NATIONAL ACADEMIES Sciences Engineering Medicine

# A Science Strategy for the Human Exploration of Mars

Lindy Elkins-Tanton, Co-Chair

Dava Newman, Co-Chair

Kelsie Krafton, Co-Director

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www.nas.edu/humans-on-mars

A Science Strategy for the Human Exploration of Mars | National Academies will identify high priority science objectives (in all relevant disciplines) to be addressed by human explorers across multiple science campaigns on the surface of Mars.

# As a NASEM FACA Committee:

- All data collection is done in public
- All deliberative discussions are confidential in perpetuity, including after publication of the report
- Please direct any questions to humansonmars@nas.edu or the NASEM staff

# Co-Chairs

**Dr. Lindy Elkins-Tanton**

Vice president of the Arizona State University Interplanetary Initiative, ASU Regents and Foundation Professor in the School of Earth and Space Exploration, the Principal Investigator of the NASA Psyche mission

**Dr. Dava Newman**

Apollo Program Professor of Astronautics at the Massachusetts Institute of Technology in Aeronautics and Astronautics, director of the MIT Media Lab, and a Harvard–MIT Health, Sciences, and Technology faculty member.

# Co-Directors

**Dr. Abigail (Abby) Sheffer**

Senior Program Officer for the NASEM Space Studies Board, Staff Officer for the Decadal Survey for Solar and Space Physics (Heliophysics), Staff Officer for the Committee on Solar and Space Physics

**Dr. Kelsie Krafton**

Program Officer for the NASEM Space Studies Board, Staff Officer for the Committee on Astronomy and Astrophysics, Staff Officer for the Committee on Planetary Protection

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| Astrobiology | Dr. Kathleen Mandt, GSFC |
| Atmospheric Science and Space Physics | Dr. Leslie Tamppari, JPL |
| Biological and Physical Sciences and Human Factors | Dr. Anna-Lisa Paul, U. Florida<br>Dr. Barrett Caldwell, Purdue |

For full panel membership and details of panel meetings, see the Our Work section on [www.nas.edu/humans-on-mars](www.nas.edu/humans-on-mars)

# Statement of Task

1. Identify the **highest priority science objectives** among all relevant science disciplines to be addressed by humans on the surface of Mars. A separate follow-on study will investigate what science objectives are highest priority for in-space phases of crewed missions to Mars.
2. Identify **types of samples and measurements** needed to address science objectives.
3. Identify and **prioritize several science campaigns** that would achieve a subset of the identified highest priority science objectives, where each campaign encompasses the first three landings of human-scale landers on Mars.
4. For the highest priority science campaigns, identify **preliminary criteria for appropriate landing sites**, based on available data, that will enable science objectives to be met. Examples of criteria that might be considered include: 1) ice within a certain surface depth, 2) salt-bearing materials accessible to crew, or 3) caves with accessible entrance points for human explorers. Discussion of specific landing sites is not requested.
5. Identify any **key equipment** needed for each science campaign to address the identified science objectives.
6. Include a discussion of the **criteria used to assign prioritization for science campaigns**.
7. Describe **commonalities with Moon exploration**. For example, discuss equipment and capabilities for each campaign that could also be developed and used for upcoming human exploration missions to the Moon, Gateway, or the International Space Station (ISS). If relevant and straightforward, note any equipment/capabilities developed for the Moon, Gateway, or ISS is relevant to Mars exploration.
8. Identify **key synergies with exploration goals**. Specifically, discuss how science activities in each campaign synergize with NASA's Moon to Mars Strategy and Objectives Development report.

# SoT: Science Objectives

a) Specify how each identified science objective maps to the respective **decadal report or discipline roadmap** as well as to one or more of the objectives identified in **NASA's *Moon to Mars Objectives***.

b) Identify any **objectives missing in NASA's *Moon to Mars Objectives*** that are relevant to this objectives mapping task.

c) Explain how the objectives change or the priority order is **altered by the number of crew or the duration of the surface mission**. This includes noting if crew size or surface duration are factors for prioritization.

*A separate follow-on study will investigate what science objectives are highest priority for **in-space phases** of crewed missions to Mars.

# SoT: Samples and Measurements

a) Specify key measurements, if any, that need to be made **before human arrival using preplaced assets**, either in orbit or on the surface.

b) Specify key measurements, if any, that must be made **in situ or on the martian surface** before return needed to achieve the identified science objectives. Justify why the measurements need to be made on the martian surface rather than in terrestrial laboratories.

c) Specify key measurements, if any, that must be made **in terrestrial labs on returned samples** to achieve the identified science objectives. Include estimates of mass of returned sample(s) required to make identified measurements, and justify why the measurements need to be made in terrestrial laboratories rather than on the martian surface.

d) Specify whether **analyses of any surface-collected samples** are needed to be **performed during the return trip**, and justify why measurements must be made in transit rather than on the Martian surface or in terrestrial laboratories.

# SoT: Science Campaigns

a) For each science campaign, describe a science "roadmap" that includes the highest **priority science objective**(s) addressed, **secondary science objectives** that are also achievable, **measurements** needed to address the objectives, and **key assets and major equipment** emplaced at each phase of the campaign (before, during, between, or after crew missions).

b) Include a discussion of the **crew's role** in achieving the science objectives.

c) If applicable, specify, and justify any **variations** in the provided guidance for campaigns needed to achieve the highest priority science objectives (for example, more than three missions).

# Special Considerations

- Planetary Protection not explicitly in the SoT, but will be a consideration
- Our remit is to include research both BY and ON humans
  - Humans as biomedical and/or psychological test subjects
  - Study of human impacts on the environment, including microflora

# Upcoming Meeting Dates

Some meetings will have open sessions. See the webpages for details.

- Biological and Physical Sciences and Human Factors Meeting 1, August 6-8
- Astrobiology Meeting 1, August 15-16
- Steering Committee Meeting 2, August 26-28
- Astrobiology Meeting 2, October 2-4
- Steering Committee Meeting 3, October 28-30
- Steering Committee Meeting 4, Dec 17-19
- Steering Committee Meeting 5, Mar 11-13

The steering committee and panels will hold closed teleconference meetings as needed and will post additional meetings on the webpage. All data gathering is done in the public sphere in an open meeting. Open sessions will be taped and put on our website. Committee deliberations are confidential and will be conducted in closed session with only committee members and NASEM staff present. The study will be published in the 2nd ½ of 2025.

# CoPP Report (2021): Evaluation of Bioburden Requirements for Mars Missions

- 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.

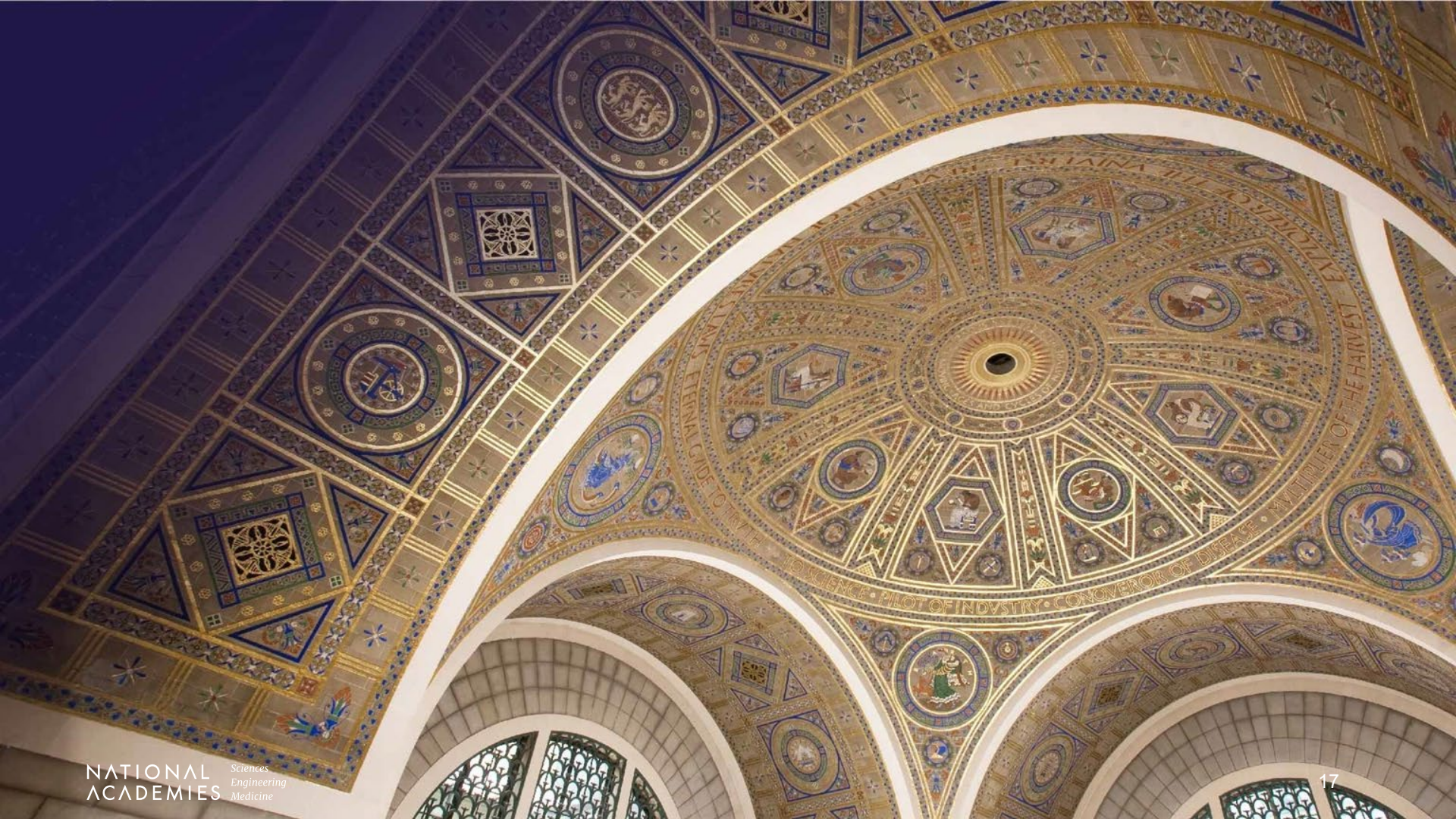
https://nap.nationalacademies.org/26336

# CoPP Report (2021): Chapter 5: Planetary Protection and Human Missions to Mars

- It remains essential that any proposed human landing **site be evaluated and characterized in advance** of human presence through both remote sensing and in situ experiments, to establish the zones of minimal biological risk.
- Given the underdeveloped nature of planetary protection policy for human missions to Mars, **caution** is necessary in addressing, even briefly, the **suitability of applying guidelines for** planetary protection for **robotic** missions to human missions.
- The presence, movement, and activities of humans have the potential to increase biological contamination on and beneath the Martian surface over time.
- **Subsurface** areas are the most interesting locations for scientific exploration of extant or extinct life on Mars and constitute the most important to protect from harmful forward contamination.
- Sustained access to, and in situ use of, subsurface water ice and possibly caves are considered critical for human missions. Meeting this need may expose such resources and areas to sustained contamination from astronauts and bioburdens of robotic, non-scientific activities (e.g., in situ resource utilization) that support human missions.
- Potential approaches to designing a planetary protection strategy for human missions include appropriate **buffer zones** between areas of human activity and locations of astrobiological significance, as well as continued scientific exploration and scientific understanding for life on Mars by humans and robotic technologies. Beyond that, the committee learned in briefings about the potential to use, where appropriate, **in situ techniques** to reduce contamination from activities undertaken by, and needed to sustain, humans.
- The need for developing a strategy for human missions through more scientific study, assessment of scientific evidence, multi-stakeholder participation, and international cooperation and harmonization remains pressing.

# Other NASEM Reports

- Safe on Mars: Precursor Measurements Necessary to Support Human Operations on the Martian Surface | The National Academies Press (2002)
  - The committee recommends that NASA establish **zones of minimal biologic risk** (ZMBRs) with respect to the possible presence of Martian life during human missions to Mars. In order to do so, NASA should conduct a precursor in situ experiment at a location as reasonably close to the human mission landing sites as possible to determine if organic carbon is present. The measurement should be on materials from the surface and down to a depth to which astronauts may be exposed. If no organic carbon is detected at or above the life-detection threshold, the landing site may be considered a ZMBR. If no measurement technique can be used to determine if organic carbon is present above the life-detection threshold, or if organic carbon is detected above that threshold, a contained sample should be returned to Earth for characterization prior to sending humans to Mars.
- Review and Assessment of Planetary Protection Policy Development Processes | The National Academies Press (2018)
  - NASA's process for developing a human Mars exploration policy should include examination of **alternative planetary protection scenarios** and should have access to the necessary research that informs these alternatives. It should also include plans to engage with other nations on the policy and legal implications of missions to Mars.
- Assessment of the Report of NASA's Planetary Protection Independent Review Board | The National Academies Press (2019)
  - NASA should consider establishing (i) **high priority astrobiology zones**, i.e., regions considered to be of high scientific priority for identifying extinct or extant life, and (ii) **human exploration zones**, i.e., regions where the larger amounts of biological contamination inevitably associated with human exploration missions, as compared to robotic scientific missions, will be acceptable.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