The International Mars Exploration Programme and Current Planetary Protection Measures

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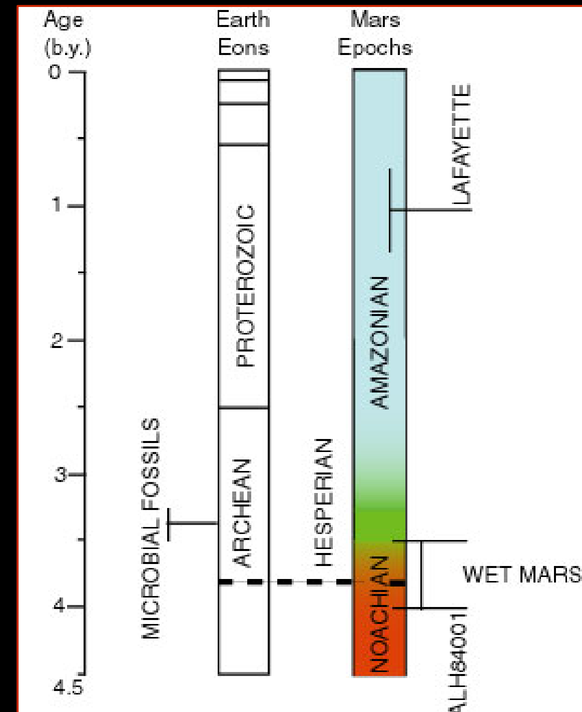
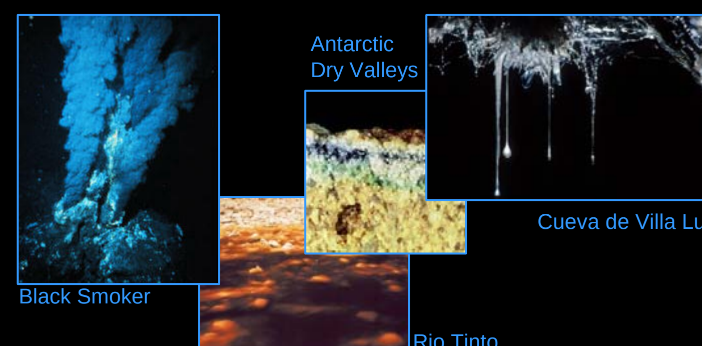
European Space Agency
Vice-Chair, COSPAR Panel on Planetary Protection

The prospect for life on Mars - up, down, and up again…

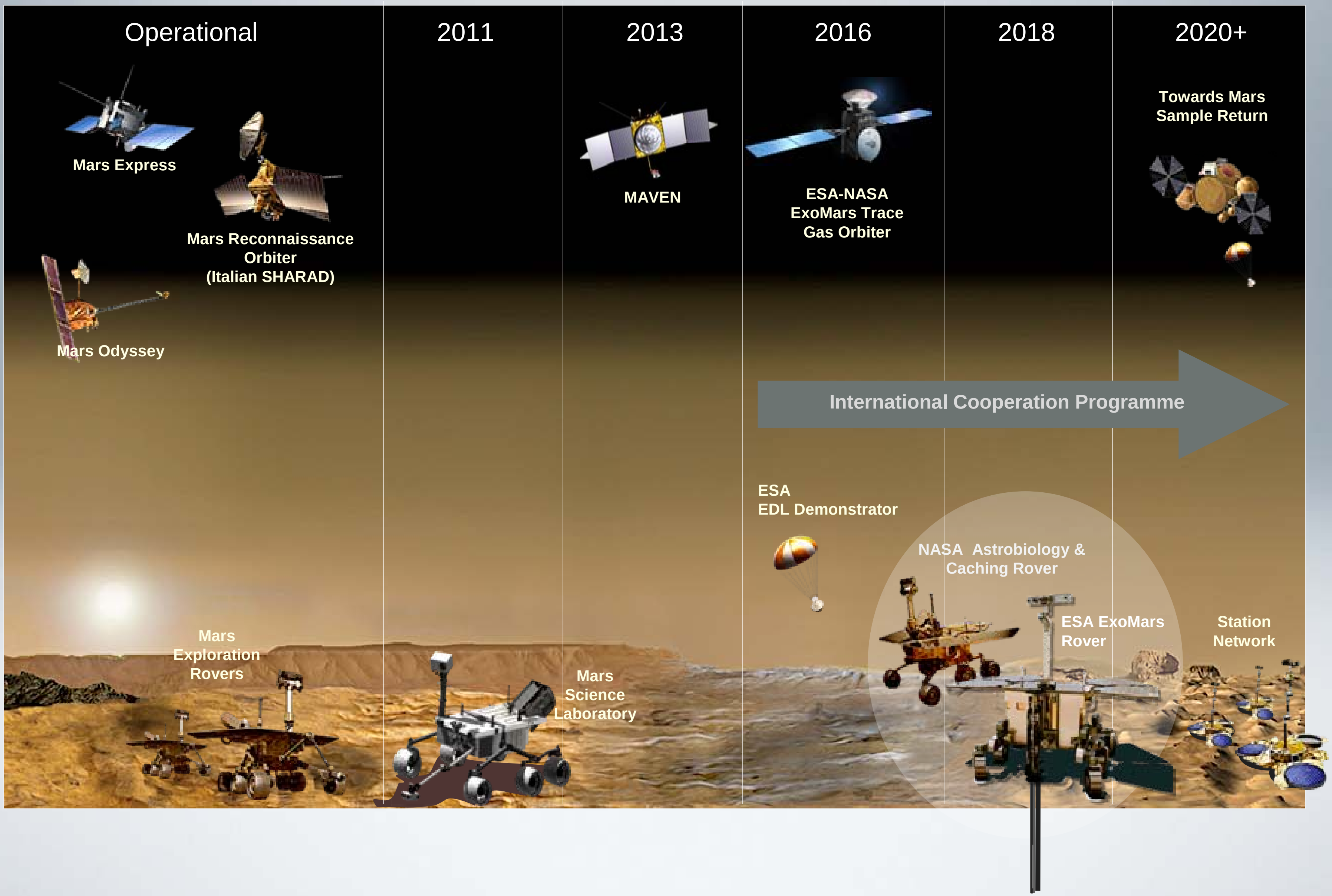
Planet Mars





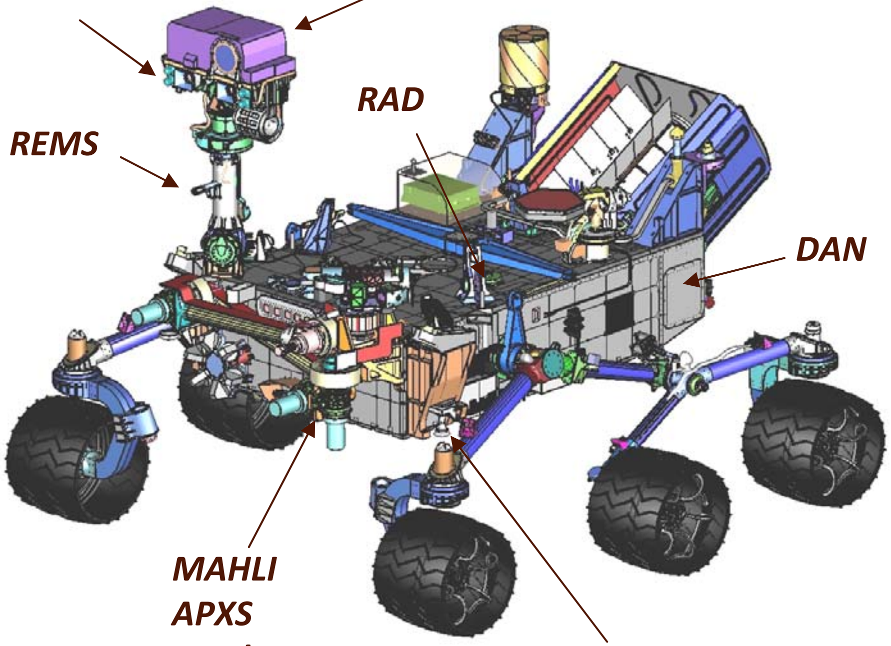
Life on Earth

Current and Planned Missions



Growing up…

MSL Science Payload



Rover Width:	**2.8 m**
Height of Deck:	**1.1 m**
Ground Clearance:	**0.66 m**
Height of Mast:	**2.2 m**

REMOTE SENSING

Mastcam (M. Malin, MSSS) - Color and telephoto imaging, video, atmospheric opacity

ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

CONTACT INSTRUMENTS (ARM)

MAHLI (K. Edgett, MSSS) – Hand-lens color imaging

APXS (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

SAM (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics

CheMin (D. Blake, ARC) - Mineralogy

ENVIRONMENTAL CHARACTERIZATION

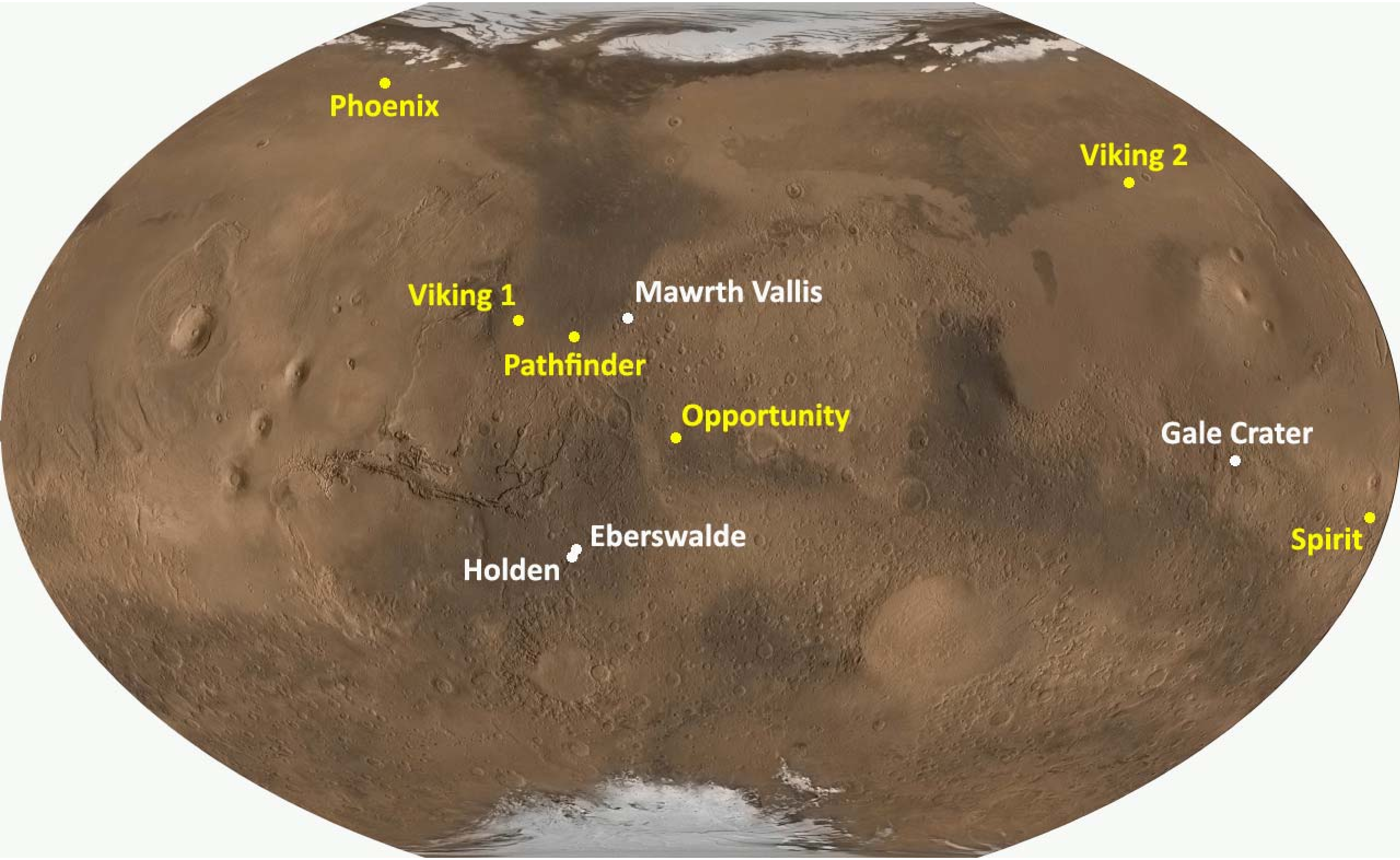
MARDI (M. Malin, MSSS) - Descent imaging

REMS (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV

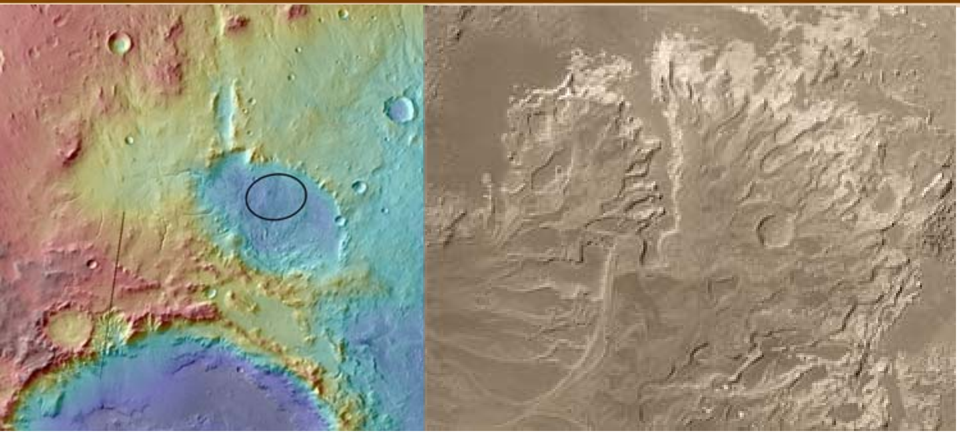
RAD (D. Hassler, SwRI) - High-energy radiation

DAN (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

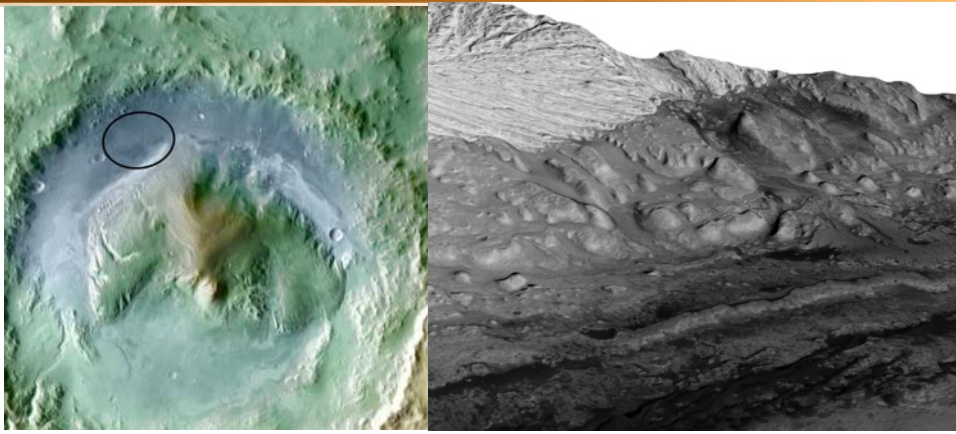
Mars Landing Sites
(Previous Missions and MSL Candidates)



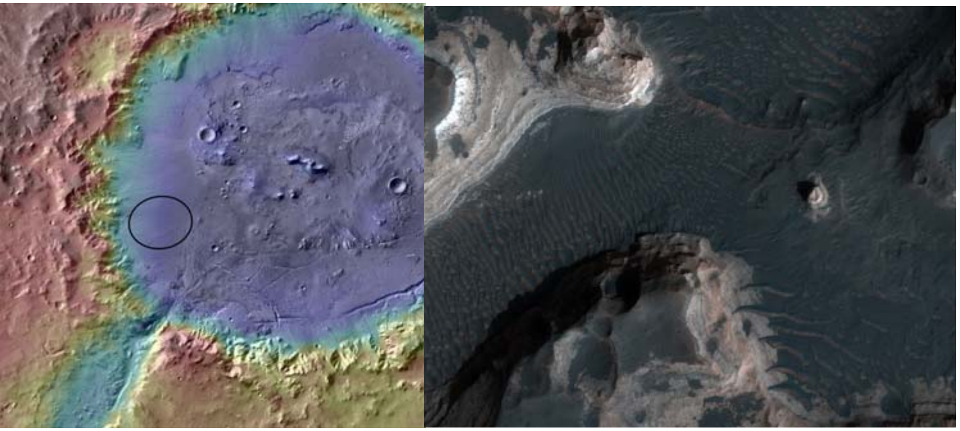
Candidate Landing Sites



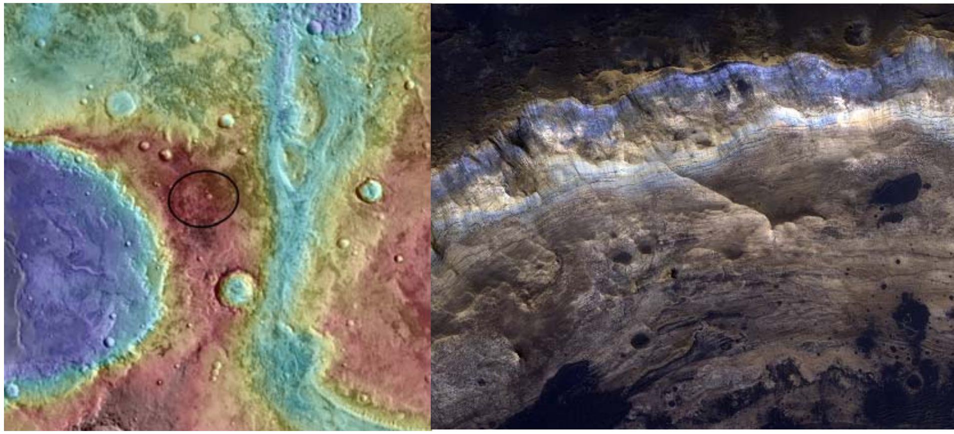
Eberswalde Crater (24°S, 327°E, -1.5 km) contains a clay-bearing delta formed when an ancient river deposited sediment, possibly into a lake.



Gale Crater (4.5°S, 137°E, -4.5 km) contains a 5-km sequence of layers that vary from clay-rich materials near the bottom to sulfates at higher elevation.



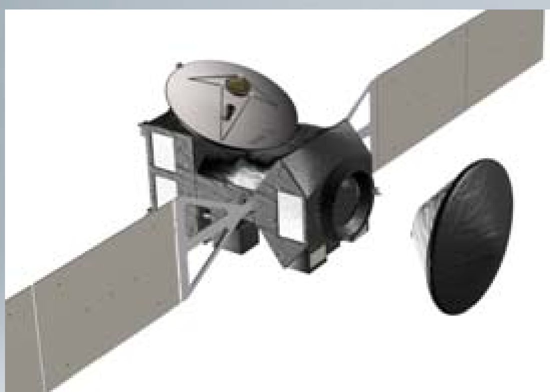
Holden Crater (26°S, 325°E, -1.9 km) has alluvial fans, flood deposits, possible lake beds, and clay-rich sediment.



Mawrth Vallis (24°N, 341°E, -2.2 km) exposes layers within Mars' surface with differing mineralogy, including at least two kinds of clays.

Programme Building Blocks

- ESA and NASA have agreed to embark on a joint Mars robotic exploration programme:
  - Initial missions have been defined for the 2016 (January) and 2018 launch opportunities;
  - Missions for 2020 and beyond are in a planning stage;
  - The joint programme's ultimate objective is an international Mars Sample Return mission.

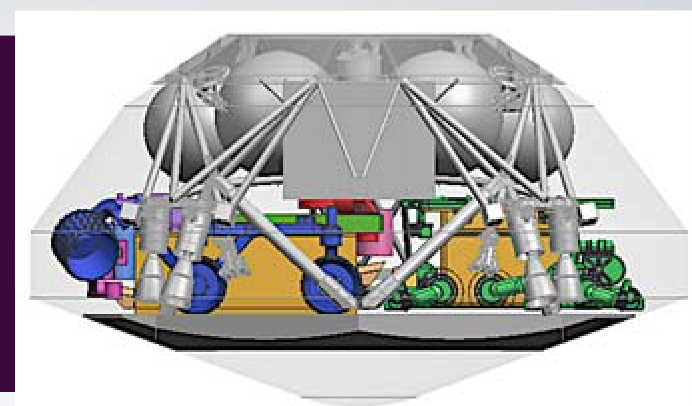


2016 — ESA-led mission

Launcher:	NASA – Atlas V-431
Orbiter:	ESA
Payload:	NASA-ESA
EDL Demo:	ESA

2018 — NASA-led mission

Launcher:	NASA – Atlas V-531
Cruise & EDL:	NASA
Rover 1:	ESA
Payload:	ESA-NASA
Rover 2:	NASA



2016 Mission Objectives

E X O M A R S

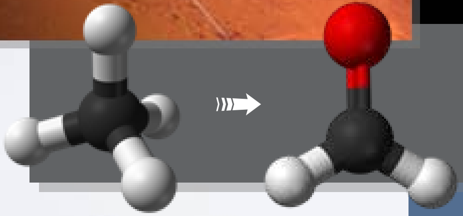
2016

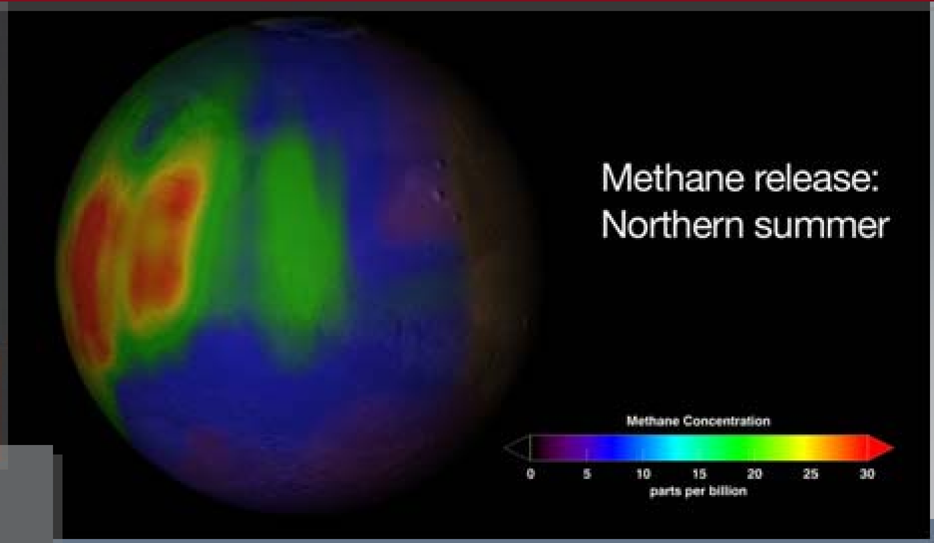
TECHNOLOGY OBJECTIVE

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

SCIENTIFIC OBJECTIVE

- To study Martian atmospheric trace gases and their sources.





- Use of aerobraking to achieve science orbit.
- Provide data relay services for landed missions until 2022.

2016 Trace Gas Orbiter Payload

E X O M A R S

PRIORITISED GOALS

PRIORITISED GOALS	INSTRUMENTS		
1. **Detect a broad suite of atmospheric trace gases** and key isotopes with high sensitivity.	**MATMOS (ppt)**	**US**, CAN B, F, RUS	H/W Science
2. **Map their spatial and temporal variability** with high sensitivity.	**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	

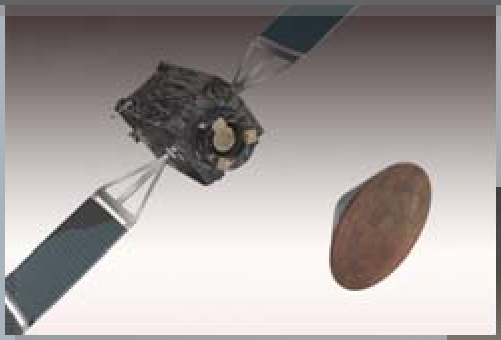
Excellent coverage of high-priority objectives.

2016 EDL Module (EDM)

EXOMARS

EDM

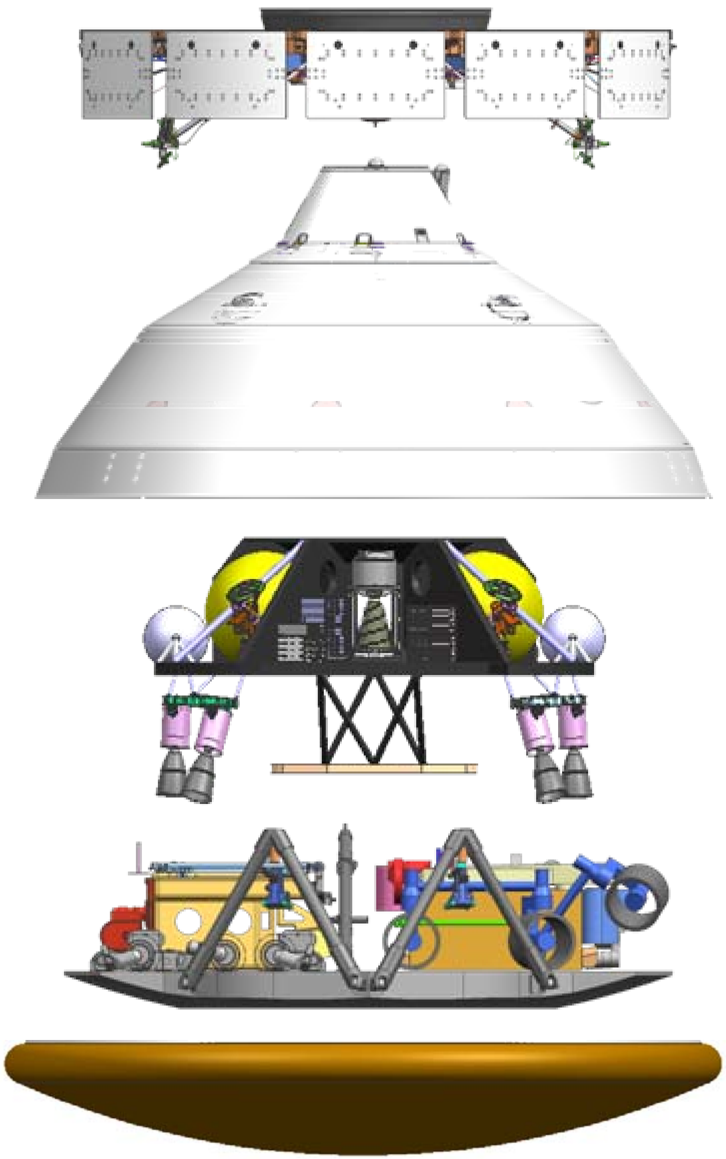
- ➢A European technology demonstrator for landing medium-large payloads on Mars;
- ➢Provides a limited, but useful means to conduct scientific measurements during the dust storm season.



EDM PAYLOAD

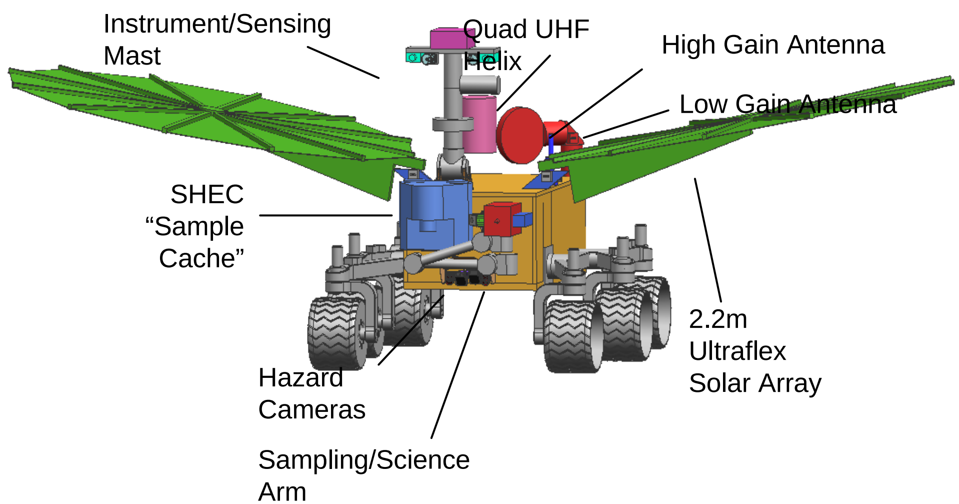
- ➢Integrated payload mass estimate: 3 kg;
- ➢Lifetime: 4 sols;
- ➢Data: 1 pass of 50 Mbits.

2018 Mission Concept



Key mission concept features

- Cruise/EDL system derived from MSL, launched on Atlas V 531 class vehicle
- Land in ~10 km radius landing ellipse, up to -1 km altitude, within +25 to -15 degrees latitude
- **NASA MAX-C rover will** perform *in situ* exploration of Mars and acquire/cache sets of scientifically selected samples



2018 ExoMars RM Objectives

E X O M A R S

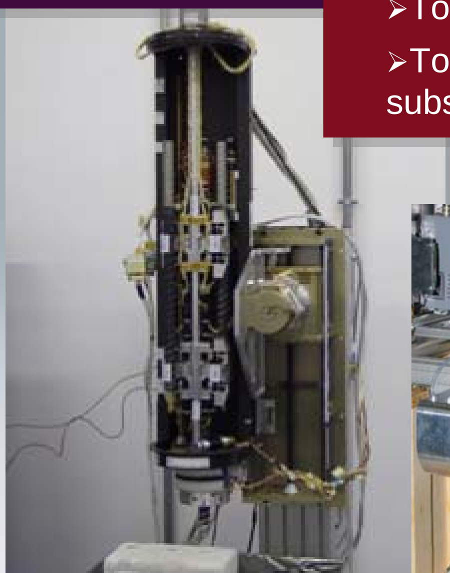
2018

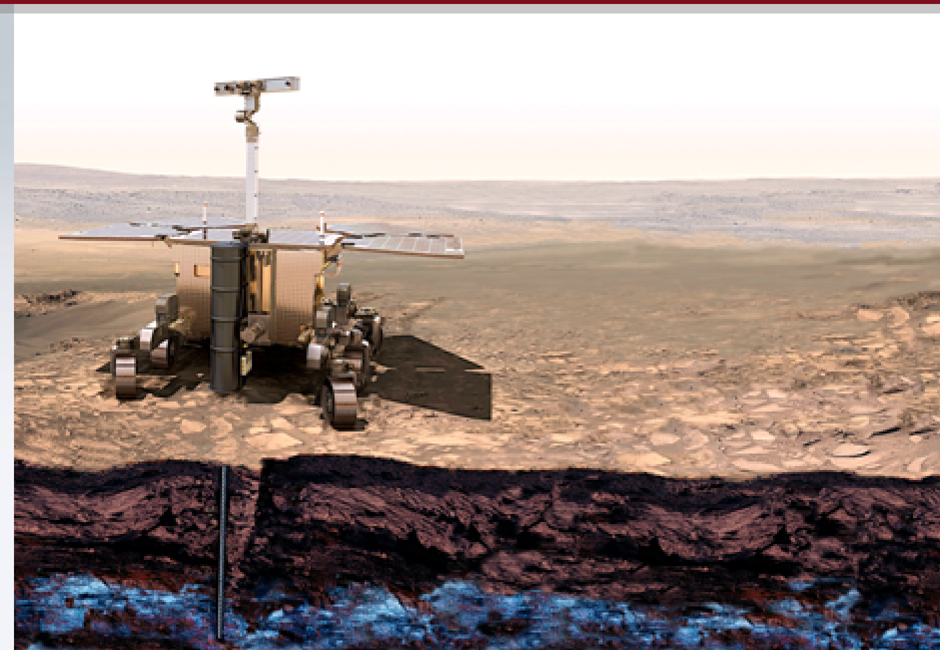
TECHNOLOGY OBJECTIVES

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

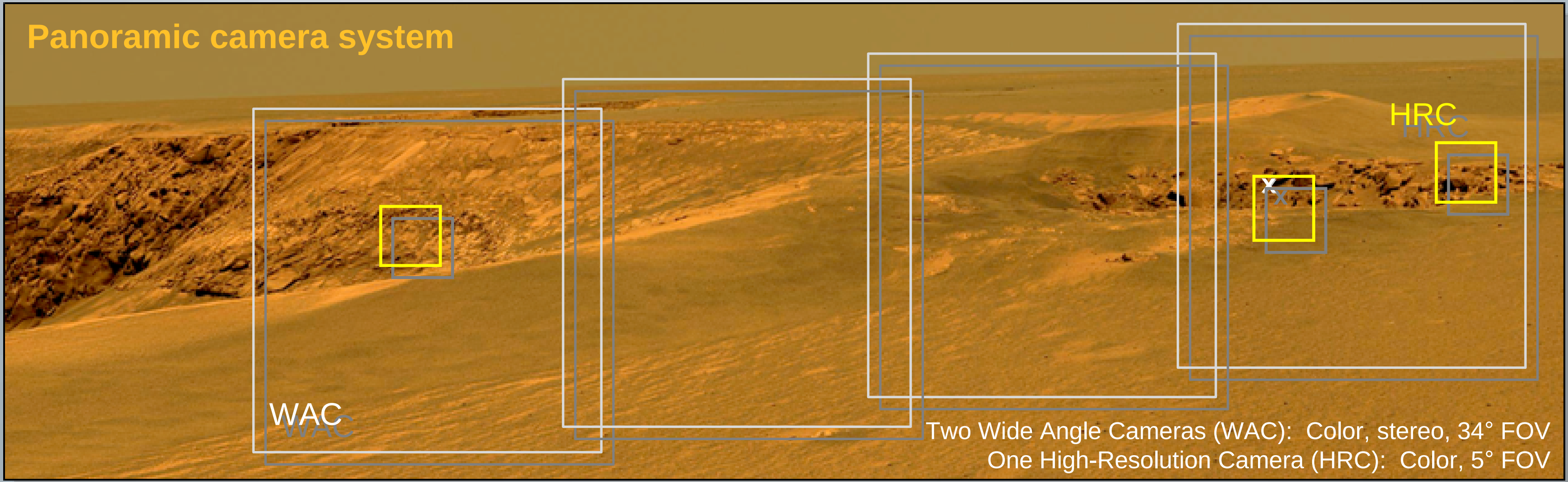
SCIENTIFIC OBJECTIVES

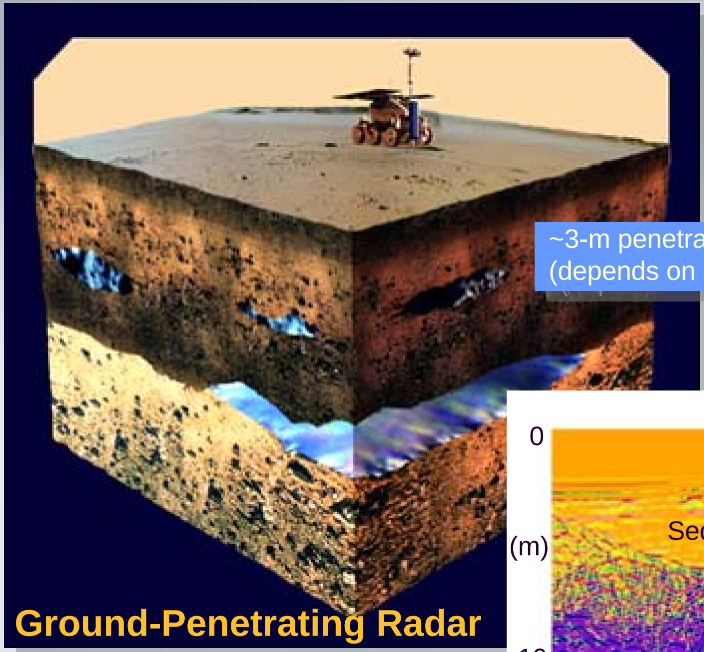
- To search for signs of past and present life on Mars;
- To characterise the water/subsurface environment as a function of depth in the shallow subsurface.



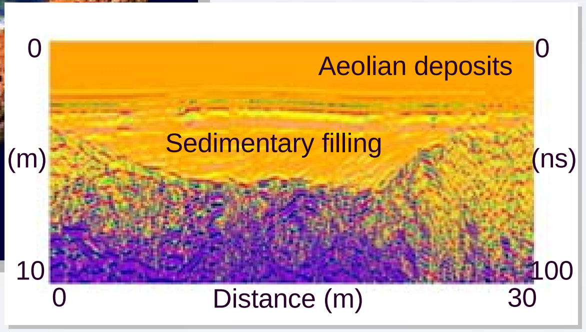


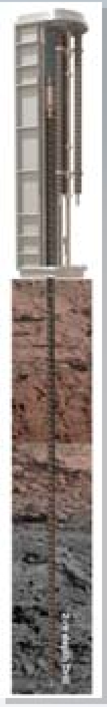
ExoMars Pasteur Payload





~3-m penetration, with ~2-cm resolution
(depends on subsurface EM properties)

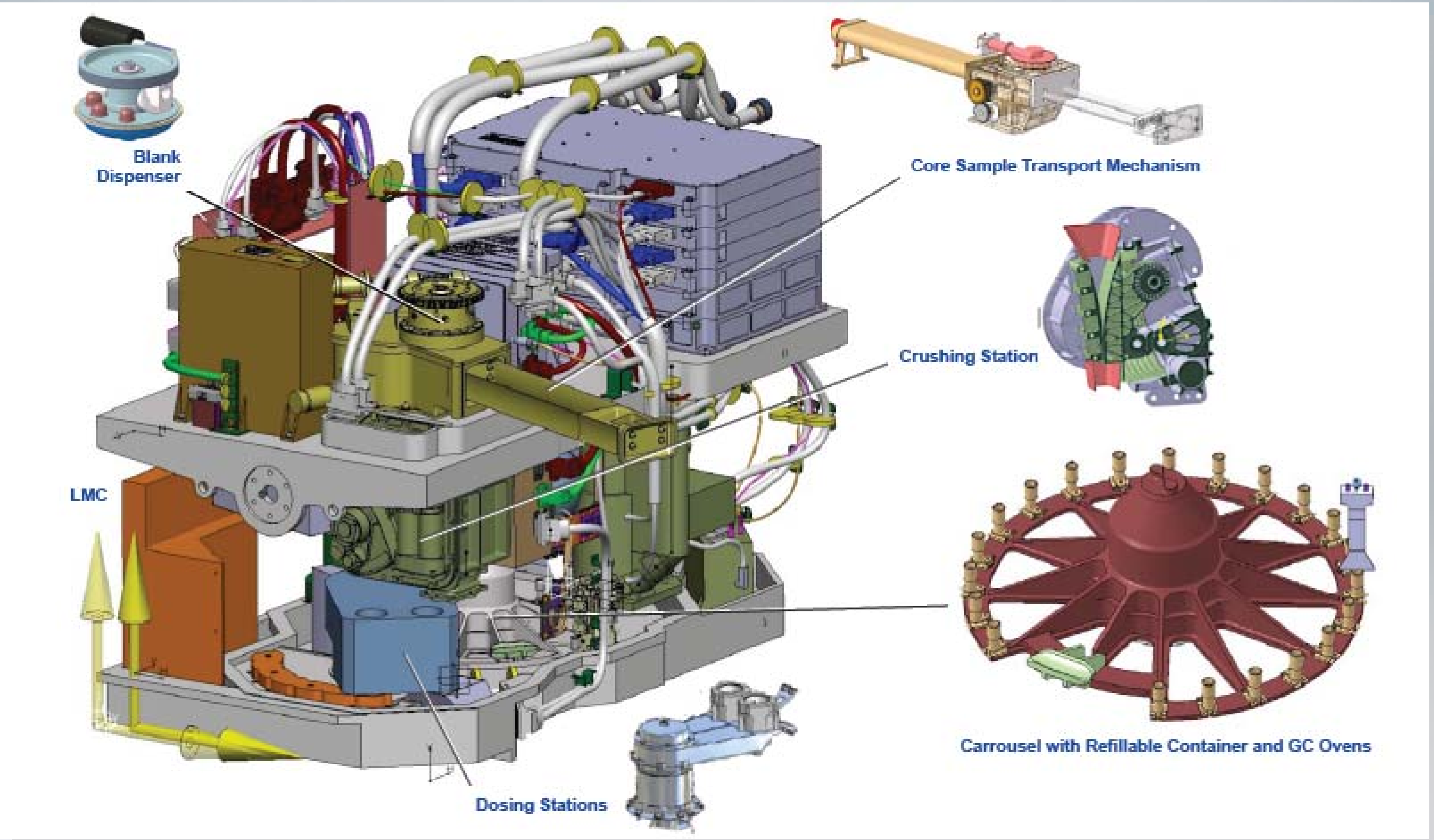




Spectral range: 0.4–2.4 µm,
Sampling resolution: 20 nm

Analytical Lab

ExoMars RM Laboratory



2018 ExoMars RM - International

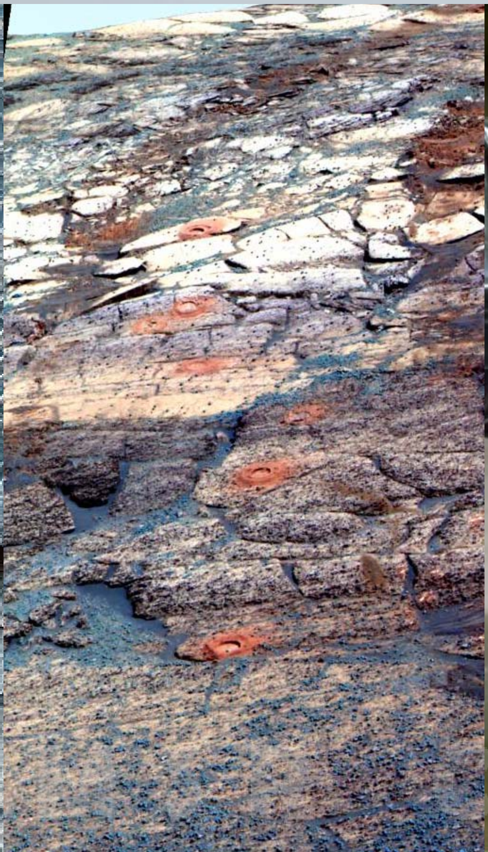
E X O M A R S

Instrument Name	Description	Countries
PanCam (WAC + HRC)	Panoramic camera system	**UK**, D, CH H/W F, I, A, USA Science
WISDOM	Shallow ground penetrating radar	**F**, D N, USA, B, I, E, UK
CLUPI in drill box	Close-up imager	**CH**, F CAN, UK, D, I, B
Ma_MISS included in 2.0-m drill	IR borehole spectrometer	**I** P, PL
MicrOmega	IR imaging spectrometer	**F** CH, RUS, I, D, UK
RLS	Raman laser spectrometer	**E**, F, UK D, NL, USA
Mars-XRD	X-ray diffractometer + X-ray fluorescence	**I**, UK E, P, NL, D, F, RUS, USA, AUS
MOMA	LDMS + Pyr-Dev GCMS for characterisation of organics	**D**, F, USA NL, S
LMC	Life marker chip	**UK**, NL, I D, N, USA

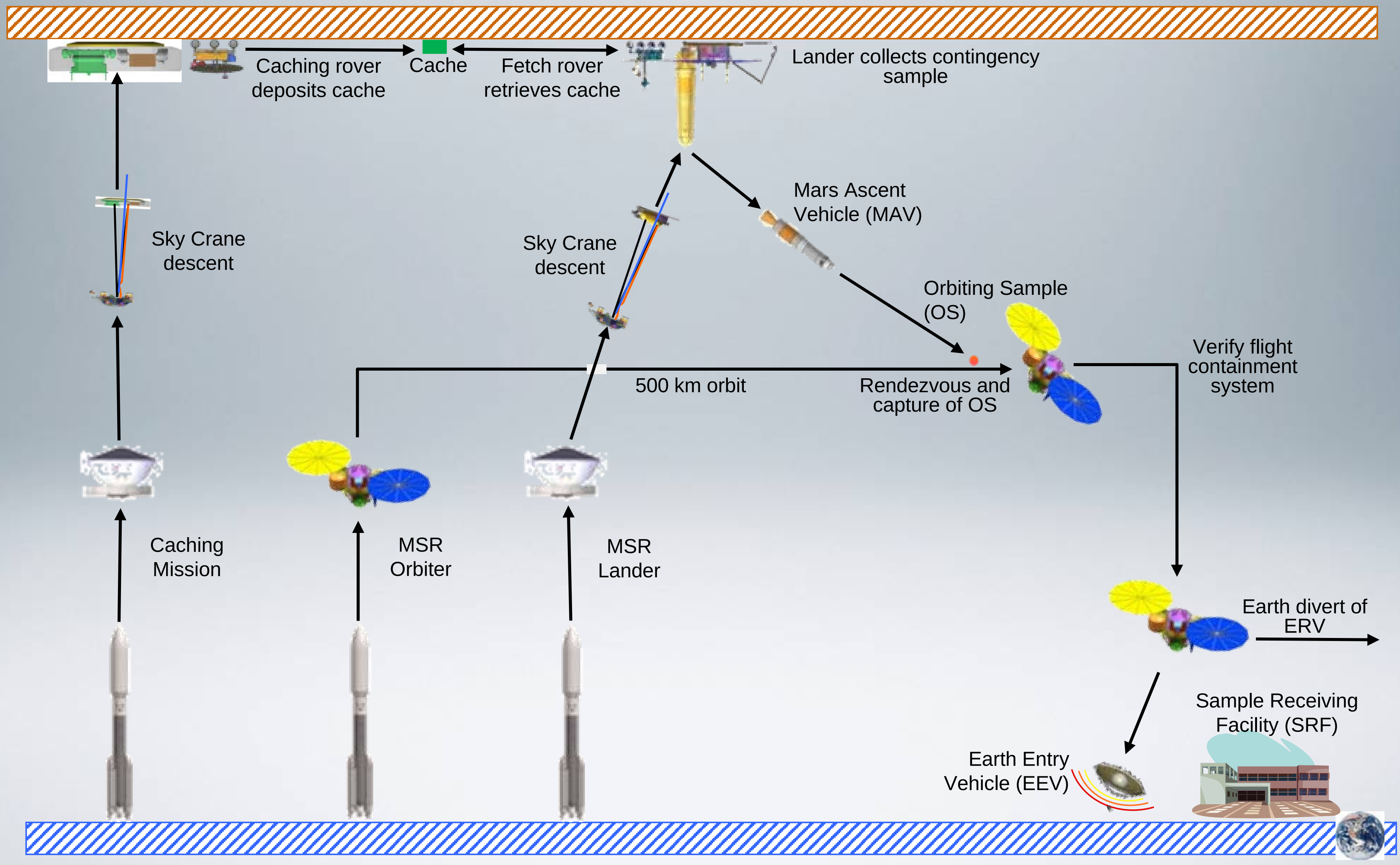
Science Aspects for Mars Sample Return

NASA has established a End-to-End Science Advisory Group with international participation to:

- Identify Mars sample return science objectives and priorities
- Identify science needs for sample selection, acquisition, control and analysis



Mars Sample Return Architecture



NASA-ESA Programme Coordination

At programme level (standing)

- Joint Mars Executive Board (JMEB):
  - Steering of the joint programme, guidance for formulating missions, requirements, and programme architecture;
  - Oversight on implementation of missions.
- Joint Mars Architecture Review Team (JMART):
  - Independent review team to assess/critique programme level architecture, programmatic risk, national priorities, etc.

At project level (ad-hoc)

- Joint Engineering Working Group (JEWG):
  - Advanced engineering planning group; standing organisation at ESTEC & JPL.
  - Develop cooperative architecture options for shared mission responsibilities.
  - Complete for 2016 ExoMars TGO, starting for 2018 Two-Rover mission, soon for Mars Sample Return.
- Joint Instrument and other Study Teams:
  - Established by the JMEB. For example, Joint Instrument Definition Team (JIDT) established the investigation capabilities for the 2016 orbiter mission.
  - 2R-iSAG two-rover science analysis group explored science cooperation possibilities for the 2018 rovers. E2E-iSAG to carry out an end-to-end MSR science analysis.

Week of 13 June 2011: “Mars Week” in Europe

Lisbon, Portugal

- **Pre-conference Mars science meetings (MSL & ExoMars TGO)**
  All day Sunday (June 12) and morning Monday (June 13): 1.5 days
- **International Conference on “The Exploration of Mars Habitability”**
  Monday afternoon (June 13) to end Wednesday (June 15): 2.5 days
- **1st International MEPAG Meeting**
  Thursday (June 16) to noon Friday (June 17): 1.5 days

Field Trip: Río Tinto, Spain

- **Visit to unique geology and acidic environment**
  Friday afternoon (June 17) to Sunday (June 19): 2.5 days

Implementing Planetary Protection Constraints

UN OUTER SPACE TREATY

Article IX: avoid harmful contamination of celestial bodies and adverse changes in the environment of the Earth

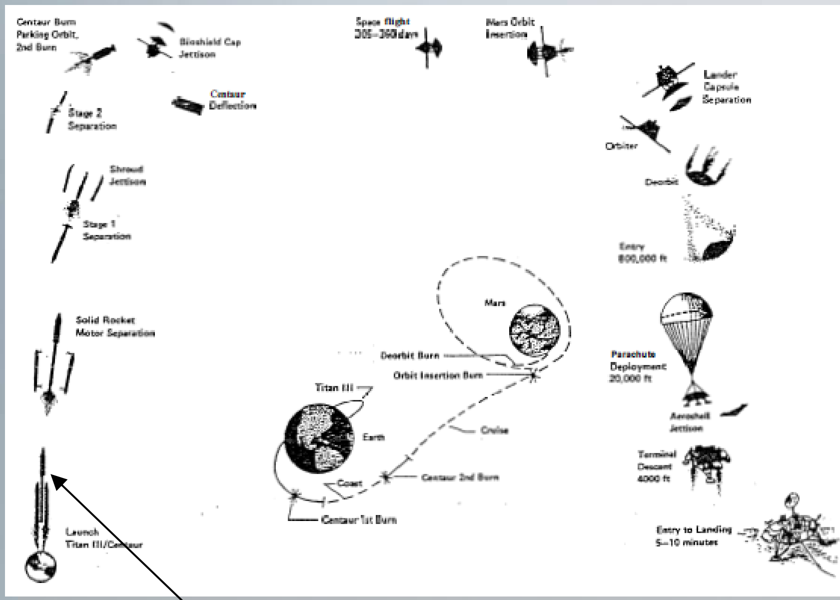
COSPAR PLANETARY PROTECTION POLICY AND IMPLEMENTATION GUIDELINES

Maintains and promulgates policy for the reference of spacefaring nations as internationally accepted standard to guide compliance with Article IX of the Outer Space Treaty

SPACE AGENCY POLICY

- States compliance with COSPAR Planetary Protection Policy
- Requirements derived from policy
- Binding for flight projects
- Coordinated between Agencies

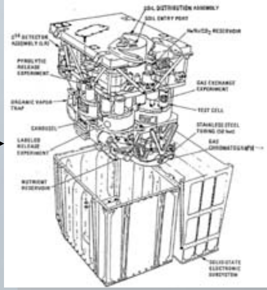
The Gold Standard – Viking '75

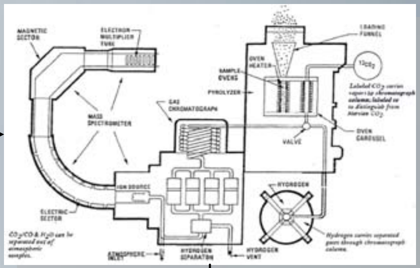


<u>Mission Objective:</u>

Search for life on Mars

Biology experiment





GC-MS

Terminal Sterilization of Lander

Bioburden controlled assembly

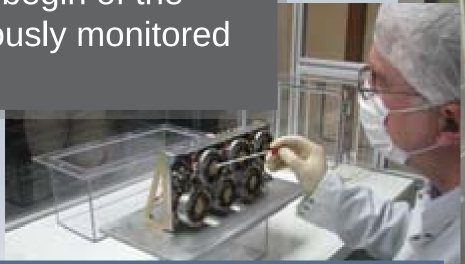
Planetary Protection Constraints Today

BIOBURDEN CONSTRAINTS

- Range from standard class 100.000 assembly to sterile flight systems
- More stringent for missions with life detection investigations, sample return and landing in Mars special regions
- Sample return missions have additional constraints for containment and hazard assessment
- Needs to be reflected from the very begin of the mission definition phase and continuously monitored during the project life cycle

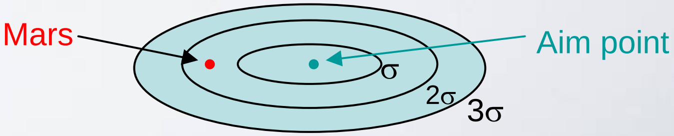

SAM/MSL


Phoenix



IMPACT AVOIDANCE CONSTRAINTS

- Impact probability constraint for launcher upper stages
- Impact probability constraints for primary and secondary targets
- Impact probability constraints for orbiter systems
- Compliance is affected by trajectory, mission design, flight hardware design, reliability of systems and redundancy levels used
- Scope goes well beyond end-of-life of the specific mission



Bioburden Control Today

TYPICAL BIOBURDEN VALUES

- Non-controlled manufacturing: 10^5 spores/m^2
- Class 100.000 cleanroom: 10^4 spores/m^2
- Class 10.000 cleanroom: 1000 spores/m^2
- Aseptic environment: < 40 spores/m^2

TYPICAL BIOBURDEN CONSTRAINTS

- Less than 300 spores/m^2 on general surfaces
- Less than $3x10^5$ spores on an entire Mars lander system

TYPICAL BIOBURDEN CONTROL MEASURES

- Frequent cleaning of all flight hardware with alcohol or precision cleaning methods
- Heat sterilization (~ 125°C) of more than 50% of the flight hardware per size
- Several thousand bioburden assays to control the bioburden levels
- Recontamination prevention by design, barriers, and analysis

People! (Pathfinder)

Large size – more than 1000 m^2 of accountable surface area (MSL)

Very complex machinery (MSL)

Last but not least - Training

TRAINING OPPORTUNITIES

- NASA and ESA training courses are offered on an annual basis
- Projects usually have their own tailored training courses
- Training needs for a typical Mars flight project is in the order of several 100 participants over a time period of several years

TRAINING LEVELS

- Depends on the mission type
- Depends how much the individual is involved with flight hardware