On-Mars measurements, encapsulation, operations scenario, science risks, summary

Lisbon, Portugal; June 16, 2011

Scott McLennan, on behalf of the E2E-iSAG committee
Overview

Prioritized MSR science objectives

Derived implications

Samples required/desired to meet objectives

Measurements on Earth

Critical Science Planning Questions for 2018

Variations of interest?

Types of landing sites that best support the objectives?

Sample size?

Measurements needed to interpret & document geology and select samples?

On-Mars strategies?

Engineering implications

Sampling hardware

Instruments on sampling rover

EDL & mobility parameters, lifetime, ops scenario

Sample preservation

Pre-decisional: for discussion purposes only
Objectives and samples required/desired

**Scientific Objectives in Priority Order**

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**Sample Types in Priority Order**

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<td>1B</td>
<td>Hydrothermally altered rocks or Low-T fluid-altered rocks</td>
</tr>
<tr>
<td>2</td>
<td>Unaltered Igneous rocks</td>
</tr>
<tr>
<td>3</td>
<td>Regolith</td>
</tr>
<tr>
<td>4</td>
<td>Air-fall dust</td>
</tr>
<tr>
<td>5</td>
<td>Atmosphere, rocks with trapped atmosphere</td>
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*Additional: Determine if the surface and near-surface materials contain evidence of extant life*

Pre-decisional: for discussion purposes only
The *in situ* scientific measurements must enable us to understand the geology of the site... sufficiently to enable sample selection AND interpretation of data from sample analyses on Earth.
Sample Science General Principles:
2. Hierarchical Need for Information

**DRAFT FINDING #3.** Putting together effective sample suites requires collecting information in the field on many more rock and soil candidates than the number eventually collected.

Example:

\[ \text{Number} \]
\[ \sim 30-40 \]
\[ \text{*See slide 20} \]

\[ 73-124 \]

\[ 598 \]

\[ \sim 20,000^+ \]

---

*In first martian year, Spirit drove about 4000 m (lander to Haskin Ridge Seminole). Using a conservative visibility band of 15 m on either side of the traverse path (4000m x 30m = 120,000 sq m) times an average rock abundance of 15% comes out to 18,000 rocks.*

*Pre-decisional: for discussion purposes only*
Measurement capabilities
Revision - what determines the requirements?

Objective 1,3,4: Subaqueous or hydrothermal sediments; Hydrothermally altered rocks or Low-T fluid-altered rocks

**Natural Variation we may encounter:**
- Facies and microfacies in a sedimentary deposit
- Physical variations in a mineral phase: texture, crystal habit, or residence in veins/ layers/ cement/ clasts / concretions
- Inferred salinity gradient in a saline mineral assemblage
- Variations in organic matter: host mineralogy, concentration, spatial arrangement in relation to context
- Sedimentary structures and textures, associated mineralogical variations
- Mineral transition across a zone of alteration
- Sequence of vein-fill deposits
- Proximal-distal trends at a hydrothermal vent

Natural Variation we may encounter:
- Petrologic character: ultramafic to granitic, mineralogic, trace element properties
- Age (although in the field this could only be hypothesized based on context)
- Type and intensity of aqueous alteration
- Type of occurrence: outcrop, “subcrop,” or float
- Igneous setting: intrusive, extrusive
- Grain size, chemical variation in minerals
- Degree of weathering
- Degree of impact shock metamorphism, including brecciation

**NEED TO BE ABLE TO RECOGNIZE, MEASURE/DOCUMENT AND SAMPLE THESE**

Pre-decisional: for discussion purposes only
To be able to recognize, measure and document the types of features listed on the previous slides: essential parts of the evidence lie in the composition of millimeter-scale features such as:

- Laminae
- Clasts (vs. matrix)
- Crystals
- Void fills
- Concretions
- Veins

Measurements would be needed that resolve composition (mineralogy, elements, organics) of these millimeter-scale features. These measurements should be able to be integrated with their larger scale context.

**DRAFT FINDING #21.** Integration of observations from macroscopic (outcrop, regional) scales down to microscopic (sub-millimeter) scales is essential for robust geological interpretation in support of sample selection and provision of context for sample analyses on Earth.
Summary of required Field Capabilities implied by science priorities

The capabilities **required** to assess the geology and select the sample suites are:

1. Ability to detect variations in mineralogy, chemical composition, textures/structures (micro-, meso-, and macro-scale) in outcrops
2. Sufficient number of interrogations by the instruments of the outcrops to fully understand the geologic context.
3. Ability to “see” the rocks below their coverings of dust and weathering products.
4. Mobility range and lifetime sufficient to conduct exploration outside of the landing ellipse (see discussion later in this package)

**this is not a priority order—all would be required**

6/4/2012

Pre-decisional: for discussion purposes only
Building on a long history of mutually beneficial cooperation in space science, the United States National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) have expressed an interest in continuing henceforth jointly their robotic exploration of Mars. Accordingly, NASA and ESA agree to consider the establishment of a new joint initiative to define and implement their scientific, programmatic, and technological goals for the exploration of Mars. Initially focusing on 2016 and 2018, this initiative would span several launch opportunities with landers and orbiters conducting astrobiological, geological, geophysical, climatological, and other high-priority investigations and aiming at returning samples from Mars in the mid-2020s.

Statement of Intent for Potential Joint Robotic Exploration of Mars. NASA/ESA: 5 November 2009
Measurements: NASA/ESA Collaboration and the Mars 2018 Mission

Current (May, 2011) relevant assumptions about the 2018 rover

1. Single joint rover delivered by MSL skycrane system
2. The mission will support both proposed Mars Sample Return science (based on science priorities updated via the E2E analysis) AND in situ science derived from prior ExoMars priorities.
3. Inclusion of Pasteur payload previously selected. Whether additional instruments for sample selection/caching would be required is analyzed by E2E; selection via future joint AO assumed.

<table>
<thead>
<tr>
<th>CURRENTLY APPROVED PASTEUR PAYLOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INSTRUMENT NAME</strong></td>
</tr>
<tr>
<td>PanCam (WAC + HRC)</td>
</tr>
<tr>
<td>MOMA</td>
</tr>
<tr>
<td>MicrOmega IR</td>
</tr>
<tr>
<td>Mars-XRD</td>
</tr>
<tr>
<td>Raman</td>
</tr>
<tr>
<td>Life Marker Chip</td>
</tr>
<tr>
<td>CLUPI</td>
</tr>
<tr>
<td>WISDOM</td>
</tr>
<tr>
<td>Ma_Miss included in 2.0-m drill</td>
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</tbody>
</table>
DRAFT FINDING #22. Mast, arm and on-board lab instruments would all be of value for achieving the proposed MSR science objectives. However, each plays a different tactical role in sample selection and establishment of geological context.

<table>
<thead>
<tr>
<th>Value to returned sample objectives</th>
<th># of potential targets</th>
<th>Operations Speed</th>
<th>Decision flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey geology and acquire/prioritize IDD targets</td>
<td>$&gt;10^3$ rocks in view, $\sim 10^3$ targeted</td>
<td>FAST: some done concurrent with driving</td>
<td>Use IDD? Continue remote survey?</td>
</tr>
<tr>
<td>Confirm/prioritize specific sample targets, analyze geologic setting</td>
<td>$\sim 10^2$</td>
<td>MEDIUM: Stop, arm deployment, 1-3 sols</td>
<td>Cache sample? Continue survey? ALD sample?</td>
</tr>
<tr>
<td>added detail &amp; verification of arm/mast measurements</td>
<td>$\sim 10^1$</td>
<td>SLOW: sample acquisition, processing 10-20 sols</td>
<td></td>
</tr>
</tbody>
</table>

Measurements can be grouped by position on rover

6/4/2012
Is the ExoMars Pasteur payload sufficient on its own to meet MSR science objectives?

Sample selection decisions would be based on a foundation of numerous (100’s to 1000’s) observations and measurements of the local geology. These would be most efficiently done with mast- and arm-mounted instruments.

**DRAFT FINDING #9. MAST/ARM INSTRUMENTS:** The majority of the information for deciding which samples to return to Earth must be based on relatively fast, efficient mast- and arm-mounted instruments, in order to keep the mission within plausible lifetime and resource constraints (reaffirms a key finding of MRR-SAG).
Planning Considerations: Mast-mounted instruments

• From the perspective of MSR science, there will be a desire to place the rover in an area where multiple interesting rock and soil sampling targets are present.
• In order to be able to do effective long-term and short-term operations planning while the rover is active on Mars, the instruments must be able to quickly:
  o acquire information about the near-field geology,
  o be able to scan fields of possible sampling targets in order to recognize and prioritize potentially valuable possibilities.
• We don’t know how to operate a rover without an optical camera
• The job of recognizing and prioritizing the geology (quickly!) is best done by combining imagery with mineralogical information about the array of visible features. This implies need for a mast-mounted mineralogy sensor.
Planning Considerations: Arm-mounted instruments

• For the scientific objectives proposed for MSR:
  - Some of the features of greatest interest in scientific sample selection are at a scale of millimeters or less (equivalent to that of the component mineral grains, laminae etc). The overall scientific value of the selected samples would depend on the integration of information about both texture (optical) and composition at this scale.
  - As has been shown repeatedly by MER, chemistry of both rock and soil is a crucial means of interpreting geology and understanding comparatively subtle, but significant, variations—thereby enabling careful sample selection.

• Because sample acquisition is both time-consuming, and potentially risky, we need to take this action only on carefully-chosen rocks/soils.

• The contact-mode sensors must be able to operate fast, in order to support the decision-making required.

• The ability to remove surface dust and a thin layer of more weathered rock would enable better decision-making.
In order to recognize the geological characteristics of interest and to provide a proper basis for sample selections, two measurement types would be required from the mast, and 3-4 more from the arm, as identified in the figure below. On-board laboratory measurements such as provided by the ExoMars ALD are highly desirable.

**Required contact measurements** on ARM:
- Microscopic imagery
- Elemental chemistry
- Mineralogy

**Highly Desired measurement** on ARM:
- Organic C detection

**Additional capability required** on ARM:
- ability to remove rock weathering layer

*Sub-mm measurement scale highly desirable for all contact measurements; required for imaging and mineralogy*

**Required on MAST:**
- Macroscopic imagery
- Mineralogy (spectroscopy)

**Highly desirable and assumed to be present (in ALD):**
- Organic carbon detection & analysis
- Mineralogy

(more detailed / precise measurements than instruments on arm or mast)
Maximizing the value of the ALD to MSR
Passing samples from arm to ALD

The value of the ExoMars ALD for meeting proposed MSR science objectives depends on how much of the range of encountered materials it can be supplied with. If any materials accessible by the arm could be passed to the ALD, the value of the ALD would be high.

If only the materials accessible by the ExoMars drill (those directly below the rover) could be passed into the ALD, the application of the ALD to MSR science is more restricted.

DRAFT FINDING #24. ONBOARD LAB INSTRUMENTS provide detailed, highly sensitive analysis of a select number of high priority targets. The value of on board lab instruments would be greatly increased if samples can be passed from the arm corer to the lab.
Maximizing the value of the drill to MSR
Getting a subsurface sample in the cache

- The **capability** to cache and return one or more rock samples from ~2m depth would be **extremely valuable**
- This would require an ability to pass a drill sample into the cache
- Such a capability is considered more important than the capability to pass arm-corer samples into the ALD
Sizing the sample collection system: Relationship between #samples and mass

- mass/sample higher than needed
- # of samples too small if field site is “target-rich”

- insufficient mass/sample
- High # of samples = mission lifetime too long

Diamonds occur where # rock samples would have a very efficient packing geometry. Other geometries are possible

Canister packing

Pre-decisional: for discussion purposes only
The rock and regolith samples would be collected into a cylindrical sample canister by the 2018 rover caching system.

The proposed MSR-L mission would place the cylinder into a spherical container for return to Earth.

The gas sample could be collected into the volume around the cylinder inside the sphere, as shown:

Pre-decisional: for discussion purposes only
The Necessity of Organic Blanks

• A critical aspect of returned sample science, especially for biology-related investigations, is recognizing false positives.
  o Organics/microbes from Earth that make the round trip
  o Organics/microbes from Earth that enter the analytical process after the samples are returned to Earth

• Correct analytic procedure to prove a detection involves introducing a system of carefully designed positive and negative control standards.

• Some materials will need to be sent round-trip. The design of “the experiment” needs community debate in order to optimize when and what to introduce into the sample chain.

DRAFT FINDING #25. Some sample spaces in the canister (2-3?) should be set aside for blanks/standards as a reserve against the outcome of future MSR scientific planning activities.
Sample Collection Mass Inventory

Assumptions: a cylindrical canister with 31 slots

- Some of the 31 sample slots need to be used for blanks and standards
- All slots in cylindrical volume would be identical size
- Relative number of sedimentary, igneous, and granular samples to be decided by future science team.

<table>
<thead>
<tr>
<th></th>
<th># samples</th>
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<th>Mean mass/sample</th>
<th>Total Sample Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqueous sedimentary / aqueous altered rocks</td>
<td>31</td>
<td>28</td>
<td>~16g</td>
<td>460g</td>
</tr>
<tr>
<td>Unaltered Igneous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granular Materials</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Blanks and standards</td>
<td></td>
<td></td>
<td>Must be planned for</td>
<td></td>
</tr>
<tr>
<td>Atmospheric Gas</td>
<td>2</td>
<td>2</td>
<td>0.0001</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
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<td>~500g</td>
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**DRAFT FINDING #26.** The collection should be sized to a total sample mass of about 500 g.
DRAFT FINDING 27. To ensure the science objectives could be met, the samples must maintain their scientific integrity while cached on the martian surface (potentially for several years) and while being transferred from Mars to Earth. Adequate sealing of the sample tubes and the sample canister are a key part of achieving this.

DRAFT FINDING #28. The volatile species for which limiting mass transfer (in/out of the sample tubes) would be most valuable is water.
Sample tube seals

**DRAFT FINDING #29a.** Sample tubes should be sealed as they are acquired. The seals should restrict the loss of particles and volatiles from the samples.

**DRAFT FINDING #29b.** Prior to leaving the martian surface, it would be extremely desirable to seal the canister sufficiently to avoid a significant pressure differential across the sample tube seals during transit. This would mean that mass transfer in/out of the sample tubes would be by diffusion only, which is a relatively slow process.

**PHASE I. ON MARS**

- Sample tube seal
- Mars atmosphere

**PHASE II. IN TRANSIT**

- Canister seal
- P = 1 Mars atm. *if canister sealed before MAV launch*
- Possible water getter?

**SAMPLES REMAIN IN MARS ATMOSPHERE**

6/4/2012

Pre-decisional: for discussion purposes only
Science Priorities Regarding Encapsulation

A number of sample tube sealing options are possible. However, there is a trade-off between degree of sealing and introduction of contaminants. The relative importance of sealing vs. contamination depends on the science objective.

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Sample Tube Sealing

Discussion

• Teflon is a good choice for seal material: because of its high chemical inertness and thermal stability, the chance of chemical interaction / degradation / contamination is very low. Moreover, the potential (although unlikely) contaminants induced by Teflon, will be fluorinated organics, easy to discriminate from Martian organics.
• Teflon is one of the very few materials routinely used in the curation of extraterrestrial samples.
• Metals, especially copper which may be easily oxidized, and - more important - may play catalytic role once in contact with the martian samples, could induce chemical changes in the samples.
• Indium is undesirable because of interference with trace element geochemical studies.

DRAFT FINDING #34. Materials used in the sealing process need to be compatible with the planned measurement objectives. Seals made of Teflon are an example of such a material.

Pre-decisional: for discussion purposes only