SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

A Review of the Decadal Strategy for Planetary Science and Astrobiology 2023-2032

May 26, 2022
10:00 a.m. Eastern Daylight Time
Online via Zoom

PURPOSE

The purpose of the hearing is to review the science priorities and recommendations from the decadal survey on planetary science and astrobiology, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032,* recently released by the National Academies of Sciences, Engineering, and Medicine.

WITNESSES

- **Dr. Robin M. Canup,** Co-Chair, Steering Group, Committee on the Planetary Science and Astrobiology Decadal Survey, National Academies of Sciences, Engineering, and Medicine; Assistant Vice President, Planetary Science Directorate, Southwest Research Institute
- **Dr. Philip R. Christensen,** Co-Chair, Steering Group, Committee on the Planetary Science and Astrobiology Decadal Survey, National Academies of Sciences, Engineering, and Medicine; Arizona State University

OVERARCHING QUESTIONS

- *What are the science priorities recommended by the decadal survey for the next ten years of planetary science and astrobiology?*
- *What are the decadal survey's recommendations for Federal investments to pursue those priorities, including for spacecraft missions, research activities, research infrastructure, and technology development?*
- *What are the decadal survey's recommendations for workforce development and addressing issues of diversity, equity, inclusivity, and accessibility?*
- *What are the potential challenges to realizing the vision of the decadal survey in planetary science and astrobiology?*

BACKGROUND

Planetary science is the study of the formation, evolution, and interactions of the planetary bodies of the solar system—including the planets and their moons, dwarf planets, asteroids, and comets orbiting the Sun—and encompasses multiple scientific disciplines, such as geology, astronomy, and atmospheric science. Astrobiology is the study of the origin, evolution, and distribution of life in the universe. Planetary scientists and astrobiologists conduct their research using a combination of space missions, ground-based telescopes, laboratory experiments, terrestrial field work, and theoretical studies. Federal support for research and development (R&D) in planetary science and astrobiology comes primarily through the National Aeronautics and Space Administration's (NASA's) Planetary Science Division, managed within the agency's Science Mission Directorate (SMD). The Division of Astronomical Sciences (AST), within the Mathematical and Physical Sciences (MPS) Directorate of the National Science Foundation (NSF), provides modest support through its relevant ground-based astronomy programs.

A decadal survey is a two-year process, conducted on approximately a ten-year cadence, culminating in the publication of a final report that aims to review the scientific progress of the previous decade in a given discipline, develop a community consensus around the scientific priorities of the next decade, and recommend a comprehensive program to best address them. NASA and NSF arranged for the National Academies of Sciences, Engineering, and Medicine[1] to conduct a decadal survey for the next decade in planetary science and astrobiology. In addition to its charge prepare a decadal science strategy, the decadal survey committee was tasked to consider and make specific recommendations regarding planetary defense[2] and diversity, equity, and inclusion for the first time in a planetary science decadal survey. On April 19, 2022, the National Academies issued the resulting report, *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032* (Planetary Decadal).[3]

Planetary Decadal Prioritized Science Questions

While previous decadal strategies were largely organized by destination, NASA requested in its charge to the decadal survey committee that the survey instead "be organized according to the significant, overarching questions in planetary science, astrobiology, and planetary defense." In that regard, the new Planetary Decadal organized its research strategy around twelve priority science questions[4] are defined across three scientific themes: Origins, Worlds and Processes, and Life and Habitability.

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[1] The National Academy of Sciences was established in 1863 by an Act of Congress signed into law by President Lincoln as an independent, nongovernmental institution to advise the government. The Academies of Engineering and Medicine were established later under the charter of the National Academy of Sciences. Activities of the National Research Council are now referred to as activities of the National Academies of Sciences, Engineering, and Medicine.

[2] Planetary defense refers to efforts to detect, track, and characterize the risk to life on Earth posed by Near Earth Objects (NEOs), or objects that orbit the Sun in close proximity to the Earth, as well as the development of techniques to mitigate a potential threat from a NEO.

[3] National Academies of Sciences, Engineering, and Medicine. 2022. *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. Washington, DC: The National Academies Press. Available at: https://doi.org/10.17226/26522

[4] Each priority question, or question topic, has associated sub-questions.

The *Origins* scientific theme organizes questions around three priority topics that explore how the solar system and Earth originated and whether planetary systems like ours are common or rare in the universe:

- *Evolution of the protoplanetary disk,* the the disk of gas and dust rotating around the Sun for about the first ten million years after the Sun formed;
- *Accretion,* or the formation and growth through collisions and build-up of material, *in the outer Solar System*, comprising planetary bodies beyond the asteroid belt, including the giant planets Jupiter, Saturn, Uranus, and Neptune; dwarf planets; and comets; and
- *Origin of Earth and inner solar system bodies,* including Mercury, Venus, Mars, the asteroid belt, and the moons of Earth and Mars.

The *Worlds and Processes* scientific theme organizes questions around five priority topics that explore how planetary bodies evolved from their earliest stages to the diverse objects we see today:

- *Impacts and dynamics,* or how collisions and gravitational interactions between and among planetary bodies have changed the location and structure of solar system bodies over time;
- *Solid body*—or planetary objects like rocky planets, icy moons, large asteroids, and comets—*interiors and surfaces*, including their physical and chemical properties and how planetary surface features are shaped;
- *Solid body atmospheres, exospheres*—or the thin, outermost layers of gas around a planet or moon—*magnetospheres, and climate evolution*;
- *Giant planet*—Jupiter, Saturn, Uranus, and Neptune—*structure and evolution*; and
- *Circumplanetary systems*, or the rings, moons, and other material that orbit around planets in the solar system, such as the rings of Saturn or the moons of Jupiter, including how they formed and how they interact with their planets.

The *Life and Habitability* scientific theme organizes questions around three priority topics, which probe what conditions on Earth led to both habitable environments and the emergence of life and whether life could have formed elsewhere:

- *Insights from terrestrial life,* or whether the processes in which life started and evolved on Earth, and in what forms, can inform scientists' understanding of the possibility of life elsewhere in the solar system;
- *Dynamic habitability,* or the concept that the degree to which certain planetary environments are hospitable to life—that is, habitable—may change over time; and
- *Search for life elsewhere,* including the questions of whether there is any evidence of past or present life, beyond Earth, and how scientists might be able to detect it.

The final scientific question prioritized by the committee is a cross-cutting topic that relates to all three scientific themes. The question on *Exoplanets*, or planets that orbit stars other than the Sun, asks both how the solar system can provide better understanding of exoplanetary systems, and how exoplanetary systems can provide better understanding of our own solar system.

Planetary Decadal Recommendations

The Planetary Decadal recommends a prioritized, integrated program of research and development activities that aligns with the priority science questions, including flight projects, research, and technology development. With respect to the prioritized program, the committee recommended maintaining a "balanced mix of small, medium, and large missions, enabling a steady stream of new discoveries and the capability to make major scientific and technical advances, as well as the needed training of future generations of planetary scientists."

The committee also reemphasized a top priority of the previous planetary science decadal survey,[5] with the new decadal recommending that "the highest scientific priority of NASA's robotic exploration this decade should be completion of the Mars Sample Return as soon as is practicably possible with no increase or decrease in its current scope." The first step in a Mars Sample Return (MSR) campaign, the Perseverance Mars2020 Rover, is collecting and storing samples of material from the surface of Mars to be returned to Earth through a NASA partnership with the European Space Agency (ESA).

Recommendations for New Small, Medium and Large Space Missions

The Planetary Decadal recommended that NASA continue to support missions across a range of mission sizes, scale, cost, and complexity, and made further recommendations regarding goals, destinations, and applications of cost constraints.

New Small Missions: Discovery Program

The new Planetary Decadal recommends that *Discovery* missions, which are competitively-selected and led by a Principal Investigator (PI), continue to be supported and that the cost cap for the combined development and operations phases of the mission, but excluding the launch vehicle cost, be raised[6] to $800 million, in Fiscal Year (FY) 2025 dollars, and that it be regularly adjusted to inflation. The committee recommended the cost cap be increased because "addressing many of the priority science questions identified in this survey will require higher levels of instrumentation and/or mission complexity, and potentially longer missions (including notably to outer solar system objects), than were required in the past." The Discovery Program also recently introduced the Small Innovative Missions for Planetary Exploration (SIMPLEx) activity, supporting very small, focused missions, with cost caps of $55 million. The new Planetary Decadal recommended an increase in the SIMPLEx cost cap of approximately 50 percent to "achieve decadal-level science and drive innovation across more destinations."

[5] A sample-caching rover, as the first step in a Mars Sample Return (MSR) campaign, was the top priority large mission recommended by the previous planetary science decadal survey. National Research Council. 2011. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. Washington, DC: The National Academies Press. Available at: https://doi.org/10.17226/13117.

[6] The most recent Discovery solicitation, issued in 2018 and awarded in 2021, had a cost cap of $500 million, in FY2018 dollars, but this cap applied to the development phase only, with no cost cap on the operations phase, which the new Planetary Decadal found made "challenging to assess the science return per true total mission cost and also undermines budgetary forecasting needed to maintain a predictable cadence of frequent selections and launches."

New Medium Missions: The New Frontiers Program

The *New Frontiers* program sponsors medium-class missions that are also led by a PI. New Frontiers missions are more technically and/or operationally complex and address broader and/or more challenging scientific questions than Discovery missions. New Frontiers missions are launched at a frequency of approximately one to two per decade. New Frontiers mission proposals are limited to a finite set of mission themes, typically defined by destination and platform or method (e.g., orbiter, rover, sample return), identified by the decadal survey.

The new Planetary Decadal recommended that the New Frontiers cost cap be increased from $1.31 billion in FY 2025 dollars for the development phase only to $1.65 billion in FY2025 dollars, including development and operations phases, excluding the launch vehicle and the quiet cruise phase, when a spacecraft is on its way to its destination. The committee recommended this increased cap in order to reflect "the associated hardware costs" of the "nature and breadth of the science that will optimally be accomplished in the New Frontiers program in the coming decade." The committee also recommended a new, separate, $30 million cap for the quiet cruise phase to allow missions to optimize mission scientific return, independently of the target destination.

The Planetary Decadal made no modifications to the list of mission themes previously identified for the fifth New Frontiers solicitation, NF-5, which was prioritized by the previous decadal. The Planetary Decadal recommended six mission themes for the NF-6 call in the upcoming decade: a Centaur[7] orbiter and lander; sample return from the dwarf planet Ceres in the asteroid belt; sample return from the surface of a comet; multiple flybys of Enceladus, an icy moon of Saturn; a Lunar Geophysical Network; a Saturn probe; and an orbiter of Titan, a moon of Saturn. For NF-7, the Planetary Decadal recommended all non-selected mission themes from the NF-6 list, plus a mission to observe the ocean world Triton, a moon of Neptune.

New Large, Strategic Missions: Planetary Flagships

NASA's largest planetary missions, known as *Flagships*, are strategic missions that are directed and managed by the agency. Flagships typically carry multiple instruments that are each competed and led by a PI. Flagships are the most scientifically ambitious, providing transformative, breakthrough science across a broad range of topics and priority science questions. In addition to its highest overall priority on Mars Sample Return, the Planetary Decadal recommends two new Flagship missions.

The Planetary Decadal's highest priority new *Flagship* mission for the upcoming decade is the *Uranus Orbiter and Probe (UOP)* mission. The UOP mission will consist of both an orbiter for a multi-year stay at Uranus, and a probe to descend into Uranus' atmosphere and provide in situ measurements. Uranus and Neptune—the "ice giants," with dense, thick atmospheres made up of far heavier materials than those of the "gas giants" Jupiter and Saturn—are the only planets that have never been studied with a dedicated orbital mission. The decadal survey committee finds that the UOP will transform scientists' knowledge of Uranus, which is "one of the most

[7] Centaurs are a population of small, rocky objects orbiting the Sun near the orbits of the outer planets, in between the asteroid belt and the Kuiper belt.

intriguing bodies in the solar system" and has a dynamically active atmosphere, a complex magnetic field, and is tilted nearly 90 degrees, such that it rotates almost completely on its side. The survey recommended that NASA initiate UOP mission development in FY2024 in order to meet the best launch opportunities for the in 2031 and 2032, but other opportunities are available throughout the 2030s.

The second-highest priority new *Flagship* mission is the *Enceladus Orbilander*. Enceladus is a large moon of Saturn made of ice and rock, with a water ocean beneath its outer layers of ice. Previous research has shown that Enceladus actively spews plumes of water and other material far out from its surface, with some evidence pointing to the possibility that the subsurface ocean may have some of the essential features to be hospitable to life. The Enceladus Orbilander, a single spacecraft, would first study the plumes from orbit to look for signs of habitability, and then descend to the icy surface to conduct a two-year landed mission. The Planetary Decadal recommends initiation of the Enceladus Orbilander late in the upcoming decade, targeting launch in the early 2050s.

Recommendations for Moon to Mars and Human Exploration

While the previous planetary decadal made passing mention of the opportunity of human exploration to planetary science, this new decadal goes further and recommends that "conducting decadal-level science should be a central requirement of the [NASA] human exploration program." The committee also recommended that NASA "engage with the science community to 1) define scientific goals for [NASA's] human exploration programs at the early stages of program planning; and 2) ensure scientific expertise in field geology, planetary science, and astrobiology in its astronaut teams."

With respect to Artemis, the decadal survey committee also discussed issues regarding roles and responsibilities in the implementation of a lunar science and exploration program and recommended that:

> "[The Planetary Science Division] should develop a strategic lunar program that includes human exploration as an additional option to robotic missions to achieve decadal-level science goals at the Moon…[and]…NASA should adopt an organizational approach in which SMD has the responsibility and authority for the development of Artemis lunar science requirements that are integrated with human exploration capabilities. NASA should consider establishing a joint program office at the Associate Administrator level for the purpose of developing Artemis program-level requirements across SMD, [Exploration Systems Development Mission Directorate], [Space Operations Mission Directorate], and other Directorates as appropriate."

For the horizon goal of landing humans on the surface of Mars, the Planetary Decadal recommended that the NASA Planetary Science Division "should have the authority and responsibility for integrating science priorities into the human exploration plans for Mars."

Recommendations for Planetary Defense

The Planetary Decadal recommended that NASA's Planetary Defense Coordination Office (PDCO), managed within the Planetary Science Division, "fully support the development, timely launch, and subsequent operation of NEO Surveyor to achieve the highest priority planetary defense near-Earth object survey goals." The NEO Surveyor is a space-based mid-infrared satellite mission dedicated for NEO surveys and currently in development. Space-based NEO searches can detect more NEOs, faster, and with higher accuracy than ground-based surveys.[8]

The Planetary Decadal also recommended, as a high priority, a "rapid-response, flyby reconnaissance mission targeted to a challenging NEO population—5- to 100-meter diameter objects posing the highest probability of a destructive Earth impact," in order to "assess the capabilities and limitations of flyby characterization methods to better prepare for a short-warning-time NEO threat." In addition, the decadal survey recommended that NASA and NSF review ground-based planetary radar infrastructure to determine how best to meet the community's needs after the loss of Arecibo, which housed a radar instrument supported by NASA for planetary science research and characterization of NEOs.

Recommendations for State of the Profession

The committee made eight State of the Profession recommendations across four areas of focus:

- *An evidence-gathering imperative*, to address the "urgent need for data concerning the size, identity, and demographics" of the community and workplace climate;
- *Education of individuals about the costs of bias and improvement of institutional procedures, practices, and policies*.
- *Broadening opportunities to advance the [State of the Profession],* including engagement of underrepresented communities at secondary and college levels.
- *Creating an inclusive and inviting community free of hostility and harassment*.

The decadal finds that "a strong system of equity and accountability is required to recruit, retain, and nurture the best talent" into the planetary science and astrobiology community.

Recommendations for Research and Analysis

While most NASA planetary science missions have small pools of money specifically allocated for research efforts within a mission's budget, the vast majority of NASA's planetary science research activities, including data analysis and theoretical and laboratory studies, are funded through the Research and Analysis (R&A) line. Individual scientists and teams submit research proposals to NASA through open competitions, which are evaluated by scientific peer review. R&A grants and cooperative agreements support researchers at all career levels, from

[8] A 2019 National Academies study concluded that a space-based mid-infrared survey is the most effective option for meeting the statutory mandate that NASA detect at least 90 percent of all NEOs larger than 140 meters in diameter within 10 years. National Academies of Sciences, Engineering, and Medicine. 2019. Finding Hazardous Asteroids Using Infrared and Visible Wavelength Telescopes. Washington, DC: The National Academies Press. Available at: https://doi.org/10.17226/25476.

undergraduate to graduate students, postdoctoral scholars, to early-career professors, to senior faculty. The decadal survey found that the fraction of the Planetary Science Division's budget devoted to R&A has dropped from 14 percent in 2010 to a projected 7.7 percent in FY2023, stating that "it is essential to the nation's planetary science efforts that this trend be reversed." The committee recommended that the PSD increase its investment in R&A to bring that fraction up to 10 percent.

Planetary Decadal Budget Scenarios and Decision Rules

The Planetary Decadal develops two notional program portfolios for the 2023-2032 decade in planetary science and astrobiology, a *Recommended Program* and a *Level Program* based on two possible budget scenarios for the decade for NASA's Planetary Science Division. The Recommended Program comprises the full set of Planetary Decadal recommendations and would require a total decade budget that is 17.5 percent above the 2023-2032 decade budget that would be available by maintaining the budget in the President's request for FY2023 for the Planetary Science Division, only adjusted annually for inflationary growth. The Level Program would comprise a subset of the Planetary Decadal recommendations that could be implemented within a 2 percent inflationary growth over the level in the President's budget request for FY2023 for the Planetary Science Division. The Planetary Decadal's Level Program would include continuing support for missions currently in operation or under development, continuing the Mars Sample Return campaign, initiating the Uranus Orbiter and Probe flagship mission, raising the caps on the Discovery and New Frontiers mission solicitations, and increasing the R&A budget to 10 percent of the portfolio by mid-decade. The Level Program, however, would require delaying the initiation of the Uranus Orbiter and Probe flagship until late in the decade, delaying the Enceladus Orbilander to the 2030s decade, and delaying NF-6 until late in the 2020s decade, likely also pushing NF-7 into the following decade.

In the case that the budget for the Planetary Science Division is lower than that of the projected budget under the *Level Program* scenario, the decadal survey committee presented *decision rules* of how the budget reductions should be applied to the implementation of the Planetary Decadal recommended priorities.