The National Academies of
SCIENCES • ENGINEERING • MEDICINE

COMMITTEE ON PLANETARY PROTECTION

Evaluation of Bioburden Requirements for Mars Missions

Committee on Planetary Protection
Space Studies Board
in collaboration with
Board on Life Sciences
and
Aeronautics and Space Engineering Board

National Academies of Sciences, Engineering, and Medicine

- The Committee's findings can lead to portions of Mars becoming more accessible to commercial endeavors
  - by relaxing planetary protection requirements
  - while remaining cautious about access to potential habitable zones

Committee Roster

- Joseph K. Alexander, Independent Consultant, Co-Chair
- Amanda R. Hendrix, Planetary Science Institute, Co-Chair
- Angel Abbud-Madrid, Colorado School of Mines
- Anthony Colaprete, NASA Ames Research Center
- Michael J. Daly, Uniformed Services University of the Health Sciences
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- Andrew D. Horchler, Astrobotic Technology, Inc.
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- Daniel Nagasawa, Study Director, SSB
- Andrea Hodgson, Senior Program Officer, BLS
- Nancy Connell, Senior Scientist, BLS
- Megan Chamberlain, Senior Program Assistant, SSB

Statement of Task

- Identify criteria (e.g., temperature, water activity) for determining locations or regions on Mars that are potentially suitable for missions of less restrictive bioburden than the current requirements for Category IV.
- Consider whether mission activities need to be constrained to an area of a specific diameter, including off-nominal operation margins.
- Provide methods (e.g., observational data, models) a mission could use to show it meets the criteria.
- Illustrate the use of those criteria by identifying some potentially acceptable locations that are suitable for reduced bioburden criteria.
- Consider the appropriateness of mission activities that occur beneath the martian surface in these locations and how deep such mission activities should be allowed.
- Comment briefly on whether these locations may be suitable for an eventual human exploration mission.
- Consider the views of the broad community of stakeholders, including Mars and astrobiological scientists, government agencies dealing with spaceflight and exploration, and the aerospace industry, including emerging commercial entities.

Important Considerations in the Committee's Analysis

- **Approaches to planetary protection:**
  - **Current – reduce spacecraft bioburden to below a specified, fixed limit.**
  - **Alternative – tailor mitigation steps in response to assessment of likelihood and consequences of different kinds of risks.**

- **NASA vs. non-NASA missions**

Important Considerations in the Committee's Analysis

- **Factors affecting risk of microbial contamination:**
  - **Delivery**
  - **Survival**
  - **Proliferation**
  - **Transport**

- **Factors affecting microbial survivability and growth**
  - **Temperature**
  - **Water/Desiccation**
  - **Atmosphere**
  - **Sources of nutrients and energy**

Study Outline + Findings

<u>Chapter 1:</u> Introduction & discussion of previous related reports, presentation of charter & Statement of Task

<u>Chapter 2:</u> Astrobiological Possibilities on Mars

How viable is astrobiology on Mars? This question and its investigation forms the foundation of our report.

<u>Finding 1</u>: Discovery of indigenous life on Mars would be a signal event in the development of human knowledge. Preserving unambiguous separation or distinguishability of terrestrial organisms from indigenous martian organisms, by application of planetary protection protocols is essential.

Study Outline + Findings

Chapter 3: Considerations for Reducing Bioburden Requirements

The Committee considered

1. **conditions for survival, proliferation and transport of terrestrial biota**
2. **Special Regions on Mars**
3. **criteria for landing sites (with reduced bioburden requirements), how to validate those criteria, and examples of potentially acceptable landing sites**

Finding 2: The environment on Mars makes the survival, growth, and proliferation of terrestrial organisms on the surface, or suspended in the atmosphere, highly unlikely as a source of harmful contamination. However, transport of a viable terrestrial organism to potentially habitable subsurface environments, such as caves, creates a risk of harmful contamination.

Study Outline + Findings

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Finding 3: Some regions of the martian *subsurface* appear to be the most promising environment for

(1) finding potential extant or extinct indigenous martian organisms; and

(2) providing terrestrial organisms with conditions that might support their survival and proliferation.

However, the martian *subsurface* remains largely unexplored and uncharacterized.

Study Outline + Findings

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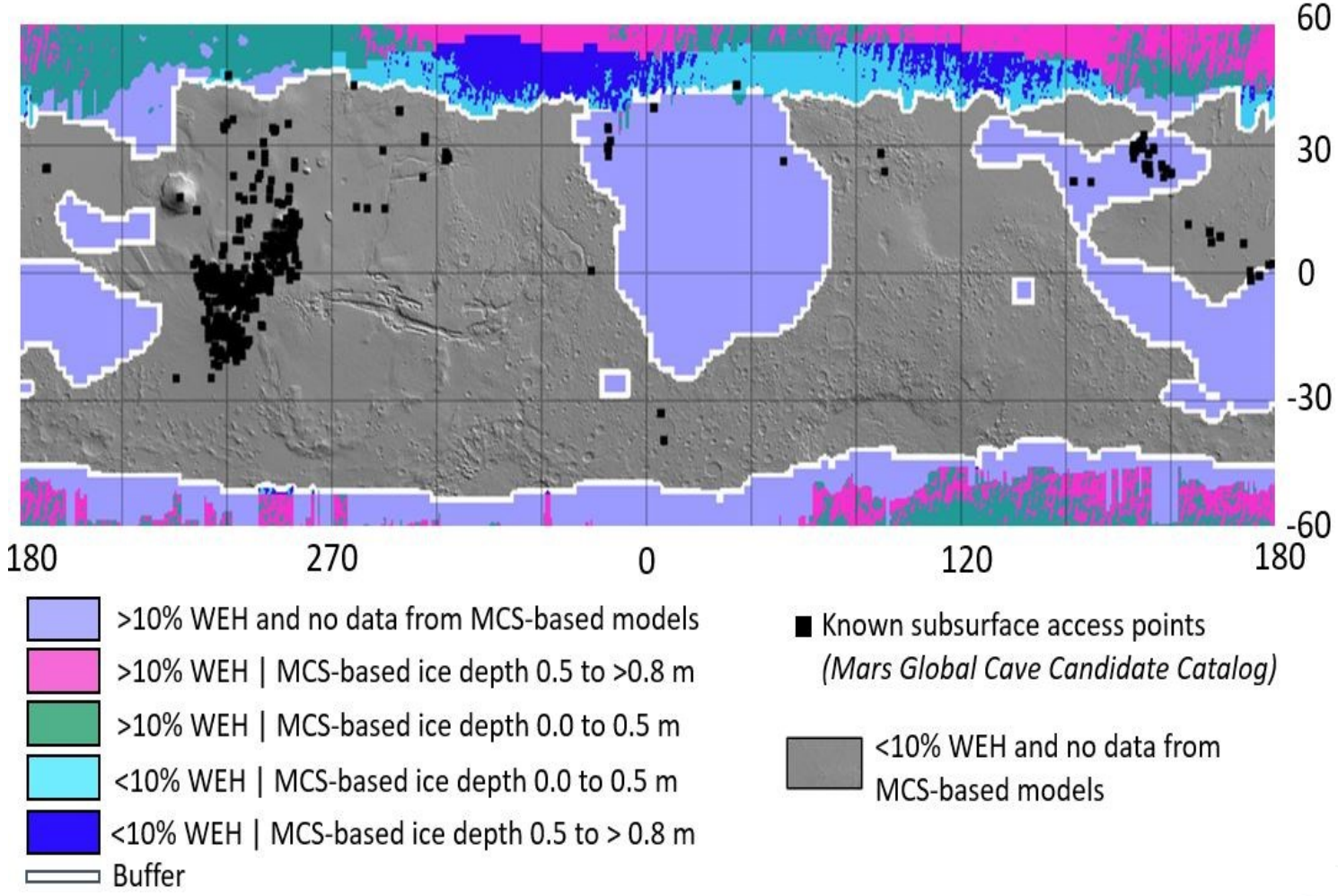
Finding 4: Relaxed bioburden requirements could be appropriate for missions that do not access the subsurface, or for missions that access the subsurface (down to ~one meter) where no evidence of ice exists. Exceptions to this finding include buffer zones around subsurface access points and sites of astrobiological interest.

Finding 5: Estimates of habitat connectivity and of brine transport within subsurface ice are needed to evaluate the risk of harmful contamination via microbial proliferation as a result of subsurface mission activities within permafrost, ice sheets or polar ice.

Finding 6: To avoid contamination of subsurface access points and sites of astrobiological interest, a mission with relaxed bioburden levels would need to land and operate at a conservative buffer distance from such locations.

Locations where Neutron Spectroscopy or Thermal IR Potentially Detect Ice in the Top Meter



Summary Conclusion: Where Robotic Lander Bioburden Requirements Could Be Relaxed

Due to the sterilizing conditions of the Martian surface, the Committee's considerations of bioburden relaxation focused on avoiding potential access to the subsurface by terrestrial microorganisms. Information on subsurface access points is uncertain, and knowledge of conditions in the Martian subsurface is incomplete and mostly model-based. Bioburden requirements could be relaxed if the following criteria are met:

1a) Mission activities do not include subsurface activities, <u>OR</u>

1b) For mission activities as deep as 1 m, the landing site is in a location where no ice is detected in neutron or thermal data;

<u>AND</u>

2) For both cases above, the landing site is a conservative distance from any subsurface access point, to be determined considering wind conditions for the location and season and best estimates of microorganism survival time in the surface UV environment.

Study Findings

<u>Chapter 3:</u> Considerations for Reducing Bioburden Requirements

<u>Finding 7</u>: To minimize the risk of harmful contamination, some pre-launch cleanliness provisions are still needed for missions landing in regions of Mars with lower bioburden requirements than under current Category IV requirements.

Study Findings

Chapter 4: Risk Management and Post-Landing Approaches to Planetary Protection

Finding 8: Planetary protection requirements for Mars missions can be met using a risk management approach as an alternative approach to meeting current NASA planetary protection requirements found in NPR 8020.012D

Finding 9: In-situ bioburden reduction may present a cost-effective alternative or complement to prelaunch bioburden control and recontamination prevention measures.

Summary Conclusion: Risk Management Approach to Comply with Planetary Protection Requirements for Mars Missions

After the planetary protection requirements for a mission to Mars are established, a risk management approach represents a method for the mission to meet those requirements, as an alternative to existing NASA or COSPAR planetary protection policy. This approach would apply a risk management framework that:

Step 1. Identifies how the mission might produce harmful contamination

Step 2. Assesses the likelihood and consequence of those possibilities

Step 3. Ranks those risks by assigning a risk rating to each (from low to high)

Step 4. Identifies validated pre-launch and/or in-situ methods to mitigate each risk rated above a certain threshold (e.g., low-medium risk)

The Committee provides a simplified example of such a risk management approach, which NASA and other stakeholders could develop into a more robust framework for planetary protection purposes for Mars missions and, potentially, for missions to other solar system bodies.

Example Risk Matrix

Likelihood	Consequence: 1 - Harmful contamination of an area of no known interest for prebiotic evolution or the search for evidence of life	2 - Harmful contamination of an area of potential interest for prebiotic evolution or the search for evidence of life	3 - Harmful contamination of an area of known interest for prebiotic evolution or the search for evidence of life	4 - Harmful contamination of a potential special region	5 - Harmful contamination of a special region, or that is global
5 - Frequent	Low Med	Medium	Med Hi	High	High
4 - Occasional	Low	Low Med	Medium	Med Hi	High
3 - Remote	Low	Low Med	Medium	Med Hi	Med Hi
2 - Improbable	Low	Low Med	Low Med	Medium	Med Hi
1 - Extremely Improbable	Low	Low	Low Med	Medium	Medium

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Thank You

Questions?

Please see the SSB website for more information, and downloadable free reports, and other ongoing activities:

https://www.nationalacademies.org/ssb/space-studies-board