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

Abigail Sheffer, Co-Director

www.nas.edu/humans-on-mars

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Disruptions of this meeting will result in removal of speaking privileges.

The Steering Committee and Panel members are here and taking notes. This meeting is being recorded and the slido materials will be included in the study's Public Access File. Files sent to the study will be added to our Public Access File.

As a NASEM FACA Committee:

- FACA is the Federal Advisory Committee Act
- 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

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.

Co-Chairs

Dr. Lindy Elkins-Tanton (NAS)

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

Steering Committee Members

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Antonelli Consulting Company, LLC

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Jet Propulsion Laboratory, California Institute of Technology

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Pennsylvania State University

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Johns Hopkins Applied Physics Laboratory

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Space Exploration Technologies

MS. WANDA A. SIGUR (NAE)

Lambent Engineering

DR. ERIKA B. WAGNER

Blue Origin

Panel Chairs

Panel	Chair
Geosciences	Dr. Jennifer Heldmann, Ames
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 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

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).

Information Gathering

- Over 50 members
- Decadal Surveys, NASA Moon to Mars documents
- All existing publications and presentations
- Invited Speakers
- Parallel Activities
- Townhall Webinars

Information Gathering: Full Membership of SC and Panels

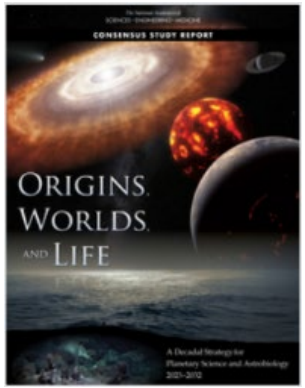
Dr. Lindy Elkins-Tanton (NAS)
Dr. Dava Newman
Mr. Dominic (Tony) Antonelli
Dr. Penelope J. Boston
Dr. Christopher E. Carr
Dr. Barbara A. Cohen
Dr. Jonathan H. Jiang
Dr. James F. Kasting (NAS)
Dr. Pascal Lee
Dr. James A. Pawelczyk
Dr. Nilton O. Renno
Dr. Michael G. Ryschewitsch
Ms. Julianna M. Scheiman
Ms. Wanda A. Sigur (NAE)
Dr. Erika B. Wagner

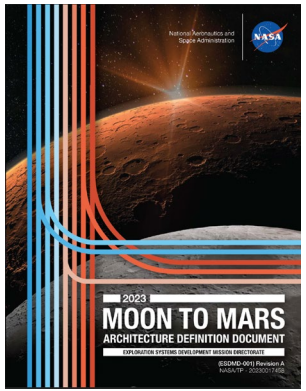
Dr. Laurie Barge
Dr. Hugo Castillo
Dr. John M Eiler (NAS)
Dr. Drew Gorman-Lewis
Dr. Betul Kacar
Dr. Kathleen Mandt
Dr. Michael A Meyer
Dr. Jorge I Núñez
Dr. Laura E Rodriguez
Ms. Nicole Schmitz
Dr. Amy J Williams
Dr. Yaireska M Collado-Vega
Dr. Jasper S Halekas
Dr. Alain S.J. Khayat
Dr. Ralph D Lorenz

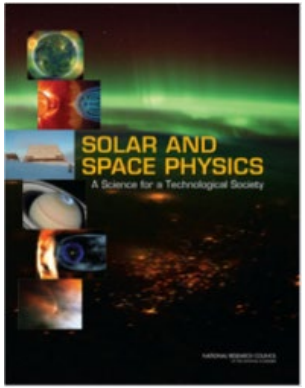
Ms. Sara Navarro López
Dr. Claire E Newman
Dr. Susanne P Schwenzer
Dr. Alejandro Soto
Dr. Leslie K Tamppari
Dr. Mark H Thiemens (NAS)
Dr. Christopher Boxe
Dr. Daniel M Ammon (NAE)
Dr. Serena Maria Auñón-Chancellor
Dr. Jay C Buckey, Jr.
Dr. Barrett S Caldwell
Dr. Ana Diaz Artiles
Dr. Nick Kanas
Dr. Craig E Kundrot

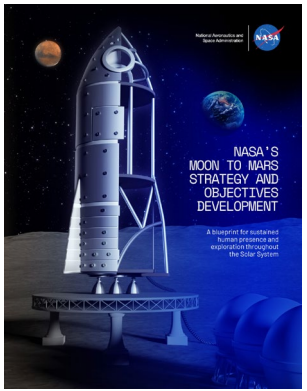
Dr. Bruce M Link
Dr. Anna-Lisa Paul
Dr. Donna Roberts
Dr. Luis Zea
Dr. William B Banerdt
Dr. Ali M Bramson
Dr. Veronica Bray-Durfey
Dr. Alexander N Halliday (NAS)
Dr. Jennifer L Heldmann
Dr. Jeffrey R Johnson
Dr. John F Mustard
Dr. Chiang Shih
Dr. Kirsten Siebach
Dr. Marcella A Yant

Information Gathering: Decadal Surveys and NASA Moon to Mars Documents









Information Gathering: Publications and Presentations

- Official NASA Documents and Presentations
- NASEM Reports
- NASA Advisory Group and Working Group Presentations and Reports
- Conference Papers and Proceedings
- Workshop Reports
- Peer Reviewed Academic Publications

Over 180 documents and counting…

Information Gathering: Invited Speakers

A Science Strategy for the Human Exploration of Mars (Open Meeting April 25-26)

- Debra Needham, Exploration Science Strategy and Integration Office, NASA
- Michelle Rucker, Exploration Systems Development Mission Directorate, NASA
- Becky McCauley-Rench, Planetary Science Division, NASA
- David Baumann, Space Operations Mission Directorate, NASA
- Nujoud Merancy, Exploration Systems Development Mission Directorate, NASA
- Robert Ferl, University of Florida
- Krystyn Van Vliet, Massachusetts Institute of Technology
- Philip Christensen, Arizona State University
- Daniel Baker, Director of LASP, University of Colorado Boulder
- Don Hassler, Southwest Research Institute
- Bruce Jakosky, University of Colorado Boulder

Panel on Biological and Physical Sciences and Human Factors Open Meeting #1

- Grace Douglas, NASA Johnson Space Center
- Darlene Lim, NASA Ames Research Center
- Dale Andersen, SETI Institute
- Chris McKay, NASA Ames Research Center
- Mica Endsley, SA Technologies
- Valerie Gawron, MITRE
- Mathias Basner, University of Pennsylvania

Panel on Atmospheric Science and Space Physics (Telecon #3)

- Tim Swindle, Ariz. State Univ.

Panel on Atmospheric Science and Space Physics (Telecon #5)

- Frances Butcher, Univ. of Sheffield, UK

A Science Strategy for the Human Exploration of Mars (Meeting August 26-28)

- Jack Stuster, Anacapa Sciences, Inc. (retired)
- Erik Conway, JPL Historian

Panel on Atmospheric Science and Space Physics (Meeting #2)

- Christina Lee, UC Berkeley

Panel on Geosciences, Meeting #11

- Vicky Hamilton, SouthWest Research Institute
- Bethany Ehlmann, Caltech

Panel on Atmospheric Science and Space Physics-Telecon 8

- Robin Wordsworth, Harvard University

Panel on Atmospheric Science and Space Physics (Telecon #8)

- Jamie Favors, NASA HQ
- Sabrina Savage, NASA HQ

Panel on Astrobiology - Meeting #22

- Katherine French, USGS

Panel on Astrobiology - Meeting #23

- Kris Zacny, Honeybee Robotics
- John Priscu, Montana State University

Panel on Geosciences, Meeting #17

- Ashwin Vasavada, JPL
- Abigail Fraeman, JPL
- Larry Crumpler, New Mexico Museum of Natural History and Science
- Ken Farley, Caltech

And more meetings to come…

Information Gathering: Parallel Activities Past and Future

- Moon to Mars Architecture Workshops, Feb 2024
- NASA Human Research Program Investigators' Workshop, Feb 13-16, 2024
- American Academy of Orthopaedic Surgeons Annual Meeting, Feb 13-17, 2024
- American Group Psychotherapy Association Annual Meeting, Feb 26 – Mar 2, 2024
- Lunar Surface Science Workshop, April 3, 2024
- Space Symposium, Apr 8-11, 2024
- Mars Sample Return Workshop, Apr 22-23, 2024
- Mars Exploration Program Analysis Group (MEPAG), Apr 24-26, 2024
- Aerospace Medical Association Meeting, May 5-9, 2024
- American Society of Neuroradiology Meeting, May 18-22, 2024
- Conference on the Inspiration of Astronomical Phenomena, May 20-24, 2024
- NASA/USGS Workshop on Planetary Subsurface Exploration for Science and Resources, May 21-22, 2024
- Lunar Surface Science Workshop, May 23, 2024
- International Society of Gravitational Physiology, May 26-31, 2024
- Plant Molecular and Cellular Biology Retreat, May 30, 2024
- OPAG, Jun 12-13, 2024
- ISS Research and Development Conference, Jun 29, 2024
- 8th international conference on mars polar science and exploration, Jul 8-12, 2024
- Mars Interior After InSight meeting, July 16-18, 2024
- International conference of Environmental Systems, Jul 21-25, 2024
- **Tenth International Conference on Mars, Jul 22–26 (presentation)**
- ISS Research and Development Conference, Jul 30 – Aug 1, 2024
- **Science and Planetary Protection in Advance of Human Missions Seminar, Jul 31 to Aug 1 (presentation)**
- Deep Space Food Symposium, Aug 15-16, 2024
- Lunar Surface Science Workshop, Aug 20, 2024
- El Gran Encuentro con El Desierto, Aug 22, 2024
- International Ergonomics Association, Aug 25-29, 2024
- ELGRA – European Low Gravity Research Association, Sep 3-6, 2024
- **International Mars Exploration Working Group (IMEWG), Sep 4 (presentation)**
- Europlanet Science Congress (EPSC) 2024, Sep 8-13, 2024
- Human Factors and Ergonomics Society, Sep 9-13, 2024
- Central American Space Congress, Sep 10-12, 2024
- The Orthopaedic Summit, Sep 13-18, 2024
- Undersea and Hyperbaric Medical Society Meeting, Sep 16-20, 2024
- Foresight Space Futures & Governance, Sep 20-21, 2024
- ASE Congress (Association of Space Explorers), Sep 29 to Oct 5, 2024
- BioInterface Workshop & Symposium, Oct 2-4, 2024
- DPS, Oct 6-10, 2024
- IAC (International Astronautical Congress), Oct 14-18, 2024
- Annual Meeting of the Lunar Exploration Analysis Group Meeting, Oct 28-30, 2024
- Science and Planetary Protection in Advance of Human Missions Workshop, Oct 30 - Nov 1, 2024
- **Mars Exploration Program Analysis Group (MEPAG), Nov 6-7 (presentation)**
- Plant Molecular and Cellular Biology Retreat, Nov 6-8, 2024
- 'Chance and purpose in the evolution of biospheres', Nov 11-12, 2024
- Beyond Earth Symposium, Nov 12-13, 2024
- 22nd Meeting of the Venus Exploration Group (VEXAG), Nov 17-19, 2024
- OPAG, Nov 20-22, 2024
- ASGSR – American Society for Gravitational and Space Research, Dec 3-7, 2024
- **American Geophysical Union (AGU) Fall Meeting, Dec 9-13, 2024 (presentation)**
- NASA Human Research Program Investigators' Workshop, Jan 28-31, 2025
- American Academy of Orthopaedic Surgeons Annual Meeting, Feb 10-14, 2025
- IEEE Aerospace Conference, Mar 1-8, 2025
- Lunar and Planetary Science Conference (LPSC), Mar 17-21, 2025
- European Geosciences Union (EGU) General Assembly, Apr 7-12, 2025
- Society For Biomaterials Annual Meeting, Apr 9-12, 2025
- Beyond The Cradle, MIT, Spring, 2025
- NSRC – Next-Generation Suborbital Researchers Conference, Spring, 2025
- Humans to Mars Summit (H2M), May 13-15, 2025
- American Society of Neuroradiology Meeting, May 17-21, 2025
- International Society of Gravitational Physiology, May 18-23, 2025
- Aerospace Medical Association Meeting, Jun 1-6, 2025
- Conference on the Inspiration of Astronomical Phenomena, Jun 9-13, 2025
- Goldschmidt Conference, Prague, Czech Republic, Jul 6-11, 2025
- Annual Meetings of the Meteoritical Society, Jul 14-18, 2025
- ISS R&D, Jul 28-31, 2025
- International Mars Society Convention, Oct 2025
- ASGSR – American Society for Gravitational and Space Research, Fall, 2025
- Brazilian Symposium on Space Farming (ISIBAE), Fall, 2025

Upcoming Meeting Dates with Potential Open Sessions

Some meetings will have open sessions. See the webpages for details: www.nas.edu/humans-on-mars

- Panel on Geosciences (Oct 30, Nov 4)
- Panel on Atmospheric Science and Space Physics (TBD)
- Panel on Astrobiology (TBD)
- Panel on Biological and Physical Sciences and Human Factors (TBD)
- Steering Committee (Dec 17-19, 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 late 2025.

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