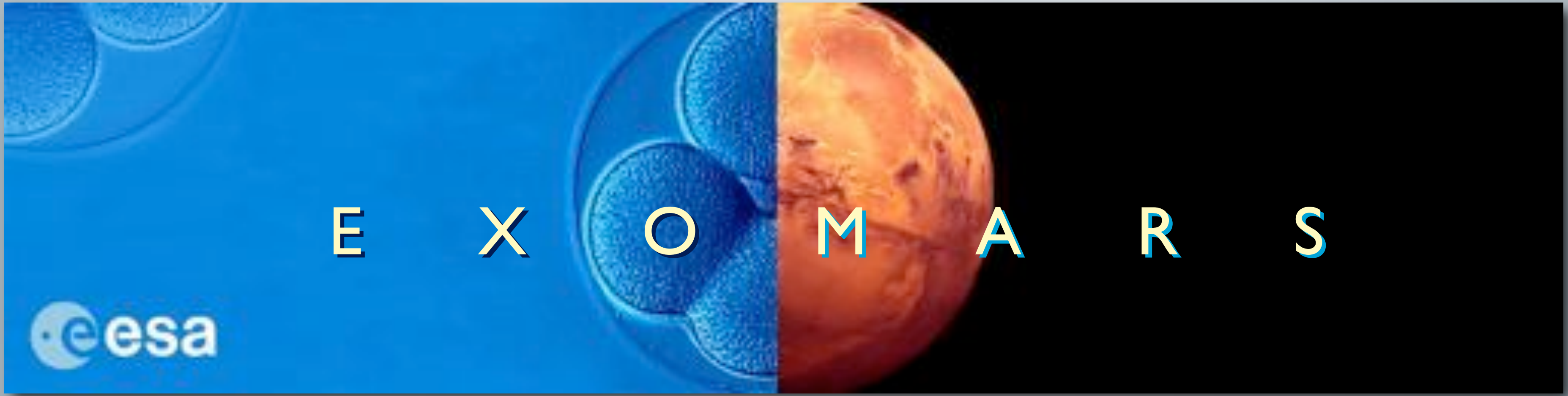


ESA's Mission to Search for Signs of Life

J. L. Vago and the ExoMars Project Team

Planetary Science Decadal Survey: Mars Panel Meeting
10 September 2009, Arizona State University, Tempe (USA)

Mission Objectives

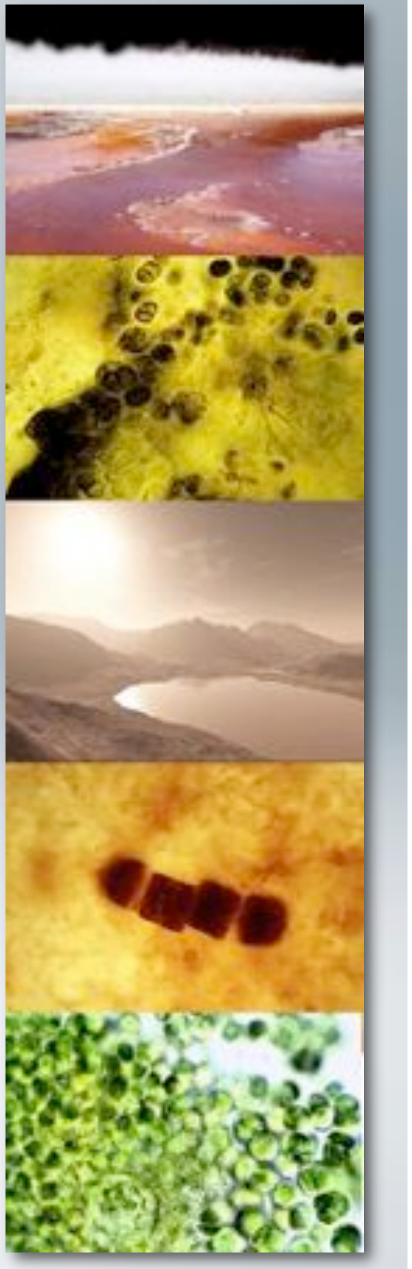
ExoMars is the first mission in ESA's Aurora Programme, but also in the wider international collaboration effort for Mars robotic exploration.

TECHNOLOGY DEMONSTRATION OBJECTIVES:

- Entry, Descent, and Landing (EDL) of a large payload on the surface of Mars;
- Surface mobility with a rover having several kilometres range;
- Access to the subsurface with a drill to acquire samples down to 2 metres;
- Automatic sample preparation and distribution for analysis with scientific instruments.

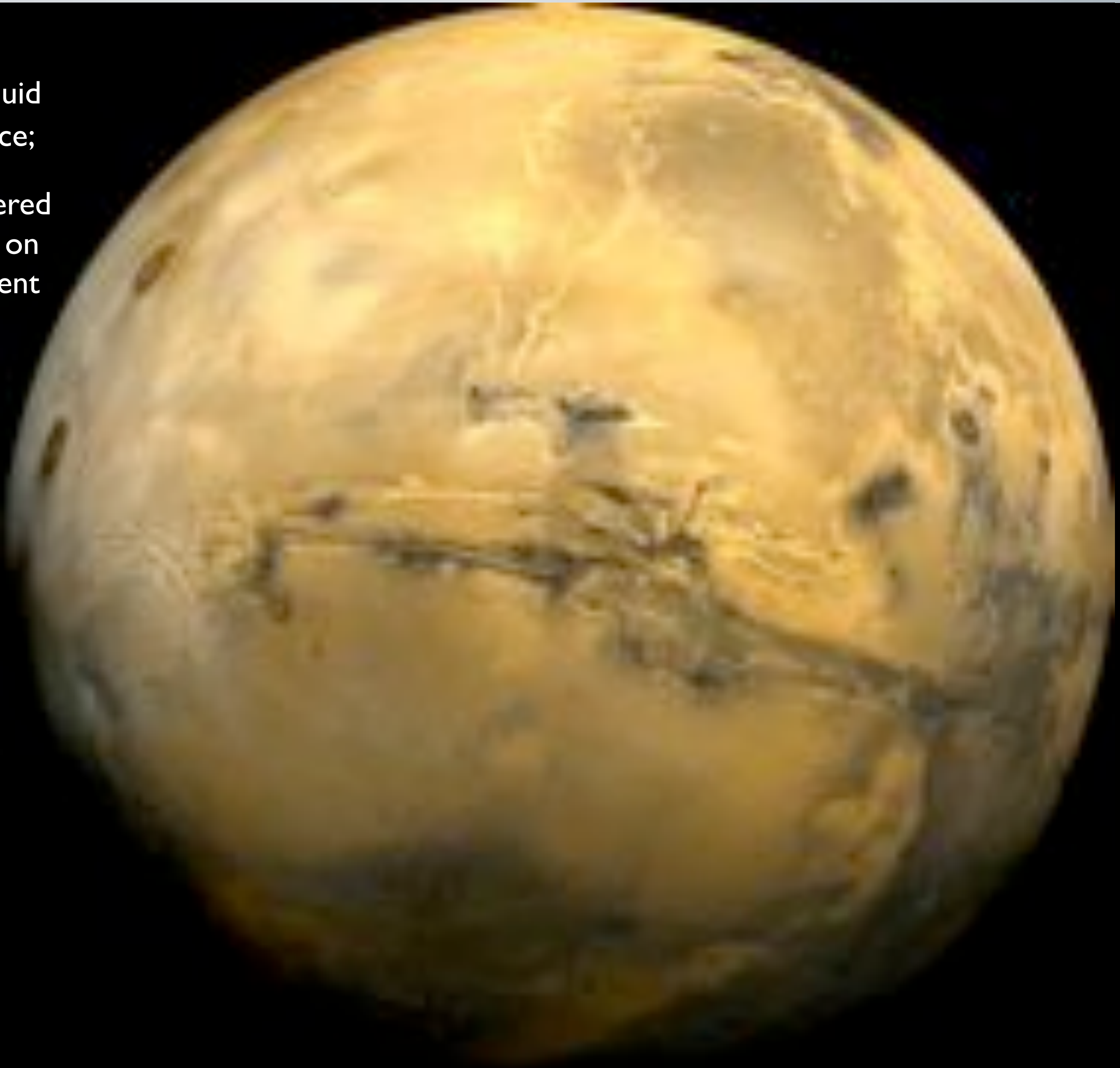
SCIENTIFIC OBJECTIVES (in order of priority):

- To search for signs of past and present life on Mars;
- To characterise the water/geochemical environment as a function of depth in the shallow subsurface;
- To investigate trace gases and their distribution in the Martian atmosphere (Orbiter).



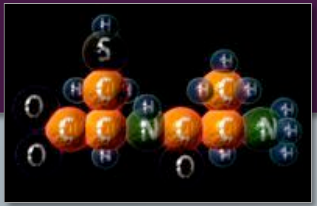
Why Life on Mars ?

- 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 <u>fundamental</u> for planning future human missions.



What to Search For

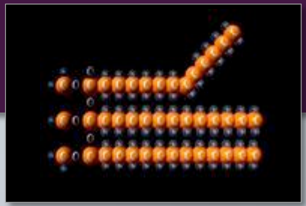
- **PRESENT LIFE:** Biological markers, such as:



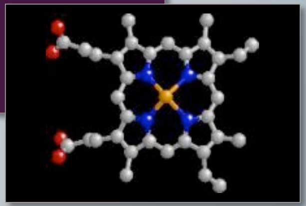
Amino acids

Nucleobases

Sugars



Phospholipids

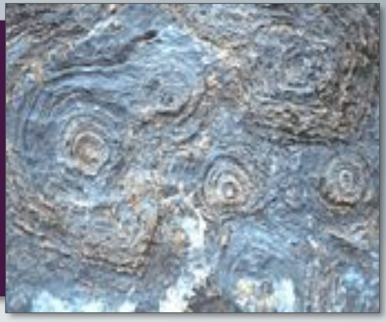


Pigments

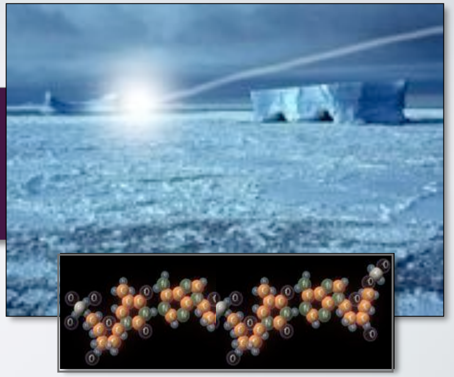
• • •

- **PAST LIFE:** Organic residues of biological origin;
  (chemical, chiral, spectroscopic, and isotopic info)

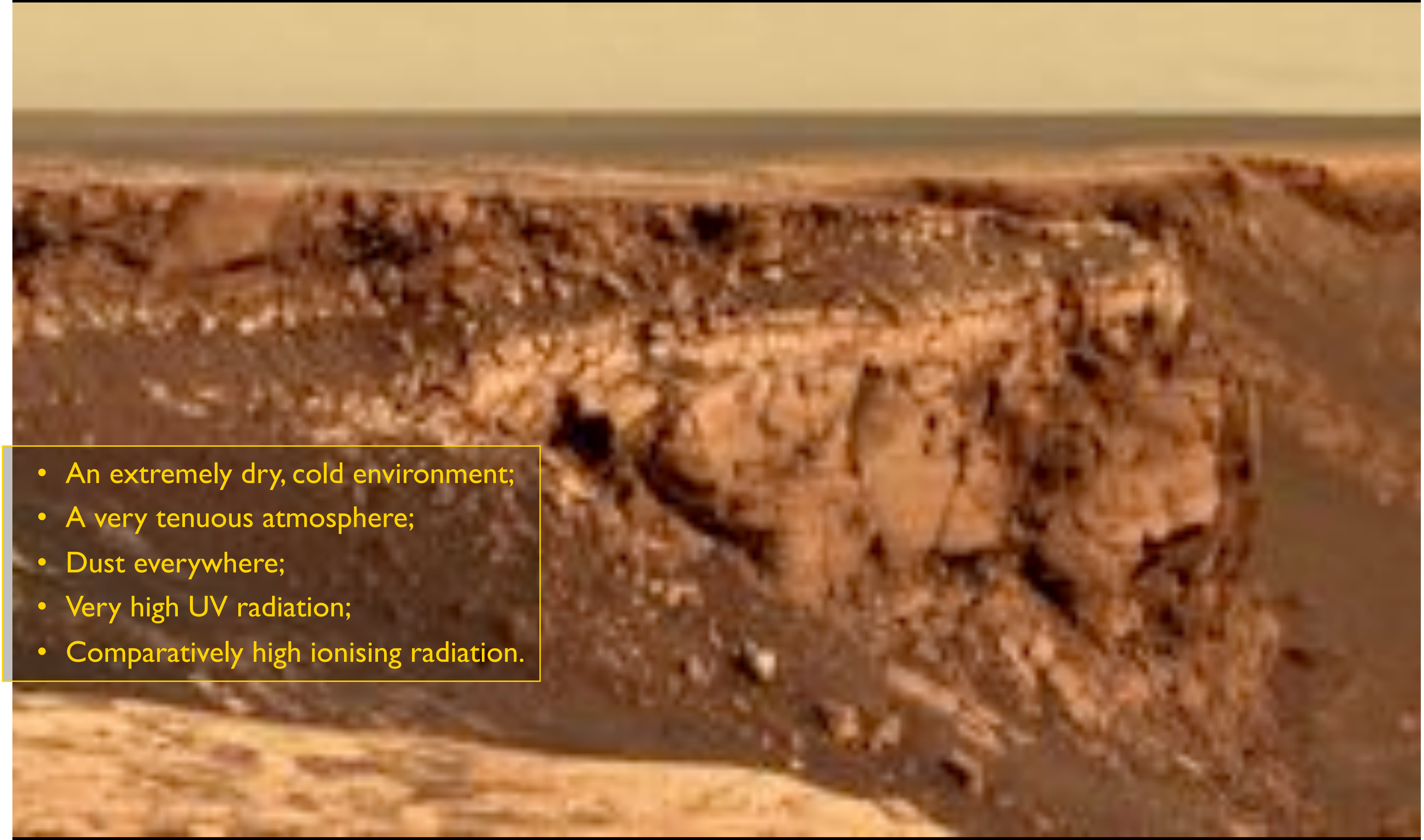
  Images of fossil organisms and their structure;
  (morphological evidence)



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



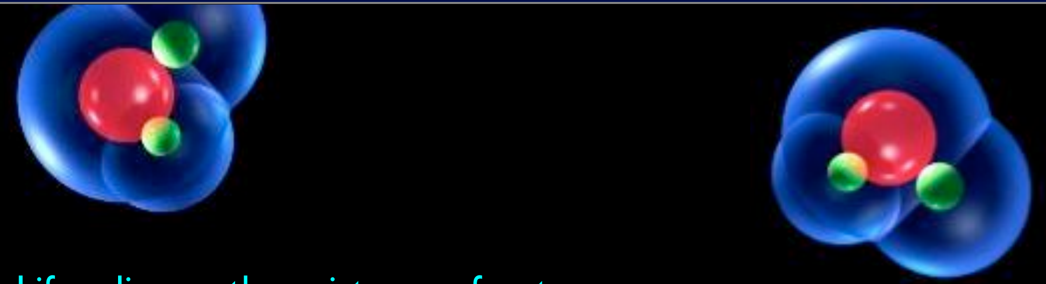
Present Surface Conditions



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

Credit: NASA - Opportunity

Where to Search



Above all else: Life relies on the existence of water

- Liquid water is presently unstable on the Martian surface (P & T are too low).
- Solar UV dose and oxidants are harmful to unprotected life and organic compounds.

➔ **the search for extant life will focus on the subsurface.**

Preferably on warm spots with evidence of water deposits at accessible depths, as identified from remote sensing satellites, i.e. Mars Express & MRO.

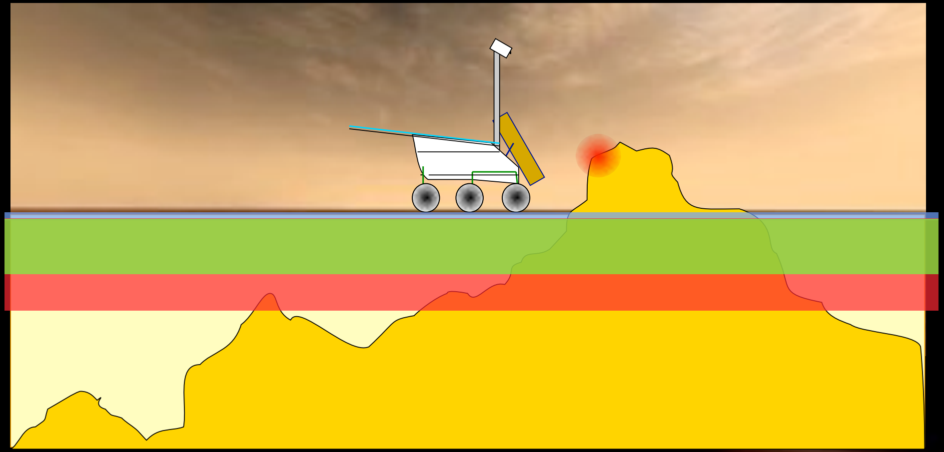
- For extinct life, the search strategy relies on looking for well-preserved biosignatures, i.e. encased in the geological record as microfossils.

➔ **the search for extinct life will also focus on the subsurface.**

On sites occupied by bodies of water over extended time periods:

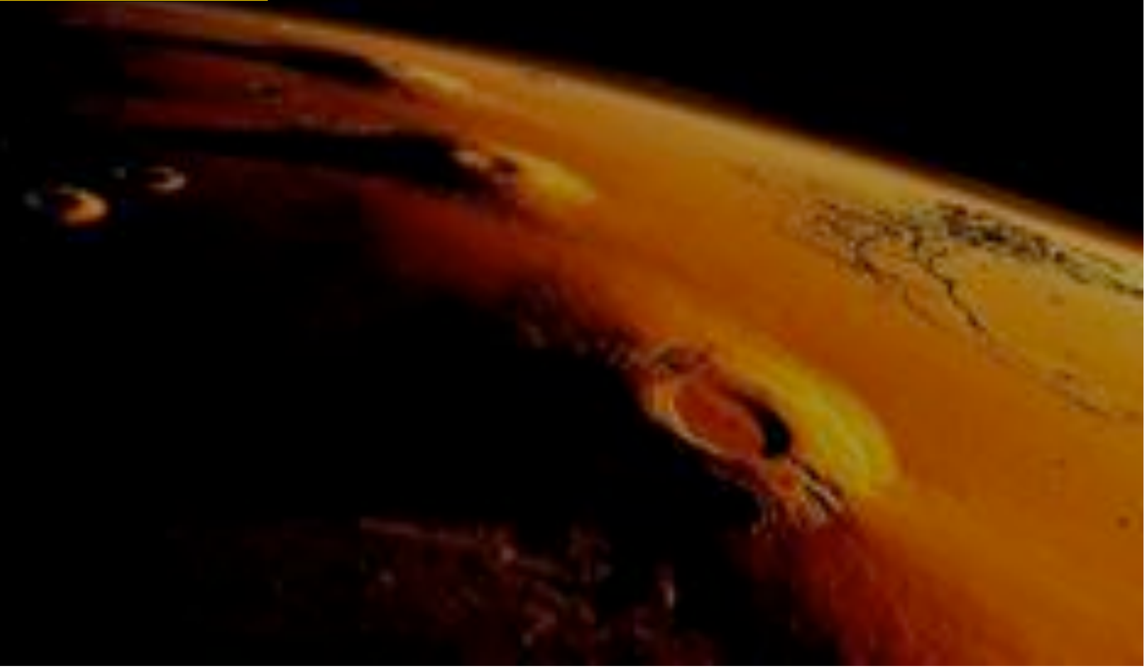
- Sedimentary deposits in ancient lake beds,
- Remains of hydrothermal systems;
- Outflow regions of past water channel system.

Where to Search

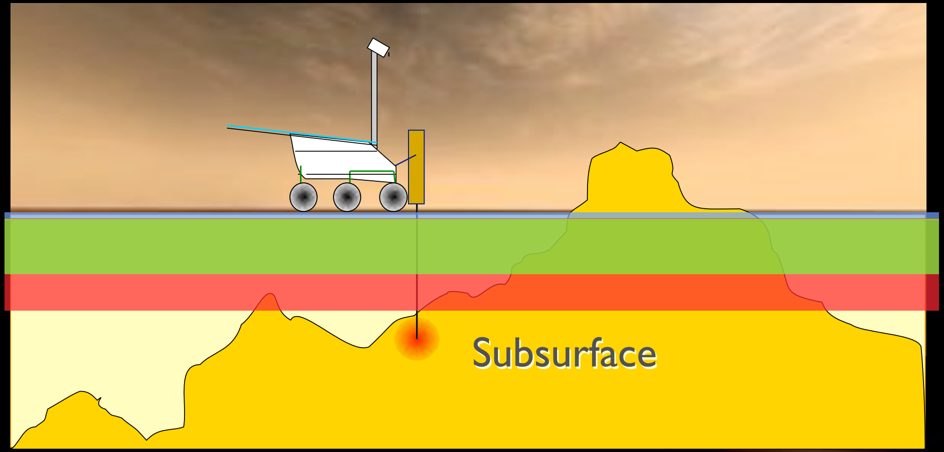


Penetration of organic destructive agents

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



Where to Search



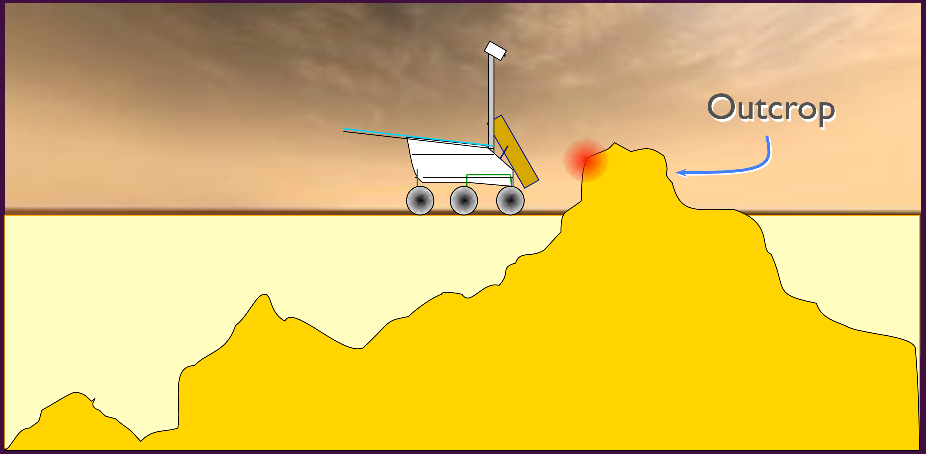
Penetration of organic destructive agents

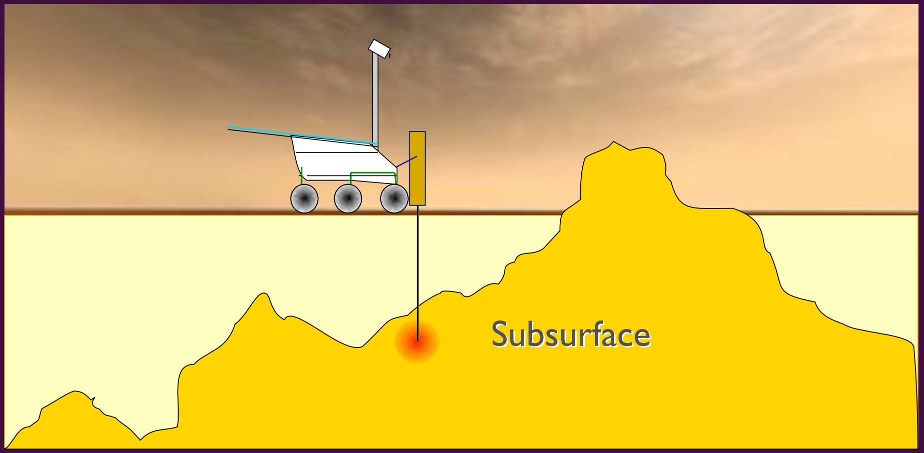
UV Radiation	~ 1 mm
Oxidants	~ 1 m
Ionising Radiation	~ 1.5 m

ExoMars Strategy:

Collect samples below the degradation horizon

Importance of Outcrops

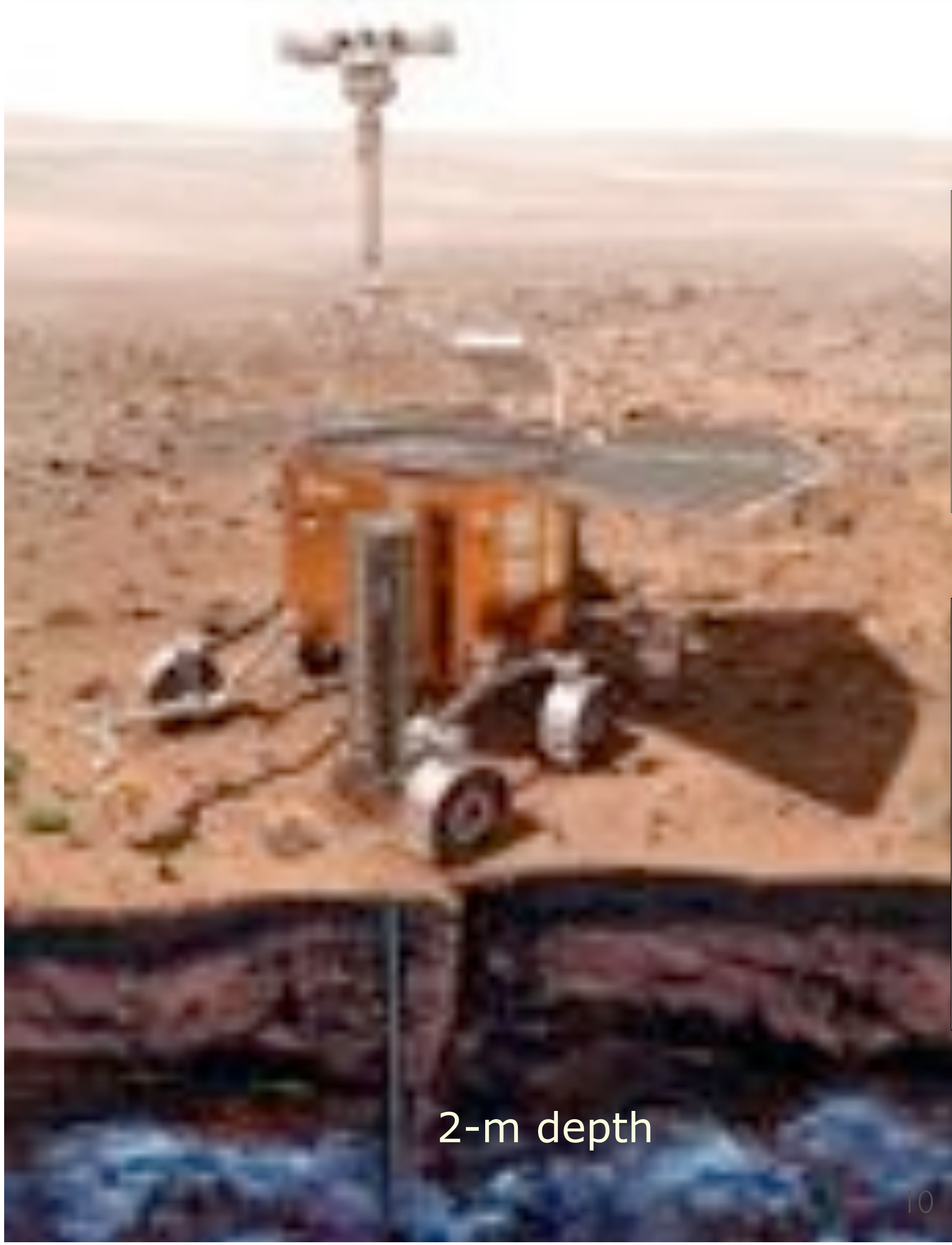


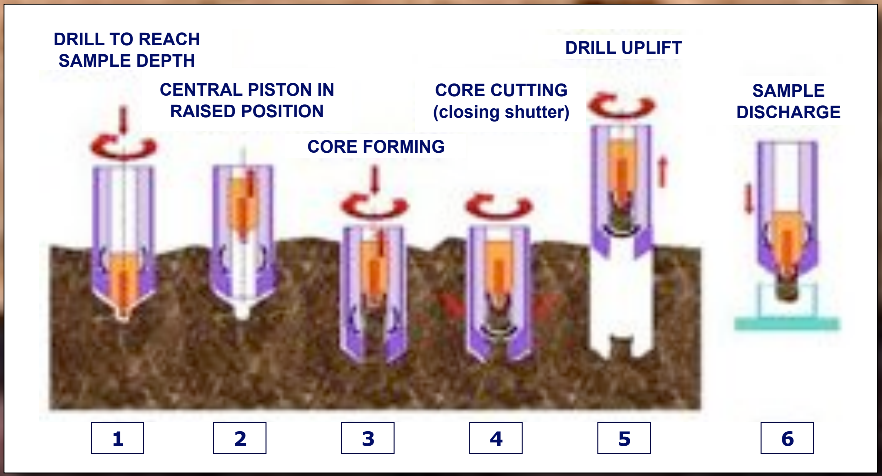


- An outcrop is the geological equivalent of the tip of an iceberg.
- By studying an exposed outcrop, scientists can obtain valuable knowledge about the nature of the underlying deposits.
- For ExoMars, the main interest is in identifying ancient surface formations associated with the past presence of water.
- However, it is the buried deposits that are of primary scientific interest. It is only in the subsurface, below 1.5-m depth, that organic molecules are likely to be well preserved from ultraviolet, oxidant, and ionising radiation damage.
- It is the subsurface samples that may hold the answer regarding the possible existence of past life on early Mars.

Mobility + Subsurface Access

Nominal mission:	180 sols
Nominal science:	6 Experiment Cycles + 2 Vertical Surveys
EC length:	15–18 sols
Rover mass:	300 kg
Mobility range:	Several km





Credit: ESA/Medialab

Science Objectives (expanded)

ExoMars Rover: Search for signs of life;
Establish the scientific importance of subsurface sampling for MSR.

- Conduct a thorough characterisation of surface outcrops (geology and biosignatures).
- Explore the shallow subsurface stratigraphy and identify candidate sites for drilling.
- Search for biomarkers.
- How do the distribution and preservation of biomarkers vary with depth ?
- Study any geochemical variations in the geological record with depth.
- Progressively learn from the surface, radar, subsurface sample study cycle to inform the selection of drilling sites.

Trace Gases Orbiter:

- Establish a data relay capability to serve all missions up to 2022.
- Map the source regions and temporal evolution of trace gases having biological and/or geological interest.

Relation to MEPAG Goals

Relation to MEPAG Goals

Expanded info for the rover mission objectives available in Excel file.

We must still perform a similar exercise for the orbiter objectives.

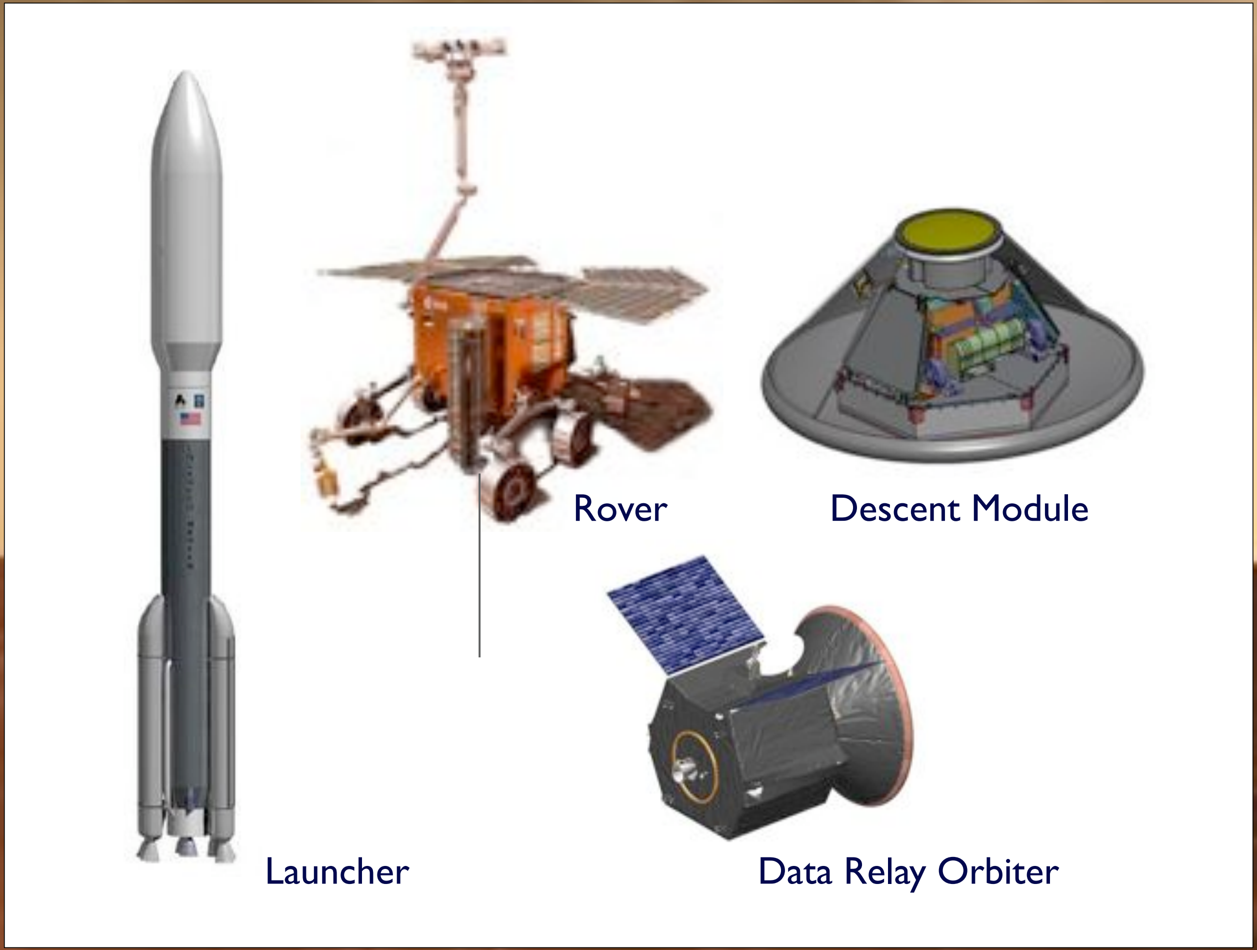
DESCRIPTION

Credit: NASA - Spirit

C-MIN 08 Mission

Launch: Jan 2016
Landing: Sep 2017

DM Release: From a parking orbit, when conditions are optimal
Landing: 100 km (target 75 km) 3-sigma, major axis dispersion

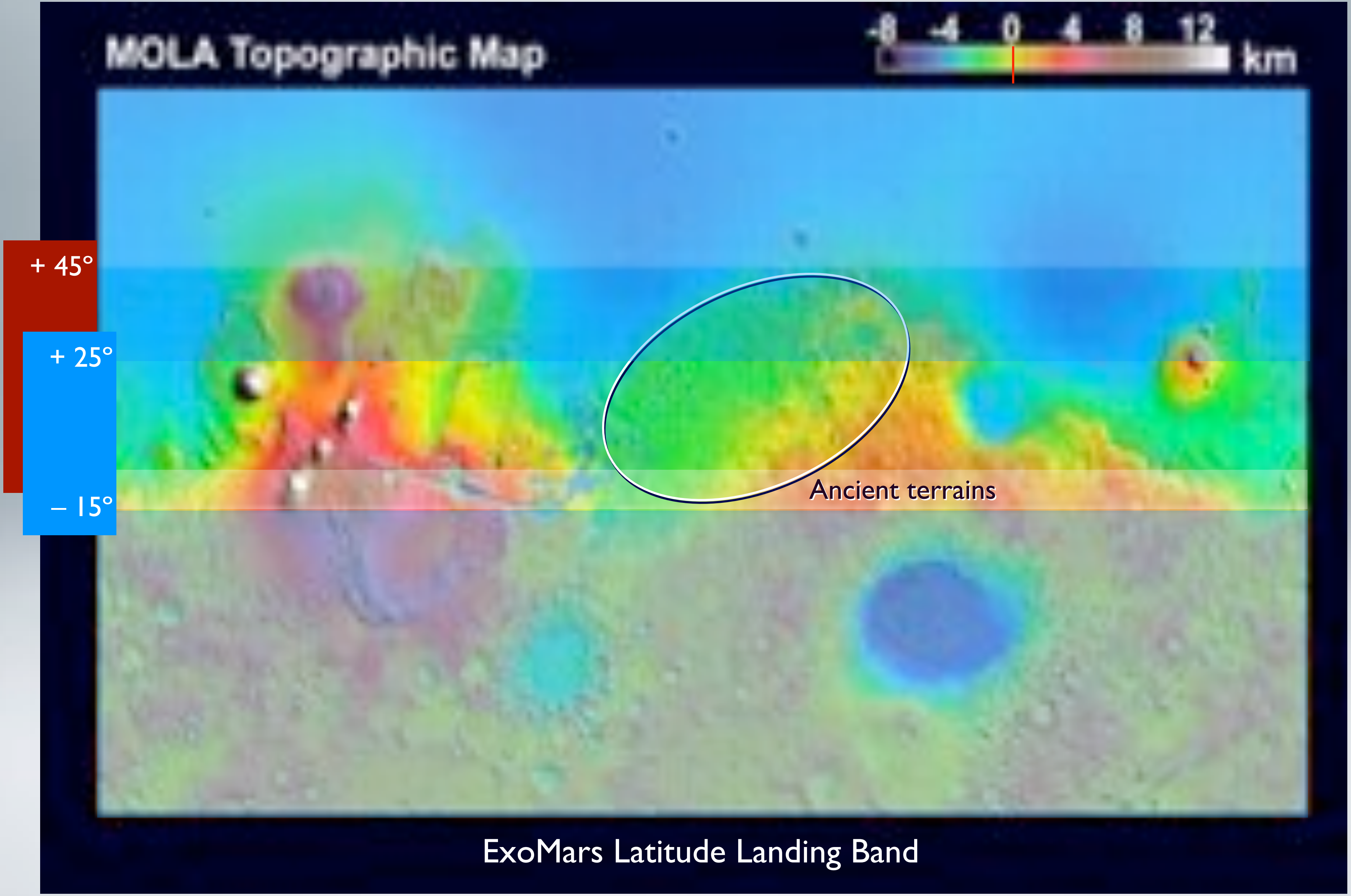


Present Mission Configuration

Nature, 5 August 2009

Please note that the launch scenario may change due to ongoing negotiations with NASA.

Landing Sites



ExoMars Latitude Landing Band

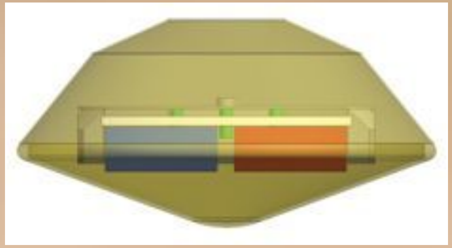
C-MIN 08 Landing

Credit: Astrium/ESA/Medialab

New Landing Concept

Based on the MSL sky crane system…

…but deliver two rovers.

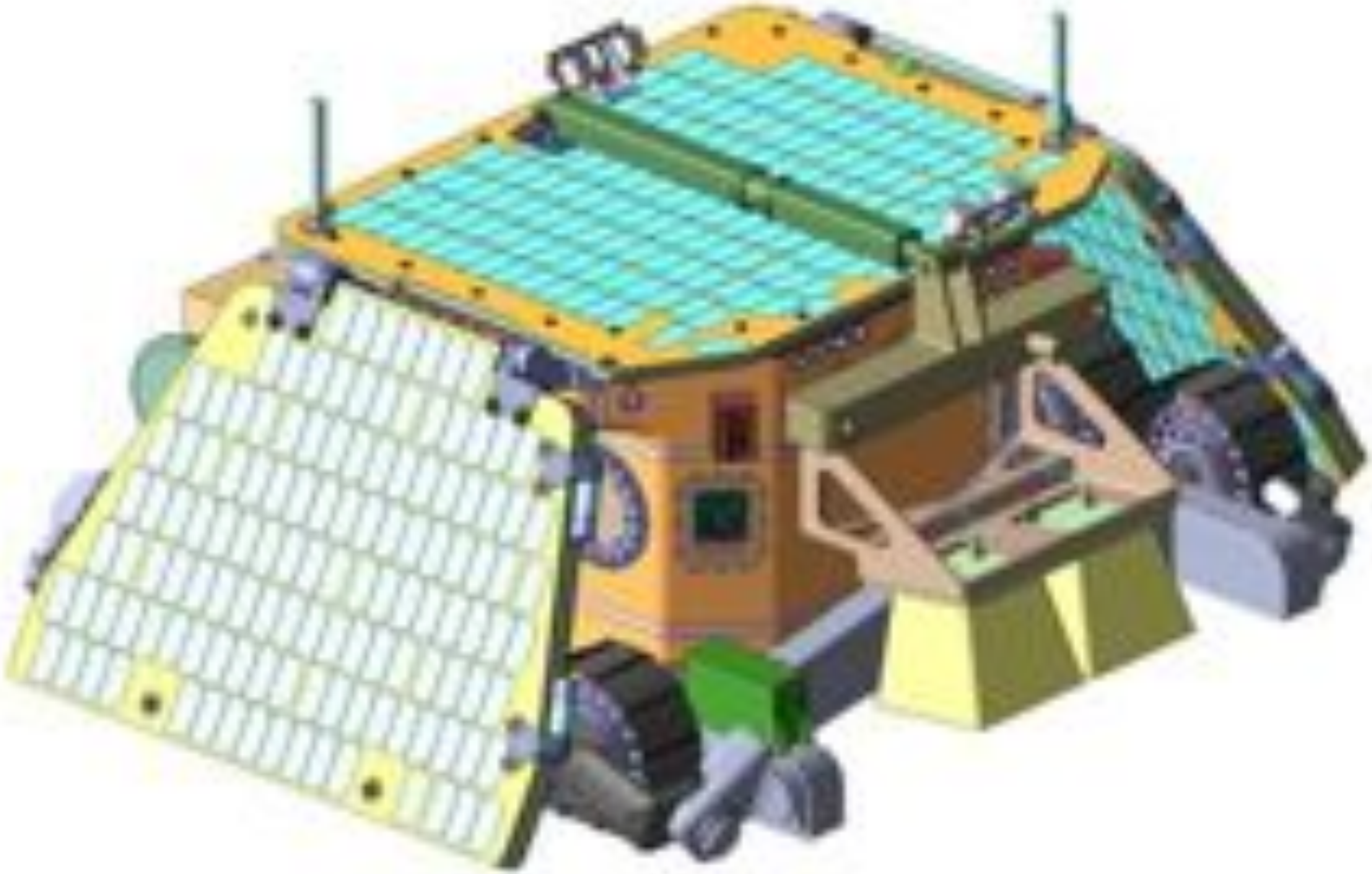


Credit: NASA - MSL

Rover Deployment

Credit: ESA/Medialab

Stowed Rover

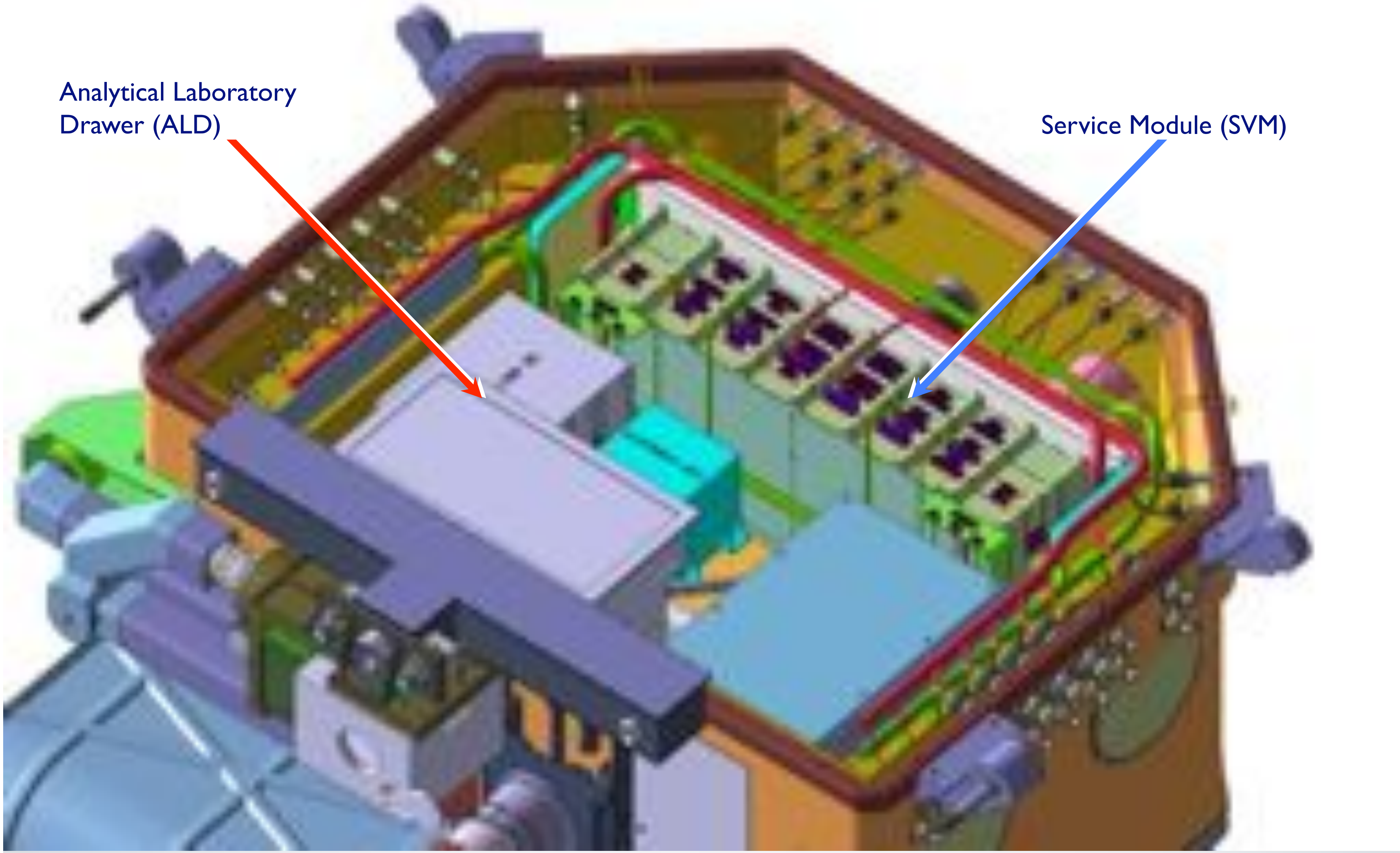


Credit: ESA/Astrium

Rover Front View

Credit: ESA/Astrium

Internal Distribution



Credit: ESA/Astrium

Pasteur Payload

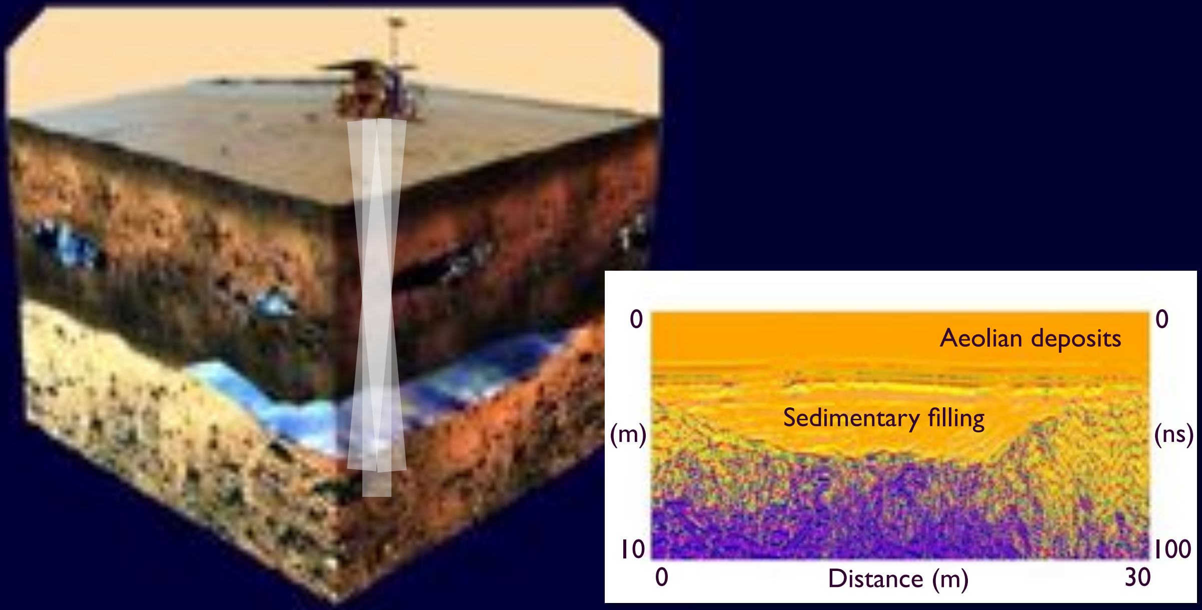
PASTEUR

Credit: ESA – Mars Express

Site Characterisation

AT PANORAMIC SCALE: To establish the geological context

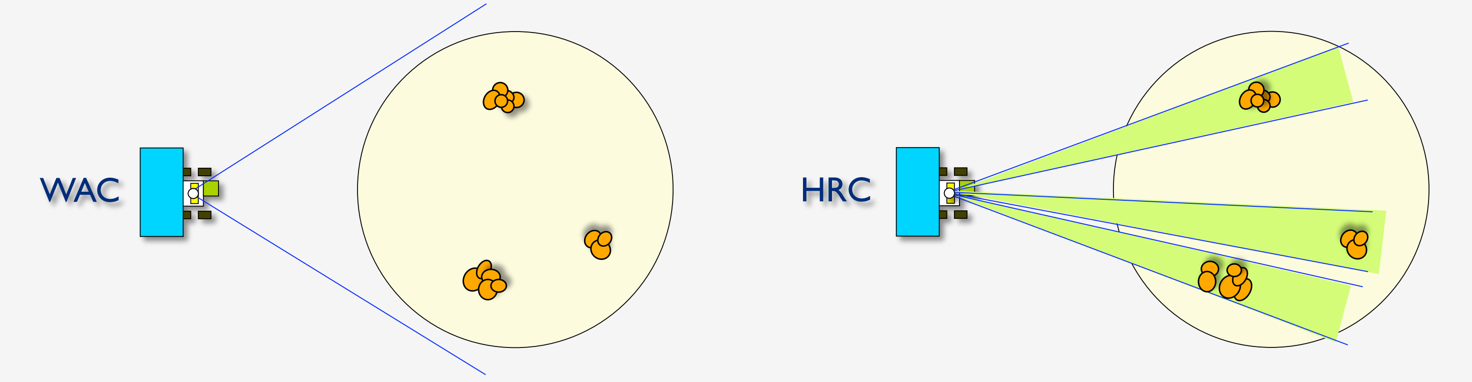
Ground-Penetrating Radar

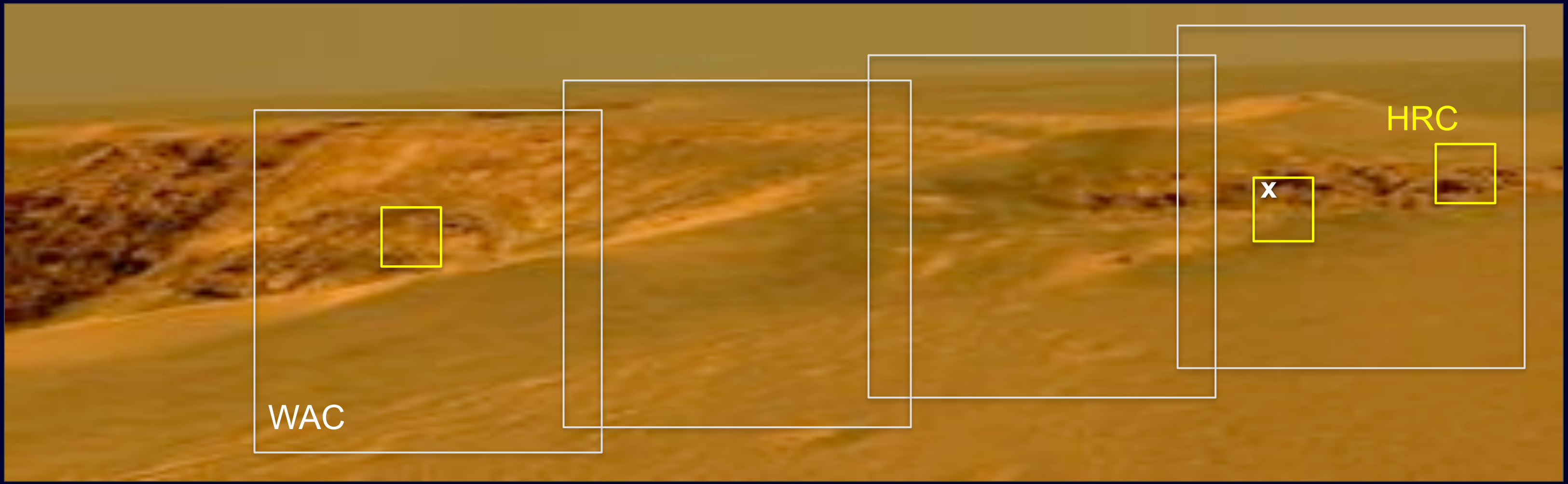


Heggy et al. 2007

Site Characterisation

Survey Phase:





Outcrop Characterisation

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

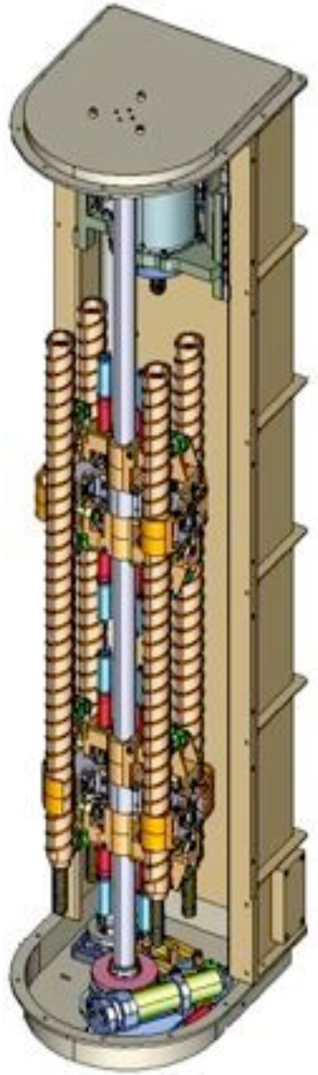
High-Resolution Camera

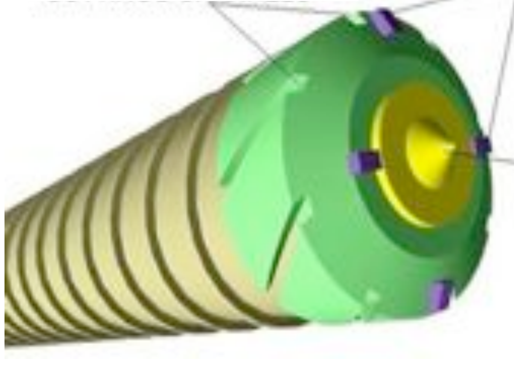
Next step: **ANALYSIS**

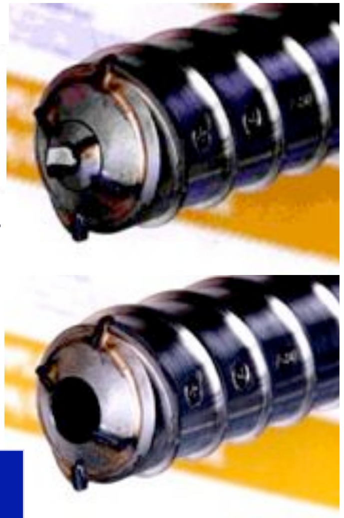
Use the drill to collect a sample
- From an outcrop
- From the subsurface

Subsurface Drill

OBTAIN SAMPLES FOR ANALYSIS: From 0 to 2-m depth





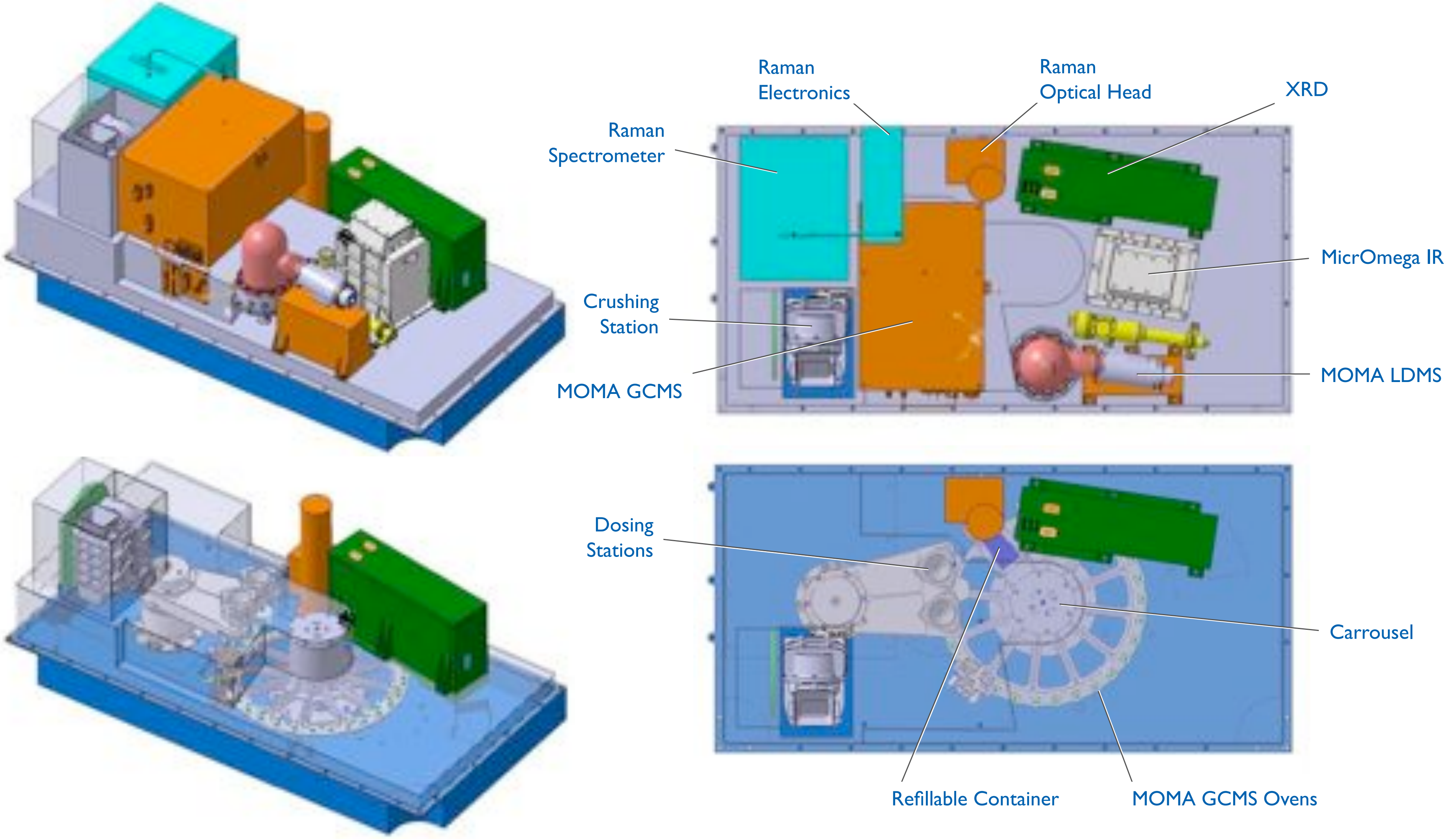


Subsurface drill includes miniaturised IR spectrometer for borehole investigations.

Sample Delivery

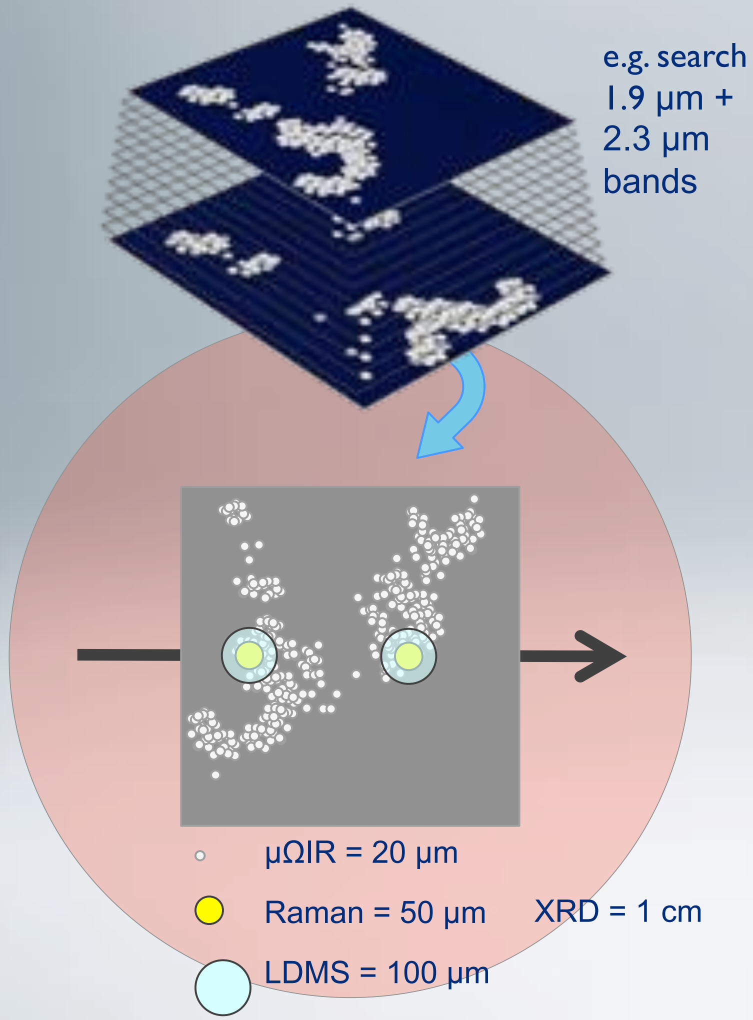
DRILL discharges sample into Core Sample Transfer Mechanism (CSTM). PanCam HRC images sample.

Analytical Laboratory Drawer



Sample Analysis

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



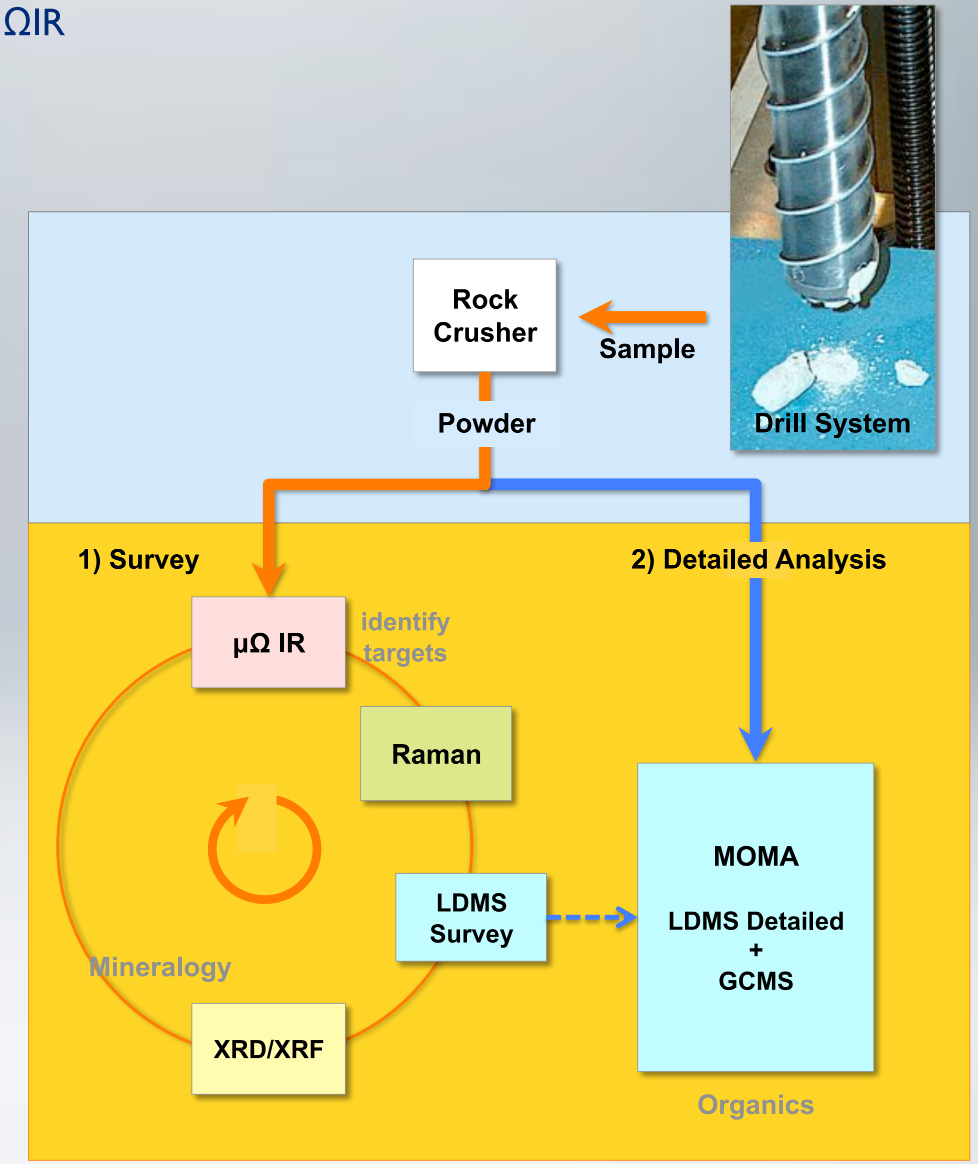
e.g. search 1.9 μm + 2.3 μm bands

○ μΩIR = 20 μm

● Raman = 50 μm

XRD = 1 cm

○ LDMS = 100 μm



Drill System

Sample

Rock Crusher

Powder

1) Survey

μΩ IR

identify targets

Raman

LDMS Survey

XRD/XRF

Mineralogy

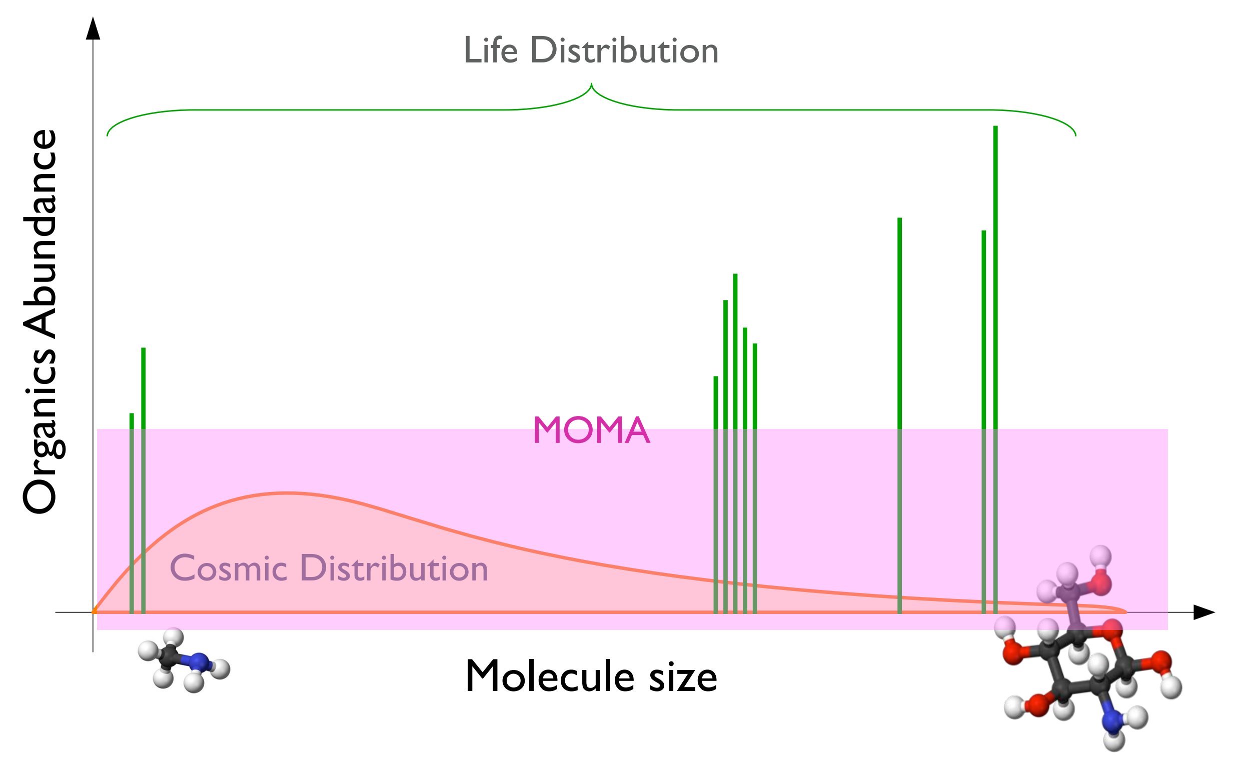
2) Detailed Analysis

MOMA

LDMS Detailed + GCMS

Organics

Organics Detection



Selected 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

Reference Surface Mission

- The ExoMars Rover's 180-sol Reference Surface Mission consists of:

  a) **MOBILITY COMMISSIONING:**
  Scientifically it serves the purpose to get away from any rocket organic contamination before opening the analytical laboratory to the Martian environment (TBC by project).

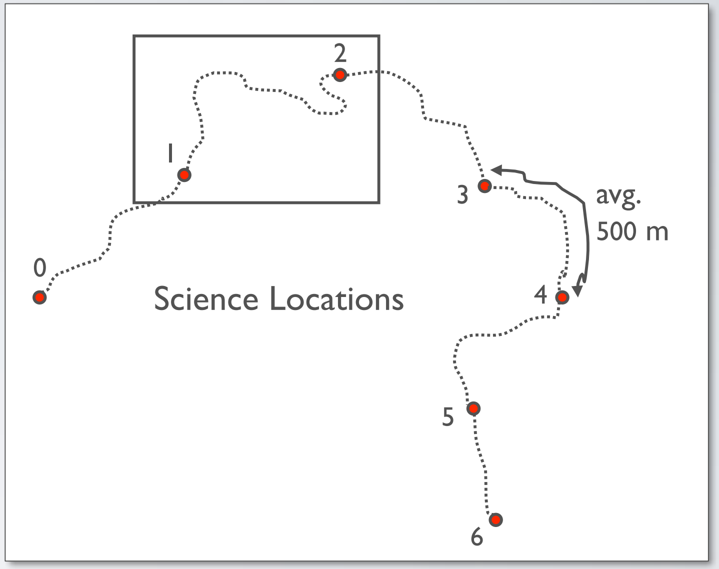
  b) **BLANK ANALYSIS RUNS:**
  To demonstrate that the Rover's sample pathway is free from terrestrial organic contamination.

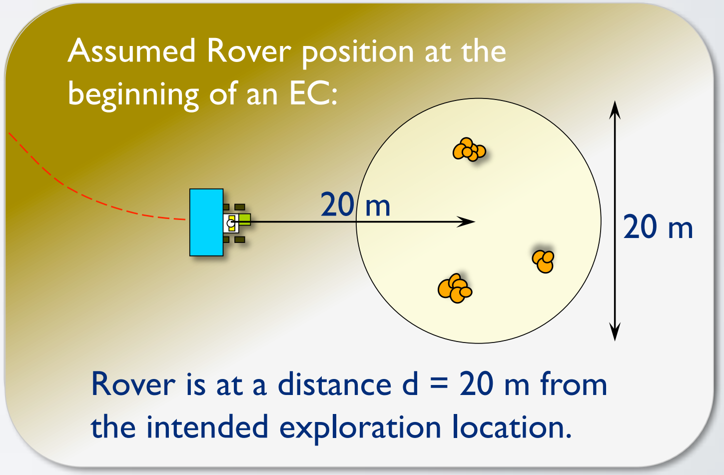
  c) **6 EXPERIMENT CYCLES:**
  Resulting in 6 surface and 6 subsurface samples.

  d) **2 VERTICAL SURVEYS:**
  At one location, collect and analyse samples at 0, 50, 100, 150, and 200-cm depth

  Resulting in 10 additional subsurface samples

  It is assumed that only minimal displacements (tens of metres) are necessary.





Assumed Rover position at the beginning of an EC:

Rover is at a distance d = 20 m from the intended exploration location.

Orbiter Mission

The Current photochemical models cannot explain the presence of methane in the atmosphere of Mars and its reported rapid variations in space and time.

- ❑ Is there ongoing Subsurface Activity?
  - Is it geochemical or biochemical?
  - Where, how much, how continuous, how long-lived…
- ❑ Are there Surface/near-Surface Gas Reservoirs (particularly ice)?
  - Time of emplacement, activation (seasonal, annual, episodic, longer term)
  - Nature of gas origin: geochemical or biochemical
- ❑ What processes control the lifetimes of atmospheric gases?
  - Role of heterogeneous chemistry
  - Atmospheric-surface interactions

Joint Instrument Definition Team (JIDT) recommendations:

- ❑ Trace Gas Detection and Mapping both are essential to achieving the science goals.
- ❑ Aerosol and temperature correlation is required to understand processes changing trace gas concentrations (transport, homogeneous and heterogeneous chemistry).
- ❑ Atmospheric and surface context are important.
- ❑ ~100 kg is likely a minimum CBE payload mass allocation.
- ❑ A mixture of limb and nadir viewing and solar occultation are required to achieve the science goals.

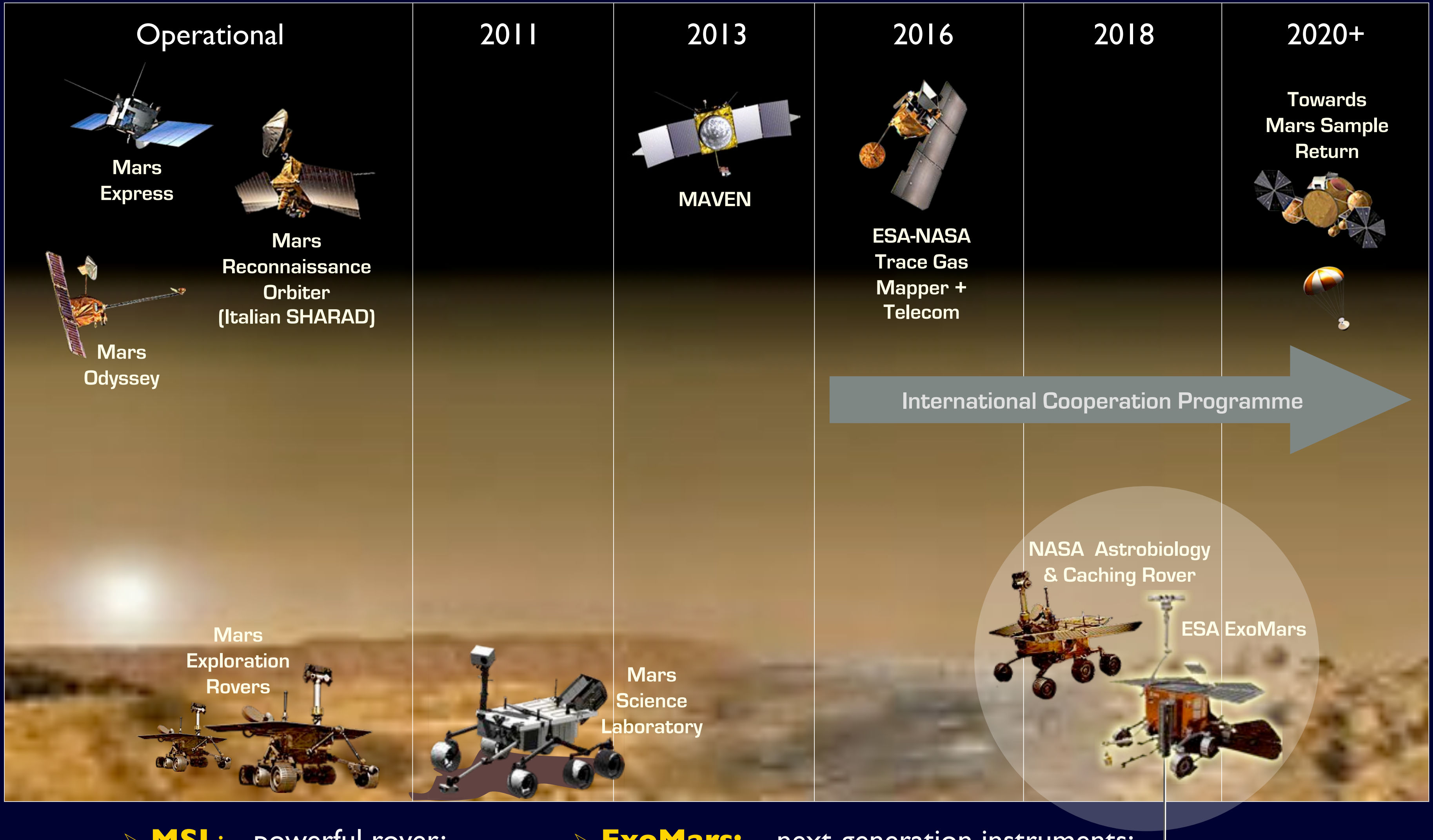
International

Credit: NASA – Phoenix

esa

New International Context

E X O M A R S



Operational | 2011 | 2013 | 2016 | 2018 | 2020+

Mars Express

Mars Reconnaissance Orbiter (Italian SHARAD)

Mars Odyssey

Mars Exploration Rovers

Mars Science Laboratory

MAVEN

ESA-NASA Trace Gas Mapper + Telecom

Towards Mars Sample Return

International Cooperation Programme

NASA Astrobiology & Caching Rover

ESA ExoMars

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

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

Conclusions

➔ ExoMars

A great exobiology mission.

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

The rover's Pasteur payload contains next-generation instruments, never flown before.

The rover will study, for the first time:

- Organic compounds and biomarkers for present and past life at depth;
- Vertical characterisation of geochemistry and water.

The rover also implements new sample handling and locomotion technologies.

➔ ExoMars

A groundbreaking planetary exploration mission, in the tradition of Huygens.

An excellent base for international collaboration with NASA.

A step closer to Mars Sample Return.

Next Steps

- Release of coordinated AO for the 2016 orbiter planned for end 2009.
- Coordinated definition of the two 2018 rover missions:

a) Why ?

If there will be two rovers delivered to the same location on Mars,

- Their science objectives and instruments should be complementary —minimise duplication.
- What unique science can we do with two rovers ?
  - Rover to rover imaging.
  - Cross analysis of similar geological targets.
  - Include a low-freq. GPR on MAX-C, fire on MAX-C, listen with WISDOM on ExoMars to construct rover to rover subsurface transects.
  - Ensure that MAX-C can receive and cache subsurface samples collected by ExoMars.

b) How ?

An MRR-SAG group has already been put in place by MEPAG and is advising on Mars Astrobiology Explorer and Caching (MAX-C) objectives.

Request this group (with a few other European scientists) to address the entire 2018 landed mission scenario: ExoMars + MAX-C.

c) What if cases ?

Consider the eventuality of a single rover in 2018, whether US or European. How would the science mission change then ? How large would the rover need to be ?

Concerns

- At present it is not possible to accommodate both rovers in an MSL-like envelope without some important modifications:

- Disconnect between typical NASA and ESA development schedule:

The ExoMars rover was in a pre-PDR status (about to start Phase C/D) until recently;

Typically NASA would start the MAX-C Phase A in 2013.

Challenge: Interfaces can only be agreed if the two projects are brought closer in sync.

Both agencies are working to resolve these issues.

Final Questions

- Coordinated definition of the two 2018 rover missions:
- Present MRR-SAG draft primary scientific objective (from MEPAG 6 Aug 09 Newsletter):

At a site with high preservation potential for physical and chemical biosignatures, evaluate paleo-environmental conditions and access multiple sequences of geological units in a search for evidence of ancient life and/or prebiotic chemistry. Samples containing the essential evidence would be collected, documented, and cached in a manner suitable for return to Earth by a future mission.

- But the underlined text precisely describes what ExoMars does.
- Why should it be done twice at the same location ?
- Is there a science capability missing in ExoMars that should be added ?