ESA’s Mars Exploration Programme

J. L. Vago and the ExoMars and MREP Teams

30 September 2010, Monrovia CA (USA)
Recognising that a Mars Sample Return (MSR) mission is very challenging, and that its undertaking will likely exceed the financial capabilities of any one agency,
• ESA and NASA have agreed to embark on a joint Mars robotic exploration programme:
  - Initial missions have been defined for the 2016 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 (MSR) mission.

2016
ESAs-led mission
Launcher: NASA – Atlas V 421
Orbiter: ESA
Payload: ESA-NASA
EDL Demo: ESA

2018
NASA-led mission
Launcher: NASA – Atlas V 531
Cruise & EDL: NASA
Rover 1: ESA
Rover 2: NASA
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.
- Data relay services for landed missions until 2022.
EXOMARS

Exomars TGO Payload

PRIORITISED GOALS

1. Detect a broad suit 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. Map their spatial and temporal variability with high sensitivity (≤ ppb):

INSTRUMENTS

| MATMOS (ppt) | USA, CAN, F |
| NOMAD (10⁻¹ ppb) | B, E, I, UK, USA, CAN |
| EMCS (P, T, dust, ices, H₂O) | USA, UK, F |
| MAGIE (Full hemisphere WAC) | USA, UK, 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: 8 sols;
- Data: Single pass of 50 Mbits.
Mission 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.

TECHNOLOGY OBJECTIVES

‣ Sample coring, acquisition, and encapsulation.

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.
Preparing the Future

Mars Robotic Exploration Preparation

Mission studies
Technologies

› 2018: ExoMars Rover

› Mars Sample Return
• Ongoing discussions with NASA to define a post-ExoMars mission scenario:
  ‣ The objective is to converge to a common understanding of the Mars robotic exploration programme.

• ESA has defined the following mission studies in preparation for C-MIN 2012:
  1. Network science mission (4–6 probes), possibly with a high-precision landing demonstrator;
  2. Sample return from a moon of Mars (Deimos or Phobos);
  3. Mars atmospheric sample return;
  4. Precision lander (≤ 10 km) including sampling-fetching rover;
  5. MSR orbiter.

Missions 1 through 4 are alternatives to cope with a possible MSR delay;
Missions 4 and 5 constitute potential European-led contributions to MSR;
The intention is to select 2–3 candidate missions by C-MIN 2012.
• ExoMars Programme: 1 B€ approved at C-2009;
  › 850 M€ already available;
  › 150 M€ will be confirmed at 2012 C-MIN.

• MREP Programme: 35 M€ for technologies and future mission studies;

Combined for MREP + General Studies Programme (GSP) + Technology Research Programme (TRP)
• **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.
  ‣ Oversight on implementation of missions.

**At programme level (standing)**

**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.
Mobility + Subsurface Access

- Nominal mission: 180 sols
- Nominal science: 6 Experiment Cycles + 2 Vertical Surveys
- EC length: 16 – 18 sols
- Rover mass: 300 kg
- Mobility range: Several km

DRILLING TO REACH SAMPLING DEPTH
CENTRAL PISTON IN UPPER POSITION
CORE FORMING
CORE CUTTING (closing shutter)
DRILL UPLIFT
SAMPLE DISCHARGE

2-m depth

Credit: ESA/Medialab
ExoMars Rover: Search for signs of life; Establish the scientific importance of subsurface samples 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 organics 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.
• Industrial negotiations completed for present stage of programme (B2X2 + Advanced CD2):
  ➡ ESA documentation defined and applied to the new contractual baseline;
  ➡ System PDR for 2016 and 2018 missions to run from 25 October – 13 December 2010;
  ➡ Statement of Intent (SOI) and Letter of Agreement (LOA) signed; good progress on Memorandum of Understanding (MOU).

• 2016 ExoMars Trace Gas Orbiter:
  ➡ Payload kickoff meeting (ESA, NASA, JPL) took place on 1–2 September 2010;
  ➡ First Orbiter Science Working Team (OSWT#1) to take place at JPL on 13–14 October 2010.

• 2018 ExoMars Rover:
  ➡ First lander accommodation workshop took place in JPL during June 2010;
  ➡ Rover design work progresses; medium-term activities to centre around prototype testing;
  ➡ Reformation of MOMA-LDMS team;
  ➡ Procurement of rover equipment and software for Phase C/D.
Flying Two Rovers

Sky Crane Maneuver: Touchdown

Horizontal Speed

Vertical Speed
Landing Latitudes

MOLA Topographic Map

Ancient Terrains
Rover Breadboard Activities

- Locomotion and navigation subsystems:
  ‣ Two chassis breadboards, wheels, GNC.

- Sample Preparation and Distribution System (SPDS) mechanisms:
  ‣ Tested in laboratory and under Mars simulated conditions.

- Drill and positioner:
  ‣ Extensively tested in laboratory and under Mars simulated conditions;
  ‣ Stand alone and on rover chassis breadboard;
  ‣ Down to 2 m depth.

- Thermal control system elements.

- Electronics;

- Next are further tests of the drill with more realistic geological strata configurations, including ice lenses.
  ‣ Dedicated science team has defined the sequences and procured suitable rocks.
Rover Deployment

Credit: ESA/Medialab
Analytical Laboratory

- Blank Dispenser
- Dosing Stations
- Crushing Station
- LMC
- Core Sample Transport Mechanism
- Carrousel with Refillable Container and GC Ovens
**Sample Delivery**

DRILL discharges sample into Core Sample Transport Mechanism (CTSM). CLUPI images sample. PanCam HRC provides a backup sample imaging capability.
Sample Analysis

Use mineralogical + image information from μΩ to identify targets for Raman and MOMA-LDMS.

e.g. search 1.9 μm + 2.3 μm bands

Imaging IR spectrometer:
- 256 x 256 pixels, 20 μm/pixel resolution,
- 0.5–2.6 μm spectral range, 500 steps

Raman: Spectral shift range 200–3800 cm⁻¹
Spectral resolution: 6 cm⁻¹

LDMS = Laser Desorption Mass Spectrometry
GCMS = Gas Chromatograph Mass Spectrometer

+ Life Marker Chip
<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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F, I, A, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WISDOM</td>
<td>Shallow ground penetrating radar</td>
<td>F, D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N, USA, B, I, E, UK</td>
</tr>
<tr>
<td>CLUPI in drill box</td>
<td>Close-up imager</td>
<td>CH, F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CAN, UK, D, I, B</td>
</tr>
<tr>
<td>Ma_MISS included in 2.0-m drill</td>
<td>IR borehole spectrometer</td>
<td>I, P, PL</td>
</tr>
<tr>
<td>MicrOmega</td>
<td>IR imaging spectrometer</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH, RUS, I, D, UK</td>
</tr>
<tr>
<td>RLS</td>
<td>Raman laser spectrometer</td>
<td>E, F, UK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D, NL, USA</td>
</tr>
<tr>
<td>Mars-XRD</td>
<td>X-ray diffractometer + X-ray fluorescence</td>
<td>I, UK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E, P, NL, D, F, RUS, USA, AUS</td>
</tr>
<tr>
<td>MOMA</td>
<td>LDMS + Pyr-Dev GCMS for characterisation of organics</td>
<td>D, F, USA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NL, S</td>
</tr>
<tr>
<td>LMC</td>
<td>Life marker chip</td>
<td>UK, NL, I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D, N, USA</td>
</tr>
</tbody>
</table>
Conclusions

« 2016: ExoMars Trace Gas Orbiter
• Its science will provide new insights into our understanding of Mars and key atmospheric processes of potential astrobiological relevance.
• An excellent base for international collaboration.
• Master landing technologies for future European missions.

« 2018: ExoMars 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.
• New sample handling and locomotion technologies.
• A step closer to Mars Sample Return.
Conclusions

‣ Lisbon, Portugal
- Opportunity for pre-conference Mars science meetings
  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) through end Wednesday (June 15): 2.5 days
- 1st International MEPAG Meeting
  Thursday (June 16) through end Friday (June 17): 1.5 days

‣ Field Trip: Río Tinto, Spain
- Visit to unique geology and acidic environment
  Saturday (June 18) to Monday/Tuesday (June 20/21): 3–4 days