Compelling Reasons To Explore Mars

- Many of the key questions in solar system science can be addressed effectively at Mars:
  - Solar system history
  - Planetary evolution
  - Potential for life

- Mars provides the opportunity to approach, and possibly answer, origin and evolution of life questions
  - Clear potential for past and possibly present biological activity

- Mars has a well-preserved record of its climate and geologic evolution exposed at the surface
  - A comparable record of ancient planetary processes, including those possibly leading to the origin of life, exists on no other terrestrial planet, including Earth

- Mars is the most accessible place in the solar system where these highest-priority science questions can be addressed

SOURCE: NRC Planetary Decadal Survey (2011)
WHAT HAVE WE LEARNED?

1. Martian science
2. How to operate on Mars
1. Mars has incredible diversity

Source: NRC Planetary Decadal Survey (2011)
2. Mars was once wet and warm

**Proposed Chemical Environments**

<table>
<thead>
<tr>
<th>clays</th>
<th>sulfates</th>
<th>anhydrous ferric oxides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep phyllosilicates</td>
<td>Layered phyllosilicates</td>
<td>Carbonate deposits</td>
</tr>
<tr>
<td>Phyllosilicate in fans</td>
<td>Plains sediments</td>
<td>Chloride Deposits</td>
</tr>
<tr>
<td>Intracrater clay-sulfates</td>
<td>Meridiani layered</td>
<td>Valles layered</td>
</tr>
<tr>
<td>?</td>
<td>Layered Hydrated Silica</td>
<td>?</td>
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</tbody>
</table>

### Geologic Eras

<table>
<thead>
<tr>
<th>Noachian</th>
<th>Hesperian</th>
<th>Amazonian</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Geologic Eras</td>
</tr>
</tbody>
</table>

**Source:** NRC

*Planetary Decadal Survey (2011)*
3. By analogy with Earth, some ancient martian environments were likely habitable.

The oldest convincing evidence of life on Earth (from Allwood et al., 2006; 2009).
Where within this scene is there possible evidence of life?
Some Lessons Learned:
1. Mobility is good

Most of our landing ellipses for MER look like this:

Gusev

Meridiani
Some Lessons Learned:
A key to scientific exploration is mobility
"The Land of Olivine"

El Dorado

Home Plate

Arad

sol 250
sol 350
sol 400
sol 500
sol 450
sol 550
sol 600
sol 650
sol 700
sol 742
sol 776
Some Lessons Learned:

2. Longevity is good

- Spirit’s most significant discovery was made 1200 sols into its 90-sol mission:

![Graph showing Raw APXS Data with 91% SiO₂](image)
3. **Steep terrain can be of critical importance**

It pays to invest in the hardware, software, and testing necessary to handle steep terrain.

- don’t just think about range and obstacle avoidance, also consider climbing and descending.
We need to be able to deliberately access places like this.
Some Lessons Learned:

4. High-Resolution orbital imagery is critical

Imagine doing traverse planning around the edge of this crater without this information!
Three primary human-related science investigation strategies are recognized.

- On-Mars laboratory investigations (and their connection to sample return)
- Investigations requiring complex in situ instrumentation
- Field Science
The **search for life** is our top scientific goal: We would like to use our most capable mission (a human Mars mission) to pursue it.

**HOWEVER,**

In order to safely land a human mission on Mars (and return the crew to Earth), we will have to **know in advance** that the risk due to biohazards is acceptable.
Solving the paradox

• The existence or absence of (extant) life at the landing site would have to be established by robotic means before a human landing.
  – This needs to constitute a primary objective of the pre-human robotic program.
  – MSR would be critically important

• The first human mission would naturally lend itself to investigations of extinct life, or characterization of life previously discovered by in-situ missions
  – Biologically safe
  – Sufficient scientific importance
Backup
Assuming a program of three crewed missions

<table>
<thead>
<tr>
<th>PLANETARY SCIENCE</th>
<th>SUSTAINED PRESENCE</th>
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</thead>
<tbody>
<tr>
<td><strong>One Site</strong></td>
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</tr>
<tr>
<td>BELOW SCIENCE FLOOR</td>
<td>BRONZE STANDARD</td>
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<tr>
<td><strong>Multiple Sites</strong></td>
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<tr>
<td>SILVER STANDARD</td>
<td>BRONZE STANDARD</td>
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<tr>
<td>GOLD STANDARD</td>
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Why Humans?

Unique attributes human explorers could bring to bear in comparison to robotic explorers:

- **Cognition**
  - Rapidly recognize and respond to unexpected findings; sophisticated, rapid pattern recognition (e.g. structural/morphological biosignatures).

- **Dexterity**
  - Humans are capable of fine-scale, non-repetitive manipulations. Valuable in sampling heterogeneous rocks/outcrops.

- **Adaptability**
  - Humans are able to react in real time to new and unexpected situations, problems, hazards and risks.

- **Efficiency**
  - Robotic manipulation requires several sols to accomplish what humans could do in a matter of minutes.