

# **A Science Strategy for the Human Exploration of Mars**

## **Committee**

### **Linda T. Elkins-Tanton**

#### **Co-Chair**

LINDA T. ELKINS-TANTON (NAS) is the director of the University of California, Berkeley, Space Sciences Laboratory; the co-founder of Beagle Learning, Inc.; and the principal investigator of the NASA Psyche mission. Elkins-Tanton formerly was the vice president of the Arizona State University (ASU) Interplanetary Initiative and the ASU Regents and Foundation Professor in the School of Earth and Space Exploration. Elkins-Tanton was Director of the Department of Terrestrial Magnetism at the Carnegie Institution for Science, and previously faculty at the Massachusetts Institute of Technology (MIT). Elkins-Tanton's research is on the physical and chemical growth and evolution of rocky planets and on volcanic activity and extinctions on Earth, as well as on effective teams and future-facing educational practices. Elkins-Tanton has led four field seasons in central Siberia. Elkins-Tanton is a member of the National Academy of Sciences and the American Academy of Arts & Sciences, and is a fellow of the American Geophysical Union, the Meteoritical Society, and the American Mineralogical Society. Elkins-Tanton received the 2020 Arthur L. Day Prize and Lectureship from the National Academy of Sciences, and the 2010 Lowell Thomas award from the Explorers Club. Elkins-Tanton received a Ph.D. in geology and geophysics from MIT. Elkins-Tanton is a member of the Aerospace Center for Space Policy and Strategy Senior Advisory Council.

## **Dava J. Newman**

### **Co-Chair**

DAVA J. NEWMAN is the Apollo Program Professor of Astronautics at the Massachusetts Institute of Technology (MIT) in Aeronautics and Astronautics, a Harvard-MIT Health, Sciences, and Technology faculty member, and former director of the MIT Media Lab. Newman previously served as NASA Deputy Administrator and was the first female engineer and scientist to serve in this role. Newman's research expertise is in multidisciplinary aerospace biomedical engineering investigating human performance across the spectrum of gravity. Newman is a leader in advanced space suit design, dynamics and control of astronaut motion, leadership development, innovation and space policy. Newman was the principal investigator on 5 experiments that flew on spaceflight missions and was a co-investigator on the Mental Workload and Performance Experiment (MWPE) that flew to space on STS-42 to measure astronaut mental workload and fine motor control in microgravity. Newman also developed the MICRO-G space flight experiment to provide a novel smart sensor suite and study human adaptation in extreme environments. Best known for the second skin BioSuit™ planetary EVA system, Newman's advanced spacesuits inventions are now being applied to "soft suits/exoskeletons" to study and enhance locomotion on Earth. She flew her Gravity Loading Countermeasure Suit for astronaut exercise as a technology demonstrator on the Axiom's AX-2 Mission. Recent research focuses on Earth systems through earth observation satellite data to accelerate solutions for the dual challenge of energy and climate using machine learning with physics informed neural networks, immersive visualizations, and story-telling with a goal to make the world work for 100% of humanity. Newman is the author of Interactive Aerospace Engineering and Design, has published more than 300 papers in journals and refereed conferences, and holds numerous compression technology patents. Newman was awarded the NASA Distinguished Service Medal. Select honors include: Hon. Doctorates from Dartmouth, the Royal College of Art, and University of Minho, Seneca's 100 Women, Society of Women's 35 World's Most Influential Women Engineers, Robert Fletcher Award, Lowell Thomas Award, Phi Beta Kappa Visiting Scholar, AIAA Fellow, AIAA Jeffries Aerospace Medicine and Life Sciences Research Award, and Women in Aerospace Leadership Award. Newman received a Ph.D. in aerospace biomedical engineering, Masters in Aerospace and Astronautics and Technology and Policy from MIT and a BS in aerospace engineering from the University of Notre Dame. Newman is a member of the Aerospace Corporation Board of Trustees and the SETI Institute Board of Directors.

## **Dominic Antonelli**

### **Member**

DOMINIC (TONY) ANTONELLI is an independent aerospace leadership and management consultant at Antonelli Consulting Company, LLC and serves on the advisory board of Karman Space and Defense. Antonelli was previously with Lockheed Martin Space, Commercial and Civil Space, as the Orion Artemis II mission director, the Advanced Programs director, and the chief technologist. Antonelli is a former NASA astronaut and pilot of two space shuttle missions to the International Space Station. Antonelli is a retired Navy Captain, naval aviator and test pilot. Antonelli has been awarded the Department of Defense's Superior Service Medal and NASA's Return to Flight Award and Spaceflight Medals. Antonelli received a master's degree in aeronautical and astronautical engineering from the University of Washington.

## **Penelope J. Boston**

### **Member**

PENELOPE J. BOSTON is portfolio scientist for New Business and Employee Development (Code S, Science) at NASA Ames Research Center. Formerly, Boston served as director of the NASA Astrobiology Institute, and prior to that, Boston was professor and department chair of the Earth and Environmental Sciences Department at the New Mexico Institute of Mining and Technology and concurrently associate director of the National Cave and Karst Research Institute. Personal research areas include geomicrobiology and astrobiology in extreme environments (caves and mines, hot and cold deserts, high latitudes and altitudes); geological processes creating caves on other planets; human life support issues in space/planetary environments especially microbiomes; and use of robotics and other technologies to assist exploration and science in extreme Earth and extraterrestrial environments. Boston holds the Lifetime Science Achievement Award from the National Speleological Society, the Caving Legend award from the Bureau of Land Management/Ft. Stanton Cave Project, and is a fellow of the NASA Institute for Advanced Concepts. Boston received a Ph.D. in microbiology and atmospheric chemistry from the University of Colorado, Boulder.

## **Christopher E. Carr**

### **Member**

CHRISTOPHER E. CARR is an assistant professor at Georgia Institute of Technology in the Daniel Guggenheim School of Aerospace Engineering with a secondary appointment in the School of Earth and Atmospheric Sciences. At Georgia Tech, Carr runs the Planetary eXploration Lab (PXL), is part of the Space Systems Design Lab (SSDL) and serves as co-director of the Astrobiology Program; Carr also serves as a Scott M. Johnson Fellow in the U.S. Japan Leadership Program. Research areas broadly include seeking and supporting life beyond Earth while enabling a sustainable human future; specific areas include space instrumentation, astrobiology, origin of life, microbial adaptation and evolution, space biology, single molecule detection, machine learning, human performance in extreme environments; bioastronautics, and extravehicular activity. Carr is an engineer and scientist with prior training in aeronautics and astronautics, electrical engineering, medical physics, and molecular biology, including 15 years on the research staff at Massachusetts Institute of Technology and the Massachusetts General Hospital. Carr received a Ph.D. in medical engineering and medical physics from the Massachusetts Institute of Technology.

## **Barbara A. Cohen**

### **Member**

BARBARA A. COHEN is a planetary scientist at NASA Goddard Space Flight Center. Cohen's main scientific interests are in geochronology and geochemistry of planetary samples from the Moon, Mars and asteroids. Cohen has been a principal or co-investigator on multiple NASA research and space flight projects, including the Lunar Flashlight CubeSat, the VIPER rover mission, and multiple instruments manifested on upcoming lunar landers. Cohen has been a member of the science teams operating the Mars rovers Spirit, Opportunity, and Curiosity, and Perseverance. Cohen serves as a subject-matter expert to human exploration missions, including serving as the Artemis IV Project Scientist. Cohen participated in the Antarctic Search for Meteorites (ANSMET) in four seasons, helping to recover more than a thousand pristine samples for the U.S. collection. Asteroid 6816 Barbcohen is named in Cohen's honor. Cohen was a member of the National Academies midterm assessment of the 2010 Planetary Science Decadal Survey and of the 2010 Planetary Science Decadal Survey's Inner Planets Panel. Cohen received a Ph.D. in planetary science from the University of Arizona.

## **Jonathan H. Jiang**

### **Member**

JONATHAN H. JIANG is a former senior research scientist at NASA's Jet Propulsion Laboratory, California Institute of Technology. His research spans astrophysics, atmospheric dynamics, climate processes, planetary habitability, and humanity's long-term future in the cosmos. He currently serves as president of the American Geophysical Union (AGU) Global Environmental Change section and previously served as editor of Earth and Space Science and editor-in-chief of the Earth and Space Science Open Archive. Dr. Jiang has received the NASA Exceptional Scientific Achievement Medal, two NASA Exceptional Achievement Medals, and is an elected Fellow of the American Meteorological Society. He is also the founder and CEO of Beacon in the Cosmos LLC, an initiative dedicated to inspiring the next generation of explorers and advancing global science education. He earned his Ph.D. in atmospheric science from York University in Toronto, Canada, and is the author of *Avoiding the Great Filter: Illuminating Pathways to Humanity's Future in the Cosmos*, which explores the scientific, societal, and philosophical challenges and opportunities for humanity's survival and progress in the universe.

## **James F. Kasting**

### **Member**

JAMES F. KASTING (NAS) is a retired Evan Pugh Professor at Pennsylvania State University (PSU). Kasting's research interests include atmospheric evolution, planetary atmospheres and paleoclimates. Before joining PSU, Kasting spent two years at the National Center for Atmospheric Research in Boulder, Colorado, and seven years in the Space Science Division at NASA's Ames Research Center. Kasting is a fellow of the American Association for the Advancement of Science, the International Society for the Study of the Origin of Life, and the American Geophysical Union. Kasting is the recipient of the Stanley Miller Medal, also known as the NAS Award in Early Earth and Life Sciences. Kasting served on the Committee on Astrobiology and Planetary Sciences, the Committee on Astrobiology Science Strategy for the Search for Life in the Universe, and chaired the Searching for Life Across Space and Time: A Workshop. Kasting received a Ph.D. in atmospheric science from the University of Michigan .

## **Pascal Lee**

### **Member**

PASCAL LEE is a planetary scientist at the SETI Institute, director of the Mars Institute, professor of planetary sciences at Kepler Space University, director of the NASA Haughton-Mars Project (HMP) at NASA Ames Research Center, and Chief Scientist for Ceres Robotics. Lee's research focuses on the Moon and Mars, in particular the history of their water and ice, on Mars' moons, Phobos and Deimos, and on the human exploration of the Moon and Mars. Lee has led over 30 expeditions in the Arctic where he established the HMP Research Base, the world's largest privately operated polar and planetary analog field research station. He also led the Northwest Passage Drive Expedition, a record-setting long-range vehicular traverse on sea-ice along the fabled Northwest Passage. Lee also spent 5 summers and a winter-over in Antarctica leading field geology research, geophysics, and searching for meteorites. Lee is a recipient of the United States Antarctica Service Medal, the National Space Society's Space Pioneer Award for Mars science and engineering, the Space Frontier Foundation's Vision to Reality Award, several NASA Group Achievement Awards, and the Sagan Prize for the popularization of science. Lee is also an FAA-certified helicopter pilot and flight instructor, and co-authored early NASA papers on robotic and human rotorcraft for Mars. Lee received an ME in geology and geophysics from the University of Paris-Sorbonne, and a Ph.D. in astronomy and space sciences from Cornell University.

## **James A. Pawelczyk**

### **Member**

JAMES A. PAWELCZYK is an associate professor of physiology and kinesiology at The Pennsylvania State University. Pawelczyk served as a payload specialist astronaut on STS-90 Neurolab. During the 16-day Spacelab flight, the seven-person crew served as both experiment subjects and operators for 26 individual life sciences experiments focusing on the effects of microgravity on the brain and nervous system. Pawelczyk's primary research interests include the neural control of circulation, particularly skeletal muscle blood flow, as it is affected by exercise or spaceflight. Pawelczyk founded and directs Penn State's unique dual-title Ph.D. program in clinical and translational sciences and serves as a co-director of translational workforce development. Pawelczyk has won numerous awards, including the Young Investigator Award from the Life Sciences Project Division of the NASA Office of Life and Microgravity Science Applications; the NASA Space Flight Medal; and the Sherrington Prize Lectureship at Oxford University. Pawelczyk has served on NASA's Human Exploration Operations Research Subcommittee and Biological and Physical Sciences Advisory Committee. Pawelczyk received a Ph. D. in biology (physiology) from the University of North Texas. Pawelczyk is a former member of the National Academies Committee on Biological and Physical Sciences in Space and the Committee on A Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research at NASA.

## **Nilton O. Renno**

### **Member**

NILTON O. RENNO is a professor at the University of Michigan, a member of the College of Engineering Executive Committee and director of the Master of Engineering program in Space Engineering. Renno's research interests include astrobiology, aerosols, instrument development, planetary science, thermodynamics, and systems engineering. Renno studies the physical processes that control the habitability of the Earth and other planets, aerosols transport, and designs and fabricates instruments for these purposes. Renno has received numerous awards including the Space Foundation John L. "Jack" Swigert Jr. Award for Space Exploration as member of NASA's Mars Science Laboratory Mission and the National Aeronautic Association Robert J. Collier Trophy as member of NASA's Phoenix Mars Mission and as member of NASA's Mars Science Laboratory Mission. Renno served on the National Research Council (NRC) Committee on Astrobiology and Planetary Sciences, the Committee on Astrobiology Science Strategy for the Search for Life in the Universe and member of the organizing committee on Searching for Life Across Space and Time. Renno received a Ph.D. in atmospheric science from the Massachusetts Institute of Technology.

## **Michael G. Ryschkewitsch**

### **Member**

MICHAEL G. RYSCHKEWITSCH is a principal professional staff engineer in the Space Exploration Sector at the Johns Hopkins Applied Physics Laboratory (APL). Formerly, Ryschkewitsch served as sector head for the exploration sector at APL, responsible for APL's portfolio of space programs for NASA and for national security sponsors. Before joining APL, Ryschkewitsch served for over 30 years at NASA including as NASA chief engineer. Ryschkewitsch received a Ph.D. in physics from Duke University. Ryschkewitsch served as chair of the National Academies Decadal Survey on Biological and Physical Sciences Research in Space 2023-2032: Engineering and Science Interface Panel.

## **Julianna M. Scheiman**

### **Member**

JULIANNA M. SCHEIMAN is the director of NASA Science Missions at Space Exploration Technologies (SpaceX). In this role, Scheiman is responsible for the mission development, contract award, and successful execution of NASA's satellite launches, including NASA's Jason-3, Transiting Exoplanet Survey Satellite (TESS), Sentinel-6, Double Asteroid Redirection Test (DART), Imaging X-ray Polarimetry Explorer (IXPE), Psyche, Plankton, Aerosol, Cloud, ocean Ecosystem (PACE), Surface Water and Ocean Topography (SWOT), Interstellar Mapping and Acceleration Probe (IMAP), Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer (SPHEREx), Habitation and Logistics Outpost (HALO) Power and Propulsion Element (PPE), Roman Space Telescope, and Europa Clipper missions. Scheiman is also a key team member on the Civil Space Advanced Development team, partnering with NASA on future mission capabilities and concepts. Prior to SpaceX, Scheiman was a management associate at Bridgewater Associates, the world's largest hedge fund, managing long-term research projects and key investment teams. Scheiman received a BA/BE in physics and mechanical engineering from Dartmouth College.

## **Wanda A. Sigur**

### **Member**

Wanda A. Sigur (NAE) is an independent consultant. She is retired from the position of vice president/general manager of civil space, space systems for Lockheed Martin Corporation. In this capacity, she had executive responsibility for national space programs relating to human space flight and space science missions; including planetary, solar, astrophysical, and Earth remote sensing for civil government agencies. These major programs included the Orion Multi- purpose Crew Vehicle, Hubble and Spitzer space telescopes, GOES-R weather satellites; the Juno, Gravity Recovery and Interior Laboratory (GRAIL), Mars Atmosphere and Volatile Evolution (MAVEN), Mars Reconnaissance Orbiter, Mars Odyssey, and Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) planetary missions, and the company's nuclear space power programs. Her responsibilities included research and science objectives and early development investments for the wide range of leap- frog technologies necessary to support anticipated space forward steps. Previously, Sigur was vice president of engineering for space systems for Lockheed Martin Corporation. In this capacity, she was responsible for leading the corporation's space systems engineering product technical validation for military space, strategic and defense missiles, commercial satellites and civil space, including personnel development, engineering process development and deployment, engineering tools and training, with emphasis on ensuring operational excellence and first-time-right engineering. She has been an active participant in many Academies' studies associated with future space technologies, particularly materials technologies, thermal protection systems, on-orbit materials processing, spacecraft design, on-orbit satellite servicing, energy systems, and human space exploration. Sigur received a B.S. for mechanical and materials science from Rice University and a M.B.A. from Tulane University.

## **Erika B. Wagner**

### **Member**

ERIKA B. WAGNER serves as the Lead for US Business Development at The Exploration Company, working to improve global access to space for science, technology, arts, education, and entrepreneurship. Wagner's interdisciplinary background includes biomedical and aerospace engineering, with research spanning both human and mammalian adaptation to microgravity, partial gravity, and centrifugation. Wagner received a Ph.D. in bioastronautics from the Harvard-MIT Division of Health Sciences and Technology. Wagner is an ASGSR Fellow and a former member of the Space Studies Board, Committee on Biological and Physical Sciences in Space, and Science Opportunities Enabled by Gateway: A Workshop.