

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](http://www.nas.edu/humans-on-mars)



## After this presentation:



To post your comments in slido using QR code or link:

You can also vote on comments that have been posted. If you would like to say your comments, raise your hand to get in the queue.

We will call on folks in order. You have up to 3 minutes to speak.

Files sent to the study will be added to our Public Access File. 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.



## 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](mailto: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**

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

**MR. DOMINIC (TONY) ANTONELLI**

Antonelli Consulting Company, LLC

**DR. PENELOPE J. BOSTON**

NASA Ames Research Center

**DR. CHRISTOPHER E. CARR**

Georgia Institute of Technology

**DR. BARBARA A. COHEN**

NASA Goddard Space Flight Center

**DR. JONATHAN H. JIANG**

Jet Propulsion Laboratory, California Institute of Technology

**DR. JAMES F. KASTING (NAS)**

Pennsylvania State University

**DR. PASCAL LEE**

SETI Institute, Mars Institute, Kepler Space University, NASA Ames Research Center, Ceres Robotics

**DR. JAMES A. PAWELCZYK**

Pennsylvania State University

**DR. NILTON O. RENNO**

University of Michigan

**DR. MICHAEL G. RYSCHKEWITSCH**

Johns Hopkins Applied Physics Laboratory

**MS. JULIANNA M. SCHEIMAN**

Space Exploration Technologies

**MS. WANDA A. SIGUR (NAE)**

Lambent Engineering

**DR. ERIKA B. WAGNER**

Blue Origin

# Panel Chairs

<b>Panel</b>	<b>Chair</b>
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](http://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**

**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 Buckley, Jr.

**Dr. Barrett S Caldwell**

Dr. Ana Diaz Artilles

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

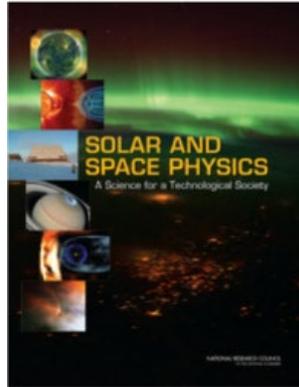
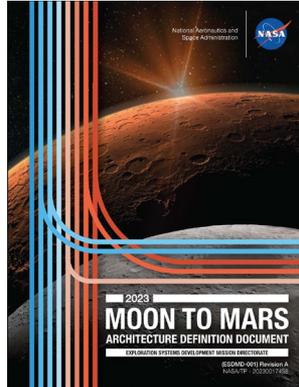
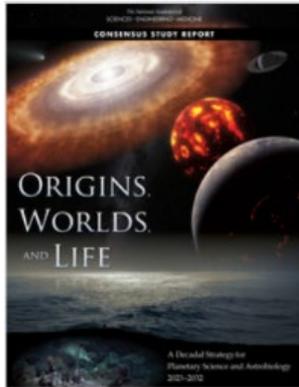
Dr. John F Mustard

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 150 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

**And many 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
- 8<sup>th</sup> 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](http://www.nas.edu/humans-on-mars)

- Panel on Atmospheric Science and Space Physics (Sep 23)
- Panel on Geosciences (Sep 25, Oct 2, Oct 9)
- Panel on Astrobiology (Sep 27)
- Panel on Biological and Physical Sciences and Human Factors (TBD)
- Steering Committee (Oct 28-30)
  - Second townhall webinar on Oct 28
- 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.

## Now it's your turn:

To post your comments in slido using QR code or link:



You can also vote on comments that have been posted. If you would like to say your comments, raise your hand to get in the queue.

We will call on folks in order. You have up to 3 minutes to speak.

Files sent to the study will be added to our Public Access File. 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.



# Thank you!

Second townhall webinar on Oct 28

See the webpages for more information:

[www.nas.edu/humans-on-mars](http://www.nas.edu/humans-on-mars)

Please direct any questions to

[humansonmars@nas.edu](mailto:humansonmars@nas.edu)

or the NASEM staff

