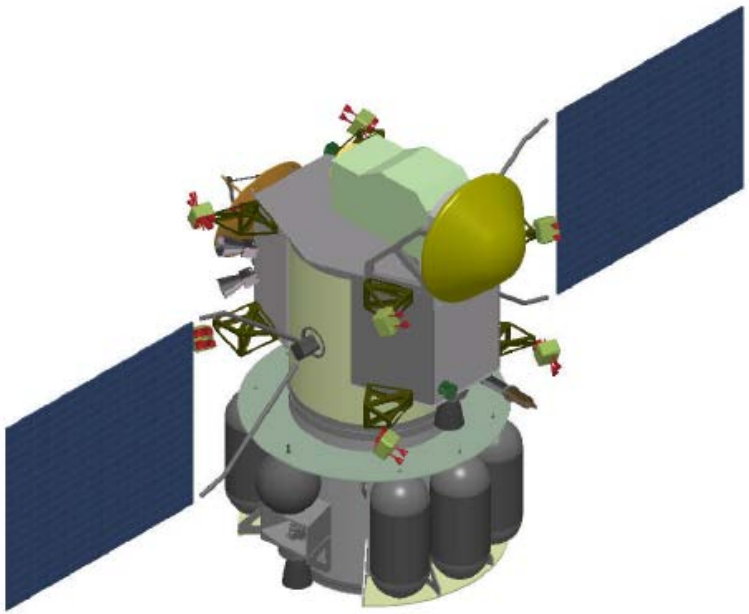
Mars Robotic Exploration Preparatory Programme

1. Aim for Europe is long-term funding line for European Mars exploration
2. With goal of ensuring a significant participation in an eventual global exploration initiative
3. More science and technology opportunities
4. Technical and science objectives can be spread over several missions

The Future: MREP Future Mission Studies

1. Following ESA/PB-HME discussions, 4 candidate missions are being studied for future Mars missions (2020-2022 timeframe):
    a. MSR Orbiter
    b. Precision Lander with a Sample Fetching Rover
    c. Network Science Mission with or w/o precision landing
    d. Sample Return Mission from a moon of Mars (Deimos/Phobos)
2. Down-selection of 2 missions expected at the next C-Min (2012)
3. Develop and consolidate the necessary technologies

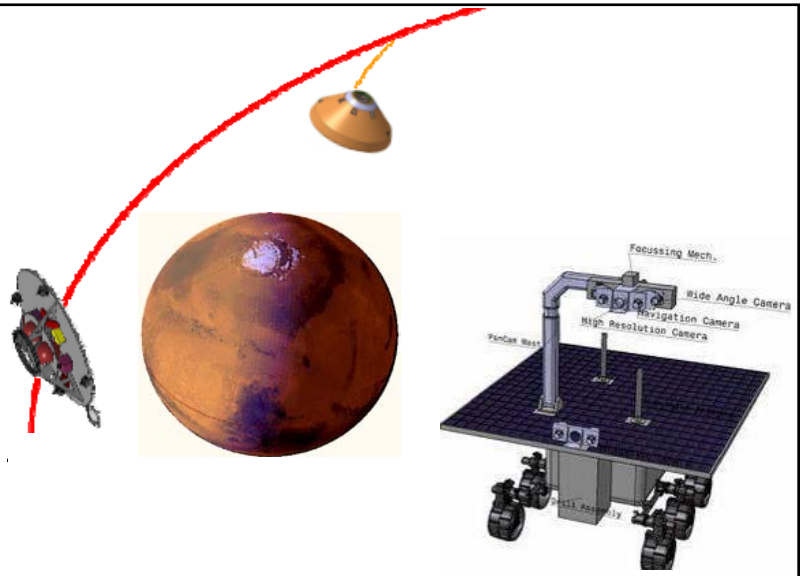
The Future: MREP Future Mission Studies



MSR Orbiter

Space segment of MSR campaign. Includes communication function, sample capture in orbit, bio-sealing, return vehicle

Parallel industrial study contracts kicked-off in Jan 2011, 1 year

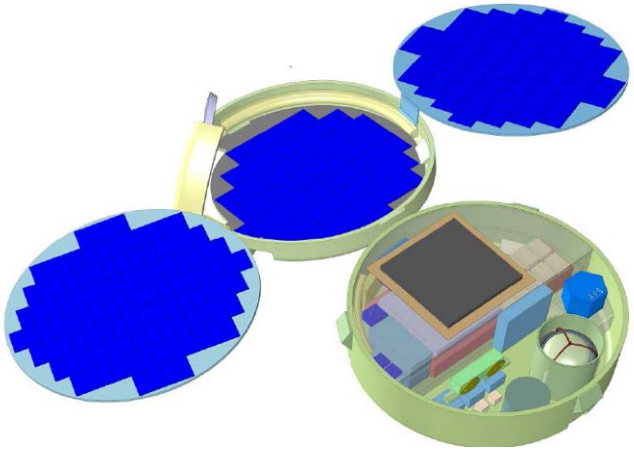


Mars Precision Lander with fetch rover

Potential space segment of MSR campaign. High precision landing (≤ 10 km) with mass delivery to Mars surface 60-300 kg

Parallel industrial study contracts kicked-off in Jan/Feb 2011, 1 year

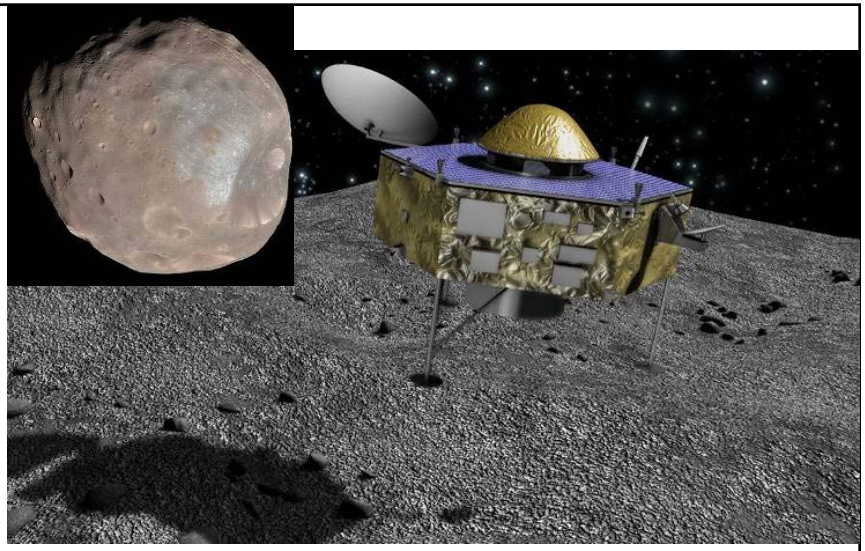
The Future: MREP Future Mission Studies



Mars network mission

Understanding Mars structure and environment.
Requires 3-4 surface elements (~40-60 kg)
Small lander technology, possible use of European RHUs

Internal study, relying on previous study contracts. To be completed early 2012

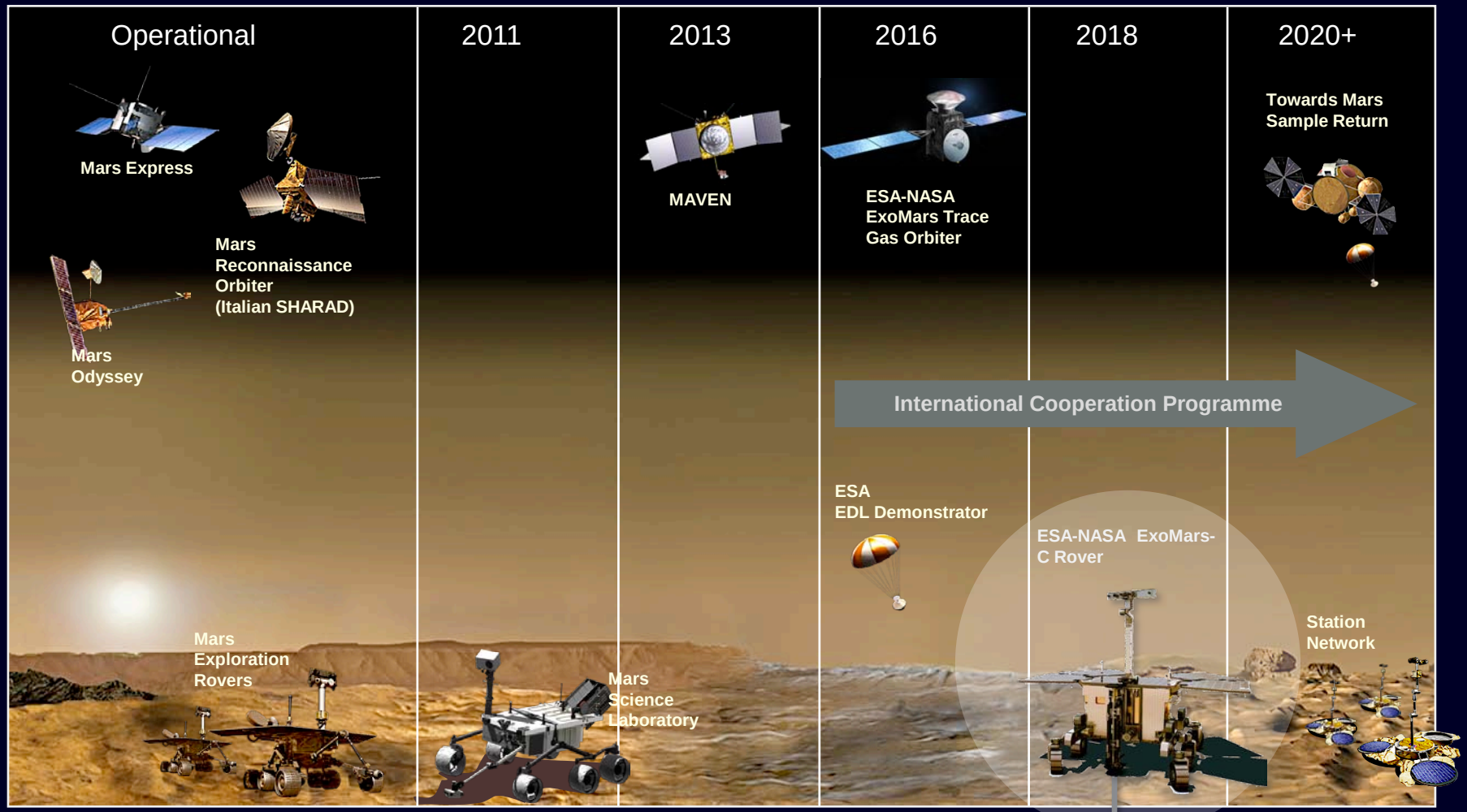


Mars moon sample return

Sample return from Phobos or Deimos.
Prepares key MSR technologies: sample conditioning and handling , re-entry vehicle
Internal study, relying on previous study contracts. To be completed early 2012

The Future: MREP Future Mission Studies

1. Activities initiated for most of MSR themes
    a. Guidance Navigation and Control, Precision EDL, Robotics and rover technologies, bio-sealing in orbit, Autonomous RdV and capture in orbit, Earth re-entry
2. No ESA activity on Mars Ascent Vehicle (MAV);
3. Long term enabling technologies: Nuclear power
    a. Fuel selected Am_2O_3. Chemical production. Demonstration contract running, to be completed by 2012
    b. Activities on thermal to electrical conversion (Stirling, thermo-electric), encapsulation and safety aspects initiated
    c. Pending sustained financial support, technology could be available for preparatory missions



- **MSL**: powerful rover; large 2-D mobility.
- **ExoMars-C**: next-generation instruments; 3-D access; sample caching.

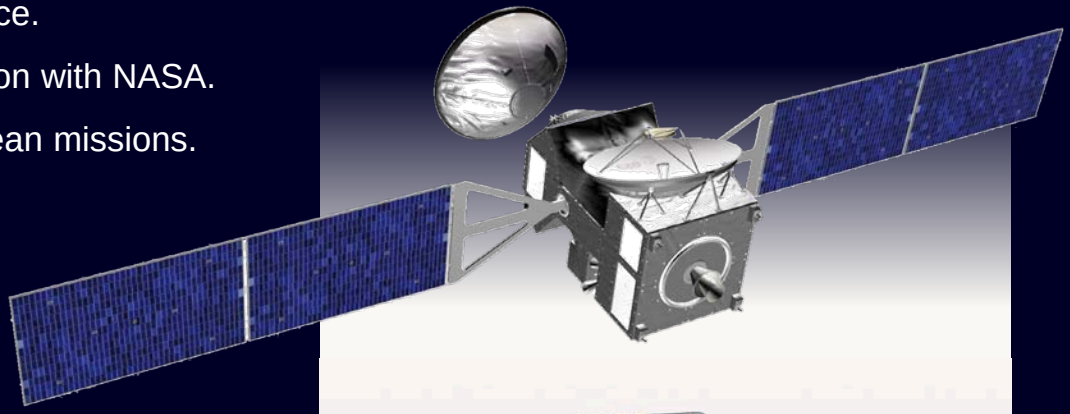
Following on the results of MSL, ExoMars is the logical next step in international Mars surface exploration.

➔ 2016: ExoMars Trace Gas Orbiter

Its science outcome will provide new insights into our understanding of Mars and of key atmospheric processes of potential astrobiological relevance.

An excellent base for international collaboration with NASA.

Master landing technologies for future European missions.



➔ 2018: ExoMars-C Rover

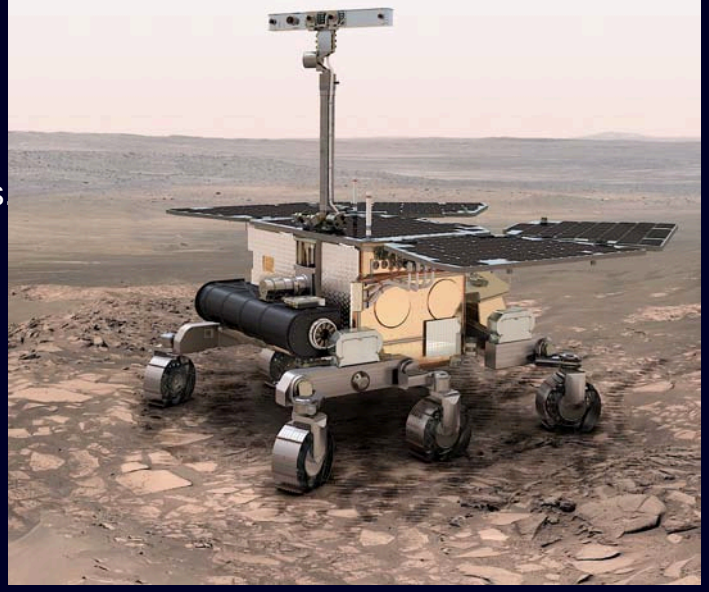
A great exobiology mission.

The first ever to combine mobility with access to the subsurface.

The rover's Pasteur payload contains next-generation instruments.

The rover will study, for the first time:

- Organics and biomarkers for past and present life at depth;
- Vertical characterisation of geochemistry and water;
- Cache samples for MSR.

New sample handling and locomotion technologies.

A step closer to Mars Sample Return.