The International Mars Exploration Programme and Current Planetary Protection Measures

G. Kminek
European Space Agency
Vice-Chair, COSPAR Panel on Planetary Protection
The prospect for life on Mars - up, down, and up again…
Current and Planned Missions

Operational:
- Mars Express
- Mars Reconnaissance Orbiter (Italian SHARAD)
- Mars Odyssey
- Mars Express
- Mars Science Laboratory
- Mars Exploration Rovers

2011:
- MAVEN

2013:
- ESA-NASA ExoMars Trace Gas Orbiter

2016:
- NASA Astrobiology & Caching Rover

2018:
- ESA ExoMars Rover

2020+
- ESA-EDL Demonstrator
- Towards Mars Sample Return
- Station Network

International Cooperation Programme
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

Rover Width: 2.8 m
Height of Deck: 1.1 m
Ground Clearance: 0.66 m
Height of Mast: 2.2 m
Mars Landing Sites
(Previous Missions and MSL Candidates)
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.
• 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

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.
PRIORITISED GOALS

1. Detect a broad suite of atmospheric trace gases and key isotopes with high sensitivity.

2. Map their spatial and temporal variability with high sensitivity.

3. Determine basic atmospheric state by characterising P, T, winds, dust and water aerosol circulation patterns.

4. Image surface features possibly related to trace gas sources and sinks.

INSTRUMENTS

- **MATMOS** (ppt)
  - US, CAN, B, F, RUS

- **NOMAD** (\(10^{-1}\) ppb)
  - B, E, I, UK
  - USA, CAN

- **EMCS** (P, T, dust, ices, H$_2$O)
  - USA, UK
  - F

- **MAGIE** (Full hemisphere WAC)
  - USA
  - B, F, RUS

- **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: 1 pass of 50 Mbits.
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

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**

**Panoramic camera system**
- **Two Wide Angle Cameras (WAC):** Color, stereo, 34° FOV
- **One High-Resolution Camera (HRC):** Color, 5° FOV

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

**Analytical Lab**
- Spectral range: 0.4–2.4 μm, Sampling resolution: 20 nm
<table>
<thead>
<tr>
<th>Instrument Name</th>
<th>Description</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>PanCam (WAC + HRC)</td>
<td>Panoramic camera system</td>
<td>UK, D, CH, F, I, A, USA</td>
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<tr>
<td>WISDOM</td>
<td>Shallow ground penetrating radar</td>
<td>F, D N, USA, B, I, E, UK</td>
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<tr>
<td>CLUPI in drill box</td>
<td>Close-up imager</td>
<td>CH, F CAN, UK, D, I, B</td>
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<tr>
<td>Ma_MISS included in 2.0-m drill</td>
<td>IRi borehole spectrometer</td>
<td>I P, PL</td>
</tr>
<tr>
<td>MicrOmega</td>
<td>IR imaging spectrometer</td>
<td>F CH, RUS, I, D, UK</td>
</tr>
<tr>
<td>RLS</td>
<td>Raman laser spectrometer</td>
<td>E, F, UK D, NL, USA</td>
</tr>
<tr>
<td>Mars-XRD</td>
<td>X-ray diffractometer + X-ray fluorescence</td>
<td>I, UK E, P, NL, D, F, RUS, USA, AUS</td>
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<tr>
<td>MOMA</td>
<td>LDMS + Pyr-Dov GCMS for characterisation of organics</td>
<td>D, F, USA NL, S</td>
</tr>
<tr>
<td>LMC</td>
<td>Life marker chip</td>
<td>UK, NL, I D, N, USA</td>
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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

- Earth Entry Vehicle (EEV)
- Orbiting Sample (OS)
- Mars Ascent Vehicle (MAV)
- Sky Crane
descent
- Lander collects contingency sample
- 500 km orbit
- Earth divert of ERV
- Rendezvous and capture of OS
- Sample Receiving Facility (SRF)
- Cache
- MSR Lander
- MSR Orbiter
- Caching rover deposits cache
- Fetch rover retrieves cache
- Verify flight containment system
- Caching Mission
- Earth divert of ERV
- Sample Receiving Facility (SRF)
- Earth Entry Vehicle (EEV)
NASA-ESA Programme Coordination

Joint Mars Exploration Program (JMEP)

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.

- 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

Mission Objective:
Search for life on Mars

Bioburden controlled assembly

GC-MS

Biology experiment

Terminal Sterilization of Lander

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Planetary Protection Constraints Today

BIOPURDEN 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 beginning of the mission definition phase and continuously monitored during the project life cycle

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
TYPICAL BIOBURDEN VALUES
- Non-controlled manufacturing: $10^5$ spores/m²
- Class 100,000 cleanroom: $10^4$ spores/m²
- Class 10,000 cleanroom: 1000 spores/m²
- Aseptic environment: < 40 spores/m²

TYPICAL BIOBURDEN CONSTRAINTS
- Less than 300 spores/m² on general surfaces
- Less than $3 \times 10^5$ 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
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