Are There Signs of Life on Mars? A Scientific Rationale for a Mars Sample-Return Campaign as the Next Step in Solar-System Exploration

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Outline

- Scientific exploration of Mars
  - Compelling reasons
  - Searching for Life/Life Detection
- Are we ready to do sample return?
  - Do we require a detection of organics first?
  - Are we ready to select a site?
- Importance of having a Mars *program*
- Summary

There Are Compelling Reasons To Continue To Explore Mars

- Many of the most important questions in solar-system science can be addressed effectively at Mars.
  - Solar system history
  - Planetary evolution
  - Potential for extraterrestrial life
- Mars has clear potential for present and/or past biological activity.
- Mars has a well-preserved record of its climate and geologic evolution accessible at its surface.
- Mars is the most-accessible place in the solar system where these highest-priority science questions can be addressed.
  - Other places provide compelling science, but at greater cost and risk.
  - A balanced planetary exploration program is necessary, but should not sacrifice addressing the driving science objectives.

Searching For Life Is The Next Step In Mars' Astrobiological Exploration

- Astrobiological exploration of Mars over the last 15 years has followed the logical flow laid out in the 1995 *Mars Exobiology Strategy* document:
  - Identify sites of interest from orbit
  - Explore role of water on the ground
  - Investigate habitability
- The highest-priority scientific goal today is to determine whether life is or was present on Mars.
- Sample return is the mission implementation that will enable these questions to be addressed most effectively and convincingly. This was identified in the 1995 strategy as the next step.

Does Searching For Evidence For Life Require Sample Return?

- Possible approaches to biosignature detection include *in situ* analysis, atmospheric trace gas measurement, and sample return. Each would have an important role to play in a broad program.
- Sample return is the approach most likely to provide convincing, definitive answers.
- No one experiment is likely to provide conclusive evidence of present or past life; multiple approaches and lines of evidence are required.
- Sample return has major advantages over *in situ* exploration
  - Analysis tools are not constrained by the limited resources on a spacecraft.
  - Analysis tools are not locked in 5-7 years in advance.
  - Analysis on Earth takes advantage of ability to do follow-on experiments, to use multiple techniques, and to analyze samples using state-of-the-art techniques not available at the time of the mission.

Life Detection Is Not Easy Or Straightforward

- **Viking** demonstrated difficulty of doing life detection *in situ*
  - In hindsight, experiments were ill conceived although based on best available science at the time.
  - Experiments did not allow suitable follow-up beyond simplest control experiments and repeated analysis.
  - Life-detection experiments required additional data (from GCMS) for interpretation.
  - Life-detection experiments were inherently ambiguous in their results, and would have required additional analyses to confirm discoveries.
- **ALH84001** demonstrated need for multiple approaches and multiple follow-on experiments
  - McKay et al. results were appropriate first analysis.
  - Large number of follow-on experiments were required before valid conclusions could be reached.
  - We must avoid being too narrow (again) in our approach to biosignature analysis.

Are We Ready To Do Sample Return?

- Do we need an additional discovery or analysis prior to sample return?
- Do we need to explore more sites prior to sample return?
- Can we pick a compelling site for sample return?

Do We Need An Additional Discovery Prior To Sample Return? The Role Of Organic Molecules (1 of 2)

- A number of people have suggested that organic molecules first be detected on the surface before committing to a sample return mission.
- Organic molecules are of special importance in life detection, but are by themselves insufficient to detect life.
  - Abiotic sources of organic molecules will confound results.
- Multiple approaches to biomarkers:
  - "The results from an ensemble of all of the relevant methodologies, combined with considerations of geological and environmental plausibility, will likely provide the best evidence for the presence or absence of life in a sample." (From *Mars Astrobiology Strategy*)
  - Organic molecules / molecular biosignatures
  - Isotopic biosignatures
  - Morphological biosignatures
  - Mineralogical and inorganic chemical biosignatures (predominantly indirect evidence)
- Inherent limitations in *in situ* organic molecule detection
  - Previous approaches (e.g., Viking) would have missed large classes of organics; no guarantees on capability of the limited instrumentation that can go onto a rover
  - *In situ* analysis cannot be as comprehensive as analysis of returned samples
  - Absence of organics does not mean absence of life nor does it preclude presence of

Do We Need An Additional Discovery Prior To Sample Return? The Role Of Organic Molecules (2 of 2)

- Astrobiological relevance of sample analysis is not based solely on detection of life.
  - Topmost scientific goal is to determine *whether* life is present or absent
  - *And* to understand planetary context of life's presence or absence
  - *And* to provide details of past and present habitability of different environments
- Scientific value of samples is very high across all disciplines
  - Based on previous sample returns, fundamental discoveries are anticipated that are not dependent on a specific pre-return analysis.
  - Detection of organics is not a litmus test for high scientific value or astrobiological relevance.
- Potential for never returning sample or for impossible-to-implement programmatics (i.e., indeterminate mission queue).

Can We Pick A Compelling Site For Sample Return?

- Site must have enough diversity of accessible materials to address multiple scientific disciplines (biology, geology, geochemical history, etc.)
  - Evidence for past and/or recent liquid water activity
  - Ability to *preserve* potential biosignatures
  - No extraordinary discoveries are needed to pick a site (e.g., active water seep or demonstrated presence of organics)
- Dozens of high-priority sites have been identified from orbital data
  - MSL considered > 30 sites alone
  - New information, whether from new orbiter observations, analysis of existing data, or from MSL rover operations can be folded into the site selection process almost until launch of caching rover (selection NET ~2017)
  - Current orbital assets or existing data can be used to certify site safety

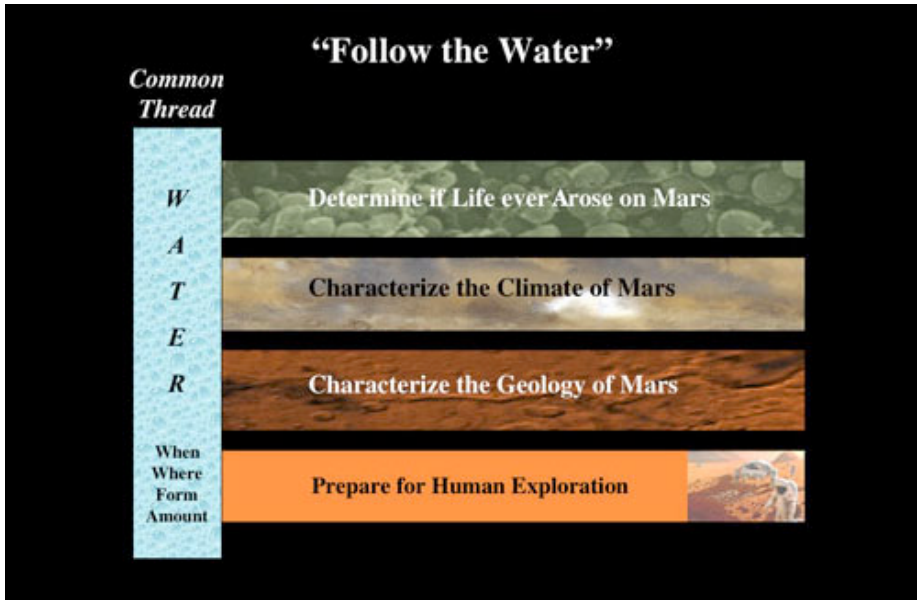
We do not need the "perfect" site. We know enough from the orbital data and from our landed exploration to choose a site whose samples will revolutionize our understanding of Mars through the science return in many disciplines, including both astrobiology and

Do We Need To Explore More Sites Prior To Sample Return?

- *In situ* analyses have been obtained at VL-1, VL-2, MPF, MER *Spirit*, MER *Opportunity*, and PHX sites, with MSL upcoming.
- At least three of the sites have been/will be at level of analysis/exploration necessary to support sample return
  - Detailed *in situ* analysis and geological/geochemical context.
  - Ground truth and determination of relation to orbiter and global measurements.
- Sample return does not need to be done from a site previously visited; caching rover can do the necessary *in situ* analyses and geological context.
- Orbital reconnaissance (MGS, ODY, MEX, MRO) has provided adequate information for assessing scientific potential of hundreds of sites
- Not demonstrated that visiting one or two additional sites would enhance our ability to select a site, as we are using the same orbital data to select the sites. No other data type with sufficient spatial resolution has been suggested.

Success Of The "Follow the Water" Theme By Having A Mars Program

- Water has been recognized for the last two decades as the common thread running through Mars science.
- Frames all of Mars exploration with overarching theme and context
- Missions over that time frame have provided increasingly detailed information on the history of water and its availability through time:
  - Orbiters to map water and identify sites of interest
  - Landers to explore some of these sites in detail



This approach has been tremendously successful scientifically, allowing each mission to build on the others.

The Existence of the Mars Program Has Enabled Both Scientific And Technical Advances

Having a Mars Program has allowed missions over the past 15 years to do double duty of providing compelling science and developing substantial technical capability and infrastructure:

Mission	Science	Technical / Infrastructure
MGS	Geological and geophysical history; mineral detection; history of water; site	Aerobraking; long-lived orbiter; near-real-time; critical events monitoring; relay; site
MPF	Local effects of water; surficial geology	Landing capability; rover operations; *in situ* science analysis
ODY	Distribution of ice; small-scale mineralogy; geochemistry	Long-lived relay; near-real-time monitoring of critical events
MEX	Geological and mineralogical history; loss to space, site characterization (science)	Long-lived relay, coverage of critical events
MRO	High-resolution geology and mineralogy; site characterization (science)	Long-lived relay; site certification (safety); near-real-time monitoring of critical events
MER	Detailed exploration of two sites; history of water	Long-lived rover; field geology; sample characterization
PHX	Exploration of high-latitude ground ice	Landing capability; sample handling
MSL	Explore habitability	Larger-mass landing capability; sample handling; analytical analysis

Impact Of Sample Return On The Rest Of The Mars Program

- The Mars program has shrunk by half in the last few years and is unlikely to recover
  - It will not support the program that was outlined even a year or two ago.
  - That program allowed both sample return and a suite of other missions.
  - The available funding likely can support *either* a Mars sample return or a mix of other missions launched at a rate of perhaps one per opportunity
- The science path that we have been following (i.e., the science questions we are asking) has led us to the point that sample return is required in order to address the key objectives.
- Addressing these science goals requires a decision to emphasize some scientific areas and deemphasize others.
- A decision to not do sample return is equivalent to a decision to not address the highest-priority and most exciting astrobiology science objectives.

Summary

- The overarching scientific theme of the Mars exploration program is to determine whether life is present today or was in the past, and what the interplay has been with the environmental/planetary boundary conditions.
- The most compelling biosignature detection requires the analysis of returned samples, as definitive answers are not likely to be obtained without having the samples in laboratories here on Earth.
- We are ready to implement sample return, in terms of:
  - Scientific context and justification for sample return
  - Technical capability to carry out the missions
  - Ability to select an appropriate site
  - Ability to handle and analyze the samples here on Earth.
- Not doing sample return means that we will not be able to address the highest-priority and most exciting science objectives for Mars.