Proposed Mars Astrobiology Explorer – Cacher (MAX-C) & ExoMars 2018 (MXM-2018) Mission Formulation Status

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(includes adaptations of slides from Charles Whetsel, Mike Wilson, Adam Steltzner, Tom Rivellini, Marguerite Syvertson)*

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Agenda

• Background and Formulation Status
• Top Level NASA and ESA Requirements
• Proposed MAX-C Rover Description
• ExoMars Rover Description
• Proposed Delivery System Description
• Summary
Science objectives for NASA’s proposed next generation Mars rover (MAX-C) have been maturing and solidifying over the last year

– Mid-Range Rover Science Analysis Group report, commissioned by MEPAG submitted to NRC Planetary Science Decadal Survey “white-paper” process in the fall – Mars Astrobiology Explorer
– Inclusion of Caching encapsulated rock cores together with in situ instrumentation for future return, would make this rover the first mission in a potential Mars Sample Return Campaign

• Additionally, NASA’s joint Mars Exploration Initiative results in a set of cooperative ventures over the coming decade
  – ESA to provide orbiter bus in support of NASA’s atmospheric science objectives in 2016
  – Future division of responsibilities and costs for ultimate Mars Sample Return campaign to be established in the near future

• The overall objectives of the proposed 2018 mission concept are:
  – Develop the proposed MAX-C Rover with in situ and caching payload, per MRR-SAG & Decadal Survey Guidance
  – Deliver both MAX-C and ExoMars Rovers to the surface of Mars
Formulation Status

• The strategy for delivering the proposed rovers to the Martian surface would be to inherit to the greatest extent possible from the MSL Cruise, Entry and Descent System.
  – Believed to minimize both mission and development risk.

• The current design maturity of the ExoMars Rover (previously planned for earlier launch) is considerably higher than that of the proposed MAX-C Rover.

• The primary focus of the study team has been on the physical accommodation of the two rovers, given
  – an understanding of what changes to ExoMars are and aren’t perceived to be feasible at this time, and
  – what is deemed to be a reasonable resource envelope to accomplish the stated in situ and caching objectives of the proposed MAX-C Rover.

• A combination of Team X sessions and a dedicated pre-project design team have been used to advance the state of the design thus far.

We have drilled down to a design point on one particularly promising branch of the architectural option space to answer a question of feasibility (“existence proof”).

We will now give other branches and sub-branches additional consideration (through ~CY2010), and then further trade and optimize the resulting baseline to simplify the system and balance risk (through ~CY2011).
NASA Program Level Functional Requirements (proposed)

- Launch to Mars in 2018 opportunity.
- Be capable of landing at altitudes up to [-1.0] km relative to the MOLA areoid.
- Be capable of landing and operating at sites between [25°N and 15°S] latitude.
- Be capable of landing with an error of [11] km or less radius from a designated point on the surface of Mars (excluding any uncontrolled effects of winds during parachute descent).
- Provide data communications throughout critical events, at a rate sufficient to determine the state of the spacecraft in support of fault reconstruction, to relay assets provided by the Mars Program or to the Deep Space Network.
- Deliver to Mars both the proposed MAX-C NASA Rover and the ExoMars ESA Rover.
- NASA Rover to have total traverse path length capability of at least [20] km.
- NASA Rover to conduct Mars surface sample selection and coring/caching operations for at least [500] sols.
- NASA Rover to be able to select, acquire, and cache at least [38] core samples ([2] caches of at least [19] cores each).
NASA Program Level Science Requirements (proposed)

- NASA Rover to carry instrumentation sufficient to scientifically select samples for caching.
  - It is assumed that this translates to the following measurements and possible strawman payload suite:
    - Must be able to remotely (i.e. with mast-mounted instruments) characterize outcrops and identify features of interest [note: Pancam, Near-IR Spectrometer]
    - Must be able to collect microscale imagery of outcrops; contact instrument [note: Microscopic Imager example]
    - Must be able to expose unweathered rock surfaces (i.e. using a surface abrasion tool with TBD characteristics) [note: Abrading Bit example, possible RAT or SRT equivalent]
    - Must be able to measure mineralogy at micro-scales (mm-cm) on the abraded rock surfaces; contact instrument [note: Raman example]
    - Must be able to measure bulk elemental chemistry on the abraded rock surfaces; contact instrument [note: APXS example]
    - Must be able to measure organic compounds at micro-scales (mm-cm) on the abraded rock surfaces; contact instrument [note: Raman example]
    - Must be able to correlate composition to micro-scale structures and textures in the rocks [note: Microscopic Imager example]
- Go to a site such that regions of scientific interest would be reachable within traverse capabilities of the rover.
  - At a high level it is assumed that this would dictate a capability to land at MSL-like sites in terms of rocks and slopes in order to put targets within reach.
    - Must be able to land at sites with [99%] areal density of up to [60 cm] rocks and [99%] areal density of up to [22.5°] slopes at scales of the landed system.
ExoMars Rover Program Level Objectives

- **Technology Objectives:**
  - Surface mobility with a Rover
  - Access to the subsurface to acquire samples;
  - Sample preparation and distribution for analyses by scientific instruments.

- **Scientific Objectives:**
  - To search for signs of past and present life on Mars;
  - To investigate the water/geochemical environment as a function of depth in the shallow subsurface;
  - To investigate Martian atmosphere trace gases and their sources.
ExoMars Rover Top Level Requirements

- Be launched to Mars in 2018 opportunity and landed at Ls 324.
- Be compatible with the “to be agreed” configurations constraints of the NASA “Skycrane”, and the associated deployment and egress constraints of its landed platform.
- Be capable of operating at altitudes \([-1.0 \text{ to } 1.0]\) km relative to the MOLA arroid.
- Be capable of operating at sites between \([35^\circ N \text{ and } 5^\circ S]\) latitude.
- Be capable of operating at sites with 7% rock abundance and [99.7\%] areal density of up to [21.5\°] slopes at 5m length scale.
- Be capable of operating for a total traverse path length of at least [3] km.
- Accommodating [7 (or 9)] scientific instruments: [3 (or 4)] survey instruments and [4 (or 5)] analytical laboratory instruments.
- Be capable of conducting Mars sample location selection, sub-surface sample collection down to 2m depth, and sample analysis operations at [6] different locations for at least [180] sols.
- Be capable of processing at least [26] core samples.
# NASA Rover Family Comparison

## Mars Exploration Rovers (MER)
![Mars Exploration Rovers (MER)](image1)

## Mars Science Laboratory (MSL)
![Mars Science Laboratory (MSL)](image2)

## Mars Astrobiology Explorer (MAX-C, proposed)
![Mars Astrobiology Explorer (MAX-C, proposed)](image3)

## Mars Pathfinder (MPF-Sojourner)
![Mars Pathfinder (MPF-Sojourner)](image4)

## Instruments + Science Support Equipment Mass

<table>
<thead>
<tr>
<th></th>
<th>MPF (Sojourner)</th>
<th>MER</th>
<th>MAX-C (proposed)</th>
<th>MSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>~1 kg total</td>
<td>~1 kg total</td>
<td>5+16 kg</td>
<td>~15+47 kg</td>
<td>82+155 kg</td>
</tr>
<tr>
<td>Rover Total = 11 kg</td>
<td>Rover Total = 11 kg</td>
<td>Rover Total = 173 kg</td>
<td>Rover Total = ~340 kg**</td>
<td>Rover Total = ~965 kg</td>
</tr>
</tbody>
</table>

**CBE mass is ~238 kg. PBE is ~340 kg with full 43% contingency on CBE.**

CBE = Current Best Estimate  
PBE = Predicted Best Estimate (with contingency)
Proposed MAX-C Rover Configuration/ Size

*All images are artist's rendition
MAX-C Strawman Payload Concept

**Mast**
- Morphology, context
- Remote mineralogy

**Rover Body:**
- Sample collection, encapsulation, and dual caching system

**Sample Caching**

**Rock and Soil Interrogation**

**Sample Caching**

**Functional requirements needed to achieve the proposed MAX-C scientific objectives:**
- Access to outcrops (mobility)
- Remote target selection capability
- Rock/soil interrogation
  - Chemistry
  - Mineralogy
  - Organics
  - Texture
- Documentation of sample context
- Sample via coring
- Encapsulation of cores

**Robot Arm:**
- Rock abrasion tool (corer bit or possible RAT)
- Corer

**Micro-Mapping Package:**
- Microscale visual imaging
- Microscale mineralogy imaging
- Microscale organic imaging

**Coarse Analysis:**
- Bulk elemental chemistry
MAX-C Strawman Payload Configuration/ Size

Arm
5-DOF (MER & MSL)
.8m Long (MER)

NIR
90

Pan Cam (MER)

RAMAN
Baseline instruments does not incorporate fiber optics

Drill/Corer
IMSAH SAT

APXS (MSL)

MAHLI (MSL)

SHEC

Dual Canister

* All images are artist’s rendition

All units mm

For planning and discussion purposes only.
Deployed configuration (1/2)

- Fixed Solar Array
- Deployable Solar Array
- Deployable Mast Assembly (DMA)
- Front Localisation Cameras (LocCam)
- Locomotion Subsystem (LSS)
- Rover Body (‘Bathtub’)
Deployed configuration (2/2)

- Crossed Dipole UHF Antennas
- Rear Localisation Cameras (LocCam)
- WISDOM Antennas
HRC can observe sample as delivered by the Drill
Drill Tool with sample acquisition mechanism
**Proposed MAX-C Overview**

<table>
<thead>
<tr>
<th>Baseline Major Mission/Spacecraft Attributes</th>
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<tbody>
<tr>
<td><strong>Science Capability</strong></td>
</tr>
<tr>
<td>Remote and Contact Science <em>(Color stereo imaging, macro/micro-scale mineralogy, elemental, micro-scale organic detection/characterization, micro-scale imaging)</em></td>
</tr>
<tr>
<td>Coring and Caching Rock Samples for Potential Future Return</td>
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<tr>
<td><strong>Mass Allocation (Launch/Entry/Landed)</strong></td>
</tr>
<tr>
<td>4440/ 3700/ 970 kg **</td>
</tr>
<tr>
<td><strong>Launch Vehicle (Baseline)</strong></td>
</tr>
<tr>
<td>Atlas V 531</td>
</tr>
<tr>
<td><strong>Power/Energy per Sol</strong></td>
</tr>
<tr>
<td>Cruise: 1250 W Solar</td>
</tr>
<tr>
<td>Surface: ~1600 WHrs/sol Solar</td>
</tr>
<tr>
<td><strong>Cruise ACS</strong></td>
</tr>
<tr>
<td>Stable Spinner (MSL Design)</td>
</tr>
<tr>
<td><strong>Landing Site (Ellipse/Altitude/Latitude)</strong></td>
</tr>
<tr>
<td>11 km radius / -1.0 km / +25 to -15 degrees</td>
</tr>
<tr>
<td><strong>Entry Vehicle Diam./Parachute Diam.</strong></td>
</tr>
<tr>
<td>4.7 m / 21.5 m</td>
</tr>
<tr>
<td><strong>Landing System</strong></td>
</tr>
<tr>
<td>Skycrane throttled monoprop with landing pallet</td>
</tr>
<tr>
<td><strong>Rover Mast Height/Wheelbase</strong></td>
</tr>
<tr>
<td>~1.7 m / ~1.6 m</td>
</tr>
<tr>
<td><strong>Ground Clearance/Wheel Diam.</strong></td>
</tr>
<tr>
<td>~0.42 m / ~0.35 m</td>
</tr>
<tr>
<td><strong>Data Return per Sol (2-week average)</strong></td>
</tr>
<tr>
<td>~250 Mbits UHF (w/TGMI); MER/MSL-class Xband DTE</td>
</tr>
<tr>
<td><strong>Data Storage</strong></td>
</tr>
<tr>
<td>32 Gbits</td>
</tr>
<tr>
<td><strong>Science Payload Mass</strong></td>
</tr>
<tr>
<td>~15 kg instruments</td>
</tr>
<tr>
<td>~62 kg including coring/caching/mast/arm</td>
</tr>
<tr>
<td><strong>Motor Architecture</strong></td>
</tr>
<tr>
<td>Brushless – hybrid distributed electronics</td>
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<tr>
<td><strong>Traverse Capability (Design Distance)</strong></td>
</tr>
<tr>
<td>20 km</td>
</tr>
<tr>
<td><strong>Flight Software</strong></td>
</tr>
<tr>
<td>MSL-based</td>
</tr>
<tr>
<td><strong>Surface WEB Thermal Range/Design</strong></td>
</tr>
<tr>
<td>-40°C to +50°C / CO2 gap insulation, RHUs, supplemental htrs</td>
</tr>
<tr>
<td><strong>Surface Design Lifetime</strong></td>
</tr>
<tr>
<td>500 Sols</td>
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*All images are artist’s rendition*

**Landed mass includes NTE ExoMars Rover allocation of 300 kg, and allocation for the proposed MAX-C Rover plus Landing Platform of 670 kg – baseline predicted best estimate (PBE) with 43% contingency.**
Proposed MAX-C/MSL EDL Architecture

**Guided Entry**
- CG offset to provide angle of attack/lift (0.24 L/D)
- RCS system would allow lift modulation range control via banking
- Lift modulation would provide range control
- PICA forebody TPS, was 4.5 m, is 4.7 m Viking geometry

**Supersonic Parachute Deploy**
- 21.5 m reference diameter DGB
- Viking geometry
- Triggered on navigated velocity

**Terminal Descent Sensing**
- TBD altimetry and velocimetry
- Terrain relative estimation

**Powered Flight/Sky Crane**
- 8 throttleable descent engines
- Closed loop descent with multi-point terrain relative navigation (Multi-X)
- Soft landing on high capability pallet

*All images are artist’s rendition*
How To Skycrane a Pair of Rovers

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* All images are artist's rendition

Focus of Proof of Concept Point Design
Landing Through Egress Overview

Sky Crane maneuver

Touchdown Through Initial Deployments

Platform Leveling Through Ramp Deployment

Stand Up Through Egress

* All images are artist’s rendition
**Summary**

- We have fleshed out a design on one particularly promising branch of the architectural option space to answer a question of feasibility.

- The resulting strawman system design was reached by exploring the aspects of the design fundamental to feasibility and with the largest influence on technical resources (e.g. mass, volume, etc.).

- We will now give other branches and sub-branches additional consideration, and then further trade and optimize to simplify the system and balance risk.

- In concert, we will explore implementation options and their influence on the technical design.

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Yes, we could deliver the proposed MAX-C and ExoMars rovers together to the surface of Mars.