

Momentous Discoveries on Mars: Science Outside MEP Pathways

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Abstract: The Mars Exploration Program has recently defined four Pathways to explore Mars in the 2009-2020 timeframe. However, missions now in progress could make some "momentous" discoveries not addressed by the pathways. In this poster, we look at seventeen different types of discoveries that could be made on Mars, of varying scientific interest, and levels of "momentousness," and how future missions could be engineered to investigate these discoveries in a more urgent timeframe. Discoveries involving evidence of water, or clear signatures of ancient or extant life have high "momentousness."

These future missions would be designed to have:

- A more regional focus,
- A quicker on-site response to interesting transient phenomena, or
- Longer baseline observations of the momentous phenomena observed (utilizing, for example, long-duration power sources). Also considered are discoveries that would induce or support a more accelerated human presence on Mars, such as biosignatures, resource recovery, etc.

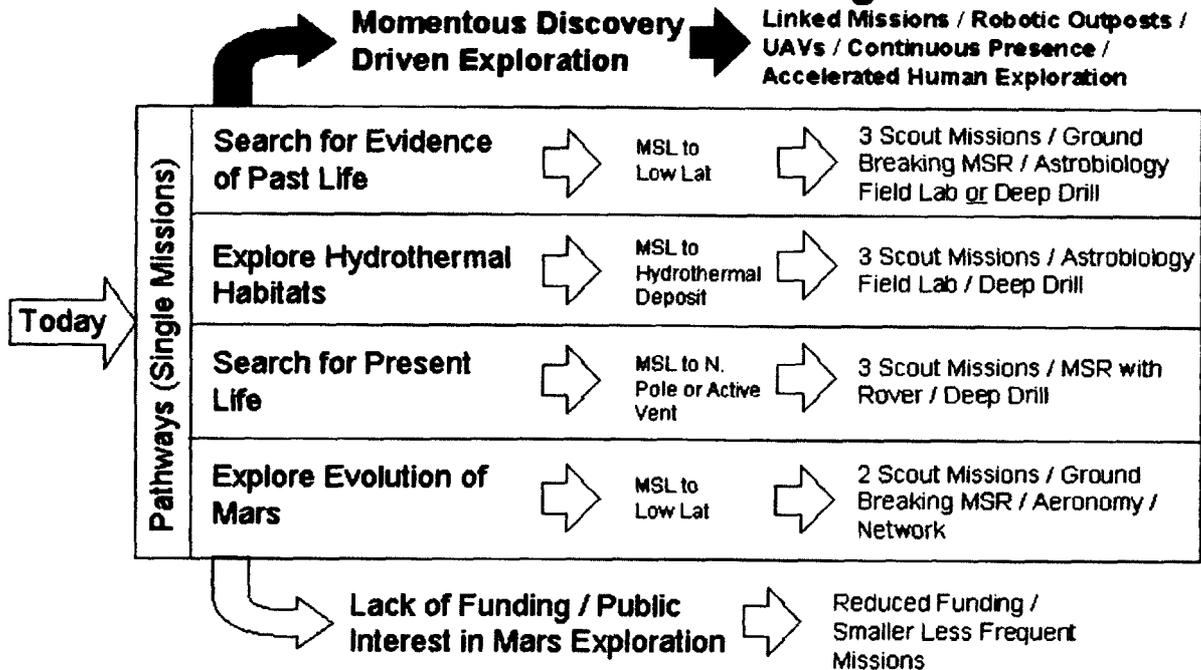
The Mars Outpost Team seeks further input from the Mars community about other possible momentous discoveries that could be made, as well as ways to respond to them (types of missions, instruments, spacecraft – orbiters, landers, rovers, airplanes, etc.).

Background: Several current Mars exploration scientific goals focus on searching for momentous discoveries at Mars, such as evidence of past or present life forms, hydrothermal habitats, volcanic activity, etc.

If and when such a discovery occurs, it might trigger the onset of a new era of Mars exploration, possibly including new types of missions such as robot bases, and possibly accelerating human exploration.

But although a momentous discovery could happen any day, no strategy for responding to it has yet been laid out – except for the case of a hydrothermal habitat. The scientific investigation requirements, potential mission architectures, and technology requirements to respond to any other potential momentous discovery, are still unknown.

Mars Outposts Address the What Ifs in the Mars Program



Approach

>> **What are the Pathways for other "Momentous Discovery" Scenarios??**

In order to answer this important question, we need to:

- Understand the science of momentous discoveries
- Develop a list of potential momentous discoveries
- Develop a measure of "momentousness" to prioritize the list, with community input
 - Identify the top 3-4 momentous discoveries based on wide community inputs
 - Develop, and refine with community inputs, the science rationale and science investigation requirements for the top 3-4 discoveries
- Develop and trade possible architecture to address momentous discoveries
 - Including a comparison of benefits/cost of various approaches
 - Including an analysis of the pathways to prepare for human exploration
- Analyze technology needs to address momentous discoveries
 - Including an analysis of the role of nuclear power for surface applications

Preliminary List of Potential Momentous Discoveries

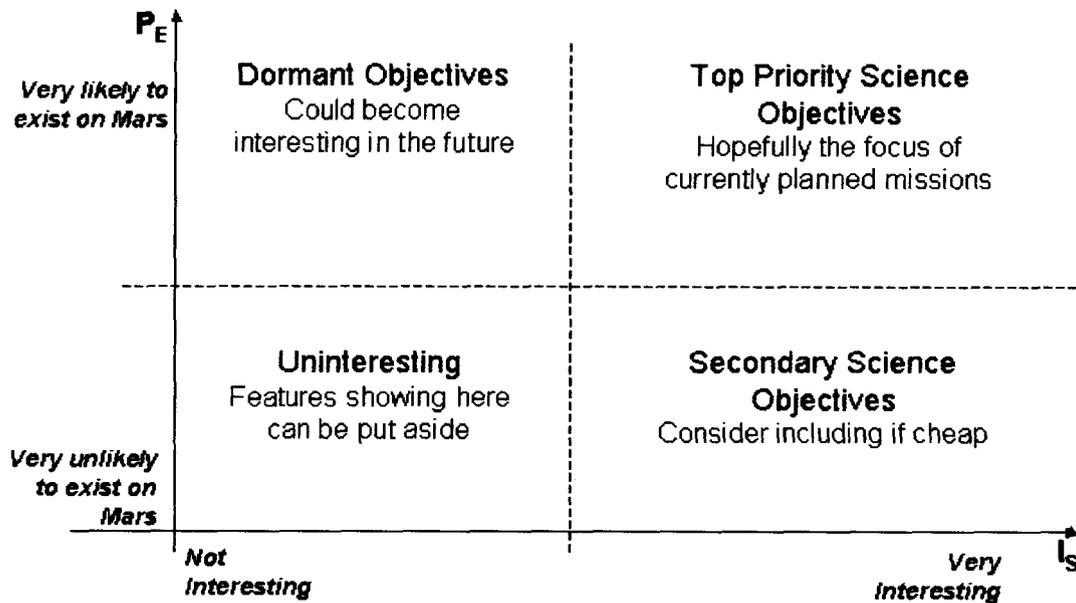
1. **Water-deposited sedimentary rock identified unambiguously**
2. **Hydrothermal signatures**
3. **Sinks and sources of H₂O and CO₂**
4. **Organic compounds detected unambiguously**
5. **Different chemistry with depth**
6. **Weathering not consistent with known Mars climate**
7. **Unexpected chemistry and mineralogy**
8. **Mineralogy showing magnetism where not expected**
9. **Any species out of equilibrium with chemistry, temperature or climate**
10. **Presence of biosignatures (organism secretion products)**
11. **Stratigraphy that can only be explained by living organisms (motion up or down)**
12. **Active volcanism**
13. **Seismic activity (e.g. marsquakes, origin of Fire-type volcanoes)**
14. **Non-natural geologic formations (e.g. fossils, archeological artifacts)**
15. **Anomalous pockets of younger terrain**
16. **Plate tectonics**
17. **Polar anomalies**

In July, 2003, the Mars Outpost Team collected opinions about momentous discoveries we might expect to make on Mars from members of the international scientific community attending the 6th Mars International Conference at Caltech. This is a summary:

Mars Conf. Survey Votes: Momentous Discoveries	Most Interesting to Discover	Most Likely to Discover	Would Radically change the Mars Prog.
1 Water-deposited sedimentary rock a. Layered terrains such as in Candor Chasma, with geologically and morphologically identical thick layers formed in lakes or shallow seas from different water levels as lakes dried up. b. High resolution images of ancient shorelines denoting stands of progressive lacustrine desiccation	7	12	10
2 Hydrothermal signatures a. Active water geysers and associated morphologies b. Spectrally distinct hydrothermally-generated mineral deposits (generated by precipitation of dissolved species from water changing temperature as it reaches the surface and precipitating out minerals and other elements) c. Hydrothermally altered rock	4	2	5
3 Sinks and sources for H2O and CO2 a. Hot springs protected by ice or snow coverings b. Underground water tables where water is seeping into or out of the ground (aquifers, etc) c. Evidence of erosional and depositional aquifer outcrops d. Near-surface liquid groundwater (actually observed)	3	14	2
4 Organic compounds detected unambiguously a. Unequivocal chromatographic or spectral evidence of organics b. Spectral information or chemical reaction products that indicate the presence of peroxides or other oxidants c. Are the organics in contact with oxidizers of any kind? How can they persist in the presence of oxidizers, unless they are continuously replenished (just as cells in Earth organisms persist in the presence of an oxidant such as oxygen)?	11	1	14
5 Different chemistry with depth a. Are surface conditions unfavorable to life and organic chemistry, but lower layers are favorable? (weeter, less oxidizing?)	1	5	3
6 Weathering not consistent with known Mars climate a. Water-eroded rocks where no fluvial formations are seen b. Unweathered materials where water was obviously flowing c. Erosion consistent with high oxygen content in the atmosphere	2	6	3
7 Weird (unexpected) chemistry and mineralogy a. Either consistent with the presence of H2O, or inconsistent with our picture of mineralogy or chemistry from Viking and Pathfinder data (e.g. oxidation states of metals not in equilibrium with Fe oxidation state) b. Change in oxidation state with time (over seasons)	3	4	4
8 Mineralogy showing magnetism where not expected a. Magnetism in areas not observed to be banded, as in MGS data b. Unmagnetized materials in areas where banding was seen (how to explain the observations of polarization, etc) c. Magnetite similar to that seen in magnetite-containing Earth bacteria (as seen in ALH8004)			
9 Any species out of equilibrium with chemistry, temperature or climate, either in the atmosphere or surface a. Oxygen or other species (CO, CH4, etc) in abundances not in equilibrium with current atmosphere	6	1	4
10 Presence of biosignatures (organism excretion products) a. Shells, waste products of any kind	23	1	24
11 Stratigraphy that can only be explained by living organisms (motion up or down) a. Example similar to organisms postulated as living in cracks on Europa and travelling up and down from the surface, leaving evidence of ecosystems along the way b. Chemical changes in the rocks from the above processes	9	1	14
12 Active volcanism a. Watch for volcanic plumes, atmospheric transport, gas signatures b. Active lava flows	3	1	10
13 Seismic activity a. Plate tectonics b. Ring of Fire-type volcanoes	1 3	3 2	6 8
14 Non-natural geologic formations a. Fossilized microbes or higher order life b. Archeological artifacts	3		4
15 Anomalous pockets of younger terrain	1	3	
16 Polar anomalies a. Signatures of chemical species in polar layers indicative of different atmospheric constituents than exist today			
17 Other: Subsurface reservoir of water or ice	1		
18 Other:			
Total Expressed Opinions:	81	56	111

Designing for this Decade

- Likelihood *versus* Scientific interest



The following survey data is sought in order to start architecting future missions to investigate these possible discoveries. What investigations need to be done – i.e., drill 200 m below Mars surface? How should we proceed – i.e., undertaking a multi-mission scientific campaign by developing a Mars outpost base?

"Momentous Discoveries on Mars" Workshop

This JPL Advanced Studies Workshop will take place on a yet-to-be-determined date before the end of the year. Please help us prepare for it – we need your feedback!

Please pick only five of the below discoveries you think are most likely to be found on Mars – number them: 1 (most likely), 2, 3, 4, and 5 (least likely).

Also, please pick only five of the below discoveries you think would be the most scientifically interesting or important to find life on Mars – please write beside them:

A (most interesting/important), B, C, D, and E (least interesting/important).

Classify five as: 1 (likely) - 2 - 3 - 4 - 5 (least likely)	Classify five as: A (interesting) - B - C - D - E (least interesting)	Discoveries that we may make on Mars	How much will each discovery change the Mars program? (i.e., not much, a little bit, a lot, radical, etc.)
		Active volcanism	
		Anomalous pockets of younger terrain	
		Chemical(s) out of equilibrium with chemistry, temperature or climate, in the atmosphere or surface	
		Different chemistry with depth	
		Hydrothermal signatures (geyser formations)	
		Mineralogy showing magnetism where not expected	
		Organic compounds detected unambiguously	
		Presence of biosignatures (organism excretion products)	
		Seismic activity	
		Sinks and sources for H₂O and CO₂	
		Stratigraphy that can only be explained by living organisms (motion up or down)	
		Water-deposited sedimentary rock, shoreline features	
		Weathering not consistent with known Mars climate	
		Weird (unexpected) chemistry & mineralogy	
		Plate tectonics	
		Non-natural geologic formations	
		Other:	

We will send you results of this poll, and more information about our upcoming Mars Workshop.