Planetary Decadal Survey says it's time for a mission to Uranus (and Enceladus too)

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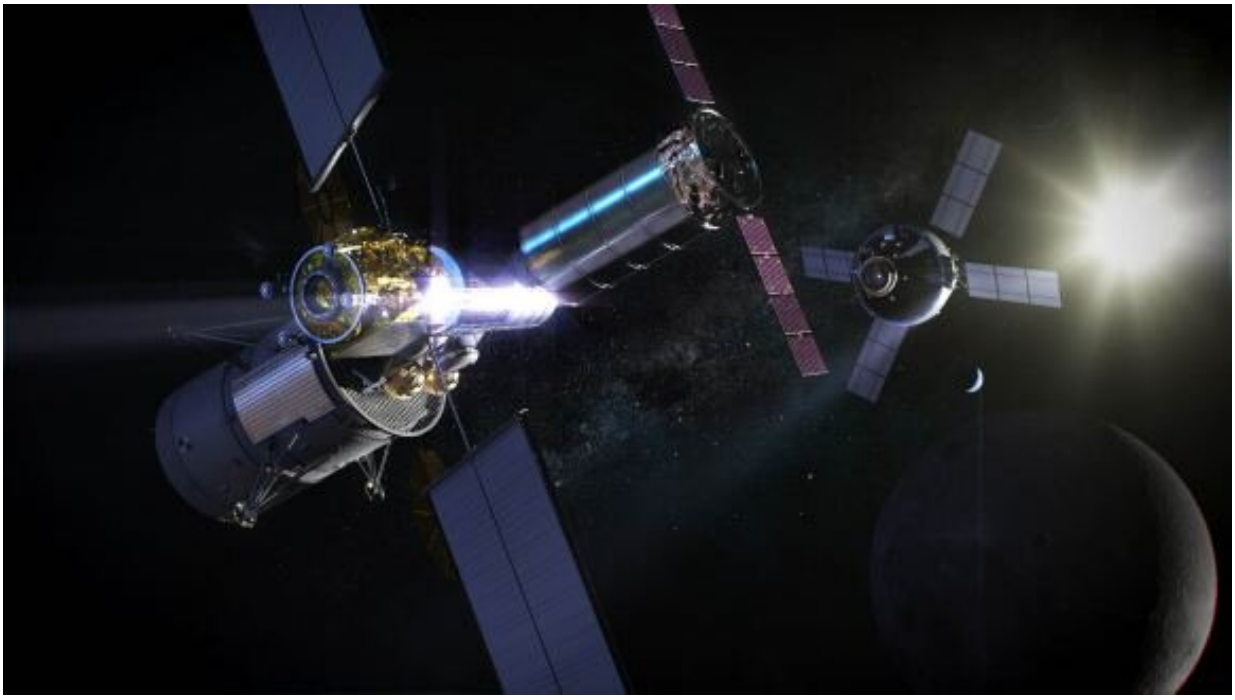

An illustration of the Gateway, which will serve as the home base for human and robotic missions to the moon and, ultimately, Mars. Credit: NASA

Since 2002, the United States National Research Council (NRC) has released a publication that identifies objectives and makes recommendations for science missions for NASA, the National Science Foundation, and other government agencies for the next decade. These reports, appropriately named Planetary Science Decadal Surveys, help

inform future NASA missions that address the mysteries that persist in astronomy, astrophysics, earth science, and heliophysics.

On Thursday, April 19th, in a briefing in Washington D.C., the National Academies of Sciences, Engineering, and Medicine (NASEM) shared the main findings of the Planetary Science and Astrobiology Decadal Survey 2023–2032. The event was live-streamed and consisted of NASEM committee members discussing the key science questions, priority missions, and research strategies identified and recommended, followed by a Q&A session with the audience.

The third Decadal Survey, titled "Origins, Worlds, and Life," consists of 522 white papers submitted by scientists from NASA-affiliated universities and research institutes worldwide. This includes the California Institute of Technology (Caltech), the University of Arizona's Lunar and Planetary Laboratory (LPL), the Southwest Research Institute (SwRI), the U.S. Naval Research Laboratory, the Planetary Science Institute (PSI), and the Johns Hopkins University Applied Physics Laboratory (JHUAPL).

The committee

The committee members that led the briefing consisted of Davis Smith, the senior program officer of NASEM's Space Studies Board (SSB); Philip Christensen, the Regents Professor in the School of Earth and Space Exploration (SESE) at Arizona State University (ASU); and Robin Canup, the assistant vice president of the Space Science and Engineering Division at the Southwest Research Institute (SwRI), part of the NASA Planetary Science Directorate (PSD).

The proposals were divided into six categories, reflecting the different panels that make up the Decadal Survey. These include the Small Solar System Bodies, Giant Planet Systems, Venus, Ocean Worlds & Dwarf

Planets, Mars, and Mercury & the Moon panels. Each reviewed the white papers submitted, identified three priority science questions, and recommended which mission proposals would help address these questions.

Robin Canup, who is also the co-chair of the National Academies' steering committee for the decadal survey, said in a NASEM news release:

"This report sets out an ambitious but practicable vision for advancing the frontiers of planetary science, astrobiology, and planetary defense in the next decade. This recommended portfolio of missions, high-priority research activities, and technology development will produce transformative advances in human knowledge and understanding about the origin and evolution of the solar system, and of life and the habitability of other bodies beyond Earth."

Overall, the committee identified twelve priority science questions divided into three categories: Origins, Worlds and Processes, and Life & Habitability. Each category contained a series of major areas of investigation (12 in total) with several specific questions about them. The NASEM committee then examined the many robotic and crewed mission proposals that are meant to happen in the next decade—to the moon, Mars, Venus, and the outer solar system.

Their recommendations are presented in the Decadal Survey, which designated priority to missions that they felt would best fulfill the objectives identified. First and foremost, they identified which concepts NASA should pursue in the coming decade as Large Strategic Science Missions (LSSM)—formerly known as "Flagship missions."

Flagship missions

The highest priority for a Flagship mission was given to a robotic mission that would explore Uranus. This mission would deliver an in-situ atmospheric probe into Uranus' atmosphere and conduct a multi-year orbital tour to study the ice giant and its system. This mission is known as the Uranus Orbiter and Probe (UOP), whose scientific objectives would include the study of Uranus' interior, atmosphere, magnetosphere, satellites, and rings.

The UOP was first recommended in 2011 as part of the "Visions and Voyages" Planetary Science Decadal Survey (2013–2022) and envisaged a launch between 2020–2023, followed by a 13-year cruise to Uranus. However, the mission was considered a lower priority than missions to Mars (the Perseverance rover) and the Jovian system (the Europa Clipper mission). If NASA decides to fund this mission proposal, the spacecraft will launch in the early 2030s to coincide with a favorable alignment of the planets.

Another proposal selected as a priority Flagship mission was the Enceladus Orbilander, a combined orbiter and surface lander that will study the active plumes of gas and particles emanating from Enceladus' southern polar region. The mission will study these plumes (which originate from Enceladus' subsurface ocean) from orbit and during a two-year landed mission. The objectives will be to search for evidence of life (biosignatures) in the plumes and obtain geochemical and geophysical context for life detection experiments.

New Frontier missions

Beyond Flagship-priority missions, the Survey identifies several medium-priority New Frontier (NF) missions. This program calls for Principle Investigator-led (PI-led) missions with specific themes to be selected through a competitive process. Using the scientific questions and priorities they identified, the committee selected several additional

missions to explore the many "Ocean Worlds" of the solar system.

These included a Ceres sample return mission, which would address questions arising from previous observations, including those conducted by NASA's Dawn mission. This mission would consist of an orbiter and lander that study Ceres from orbit and land on the surface to obtain a sample from its icy crust and return it to Earth for analysis. Their findings would help scientists better constrain the composition of the largest body in the Main Asteroid Belt.

The Europa Clipper and Europa Lander concepts were also recommended, which would travel to the Jovian system in the next decade to survey Europa's surface and plume activity for potential signs of life (aka. biosignatures). As noted, the Europa Clipper was deprioritized this time around in favor of a mission to Enceladus (along with the UOP). According to the committee, the radiation environment around Jupiter is more favorable for an astrobiology mission.

Eight other missions were prioritized for the NF program to augment other mission proposals and fulfill other established science objectives. These included a Centaur orbiter and lander, a comet surface sample return, an Enceladus orbiter that would conduct multiple flybys, a Lunar Geophysical Network, a Saturn probe, a Titan orbiter, and Venus In-Situ Explorer. More information on these missions can be found in the Survey Report here.

Mars exploration

Regarding future exploration missions to Mars, the committee indicated that the highest scientific priority was the Mars Sample Return (MSR) mission. A joint effort by NASA and the ESA, this mission would consist of an orbiter, lander, rover, and launch vehicle that would retrieve samples obtained by the Perseverance rover and return them to

Earth for analysis. As NASEM summarized in Chapter 22 of the Survey Report:

"The Perseverance rover is collecting samples from Jezero Crater, a former lake basin with a feeding channel system that was carved into Noachian (>3.7 Ga*) stratigraphy. Distinct types of sedimentary, igneous, water-altered, and impact-formed rocks accessible in this region will provide a geological record of a time interval particularly important for understanding Mars's environmental evolution and, potentially, its biology."

"Sample return will provide geologic materials that are not represented among Martian meteorites and whose volatile, organic, and secondary mineral composition have not been altered by impact… In addition, sample return will allow for future analyses by instruments and techniques not yet developed. As has been the case with the Apollo samples from the moon, future analyses are expected to yield profound results for many decades after sample return."

Priority is also given to a Mars Life Explorer (MLE) mission, which would build on NASA's Mars Exploration Program (MEP), which the report identifies as a "scientific success story." Established in response to NASA's 2014 Strategic Plan, the MEP has dispatched a series of robotic orbiters, landers, and rovers to search for evidence of past life on Mars and provide the information necessary for the future human exploration of Mars—which are scheduled to begin by 2033.

The long list of MEP missions includes (but is not limited to) the 2001 Mars Odyssey, Mars Reconnaissance Orbiter (MRO), and Mars Atmosphere and Volatile EvolutioN (MAVEN) orbiters, the InSight Lander, and the Curiosity and Perseverance rovers. For the MLE, the mission proposal envisions a near-surface water ice investigation that would validate in-situ resource utilization (ISRU) technologies that

crewed missions would depend on to provide a steady water supply.

Lunar Discovery and Exploration Program (LDEP)

Another major priority identified in the report relates to NASA's plans for sending crewed missions to the moon in the near future (the Artemis Program) and related lunar activities. Given the ambitious goals of this program, which include establishing a "sustained program of lunar exploration," the report stresses how considerable investment and research and development are required now to "enable and optimize high-priority lunar science activities with humans at the moon."

To this end, a Lunar Discovery and Exploration Program (LDEP) is identified as being vital to the future of human exploration efforts because of the exploration and science goals involved. Similarly, there's the way a "sustained program of lunar exploration" will continue fostering industry partnerships and innovation—as exemplified by the Commercial Lunar Payload Services (CLPS) program, where NASA has contracted with commercial partners to provide lunar landing services.

The committee also indicated that the Endurance-A sample return mission should be the highest priority of this program. Similar to the MSR, this mission would see a medium-class lunar rover delivered to the moon's south pole Aitken Basin through the CLPS program, which would then collect high-value samples from key locations around the moon's south pole Aitken Basin. The Artemis astronauts would retrieve these samples and return them to Earth for analysis.

In addition, the report stresses that an LDEP would demonstrate the potential for cohesion between robotic and human missions:

"The Endurance-A sample return mission, a medium-class robotic mission to collect samples from key lunar locations for later retrieval by

Artemis astronauts, exemplifies this synergy. This mission would enable the highest priority lunar science not possible through the local collection of limited samples and could revolutionize our understanding of the moon and the early history of the solar system."

Human exploration

Human exploration is identified as a major priority because of the commercial, technological, and scientific benefits it allows for. In addition, it is a source of inspiration for people worldwide, encouraging the younger generation to pursue careers in space exploration and the STEM fields. To this end, the committee addresses the opportunities for science within the context of current plans to explore the moon and Mars in the next decade.

This includes the Artemis missions and related efforts to establish the infrastructure to support a long-term moon presence, including the Lunar Gateway and the Artemis Basecamp, scheduled to be completed by 2028. These elements are also part of NASA's long-term plans to send crewed spacecraft to Mars during the 2030s (aka. the Moon to Mars program). As the committee states in Chapter 19, science activities should be selected to support human flight activities.

"For this decade with a near-term plan for human exploration of the moon and preparatory activities at Mars, the decadal survey emphasizes the importance of carefully crafted collaboration," they write. "A program of scientific exploration can be constructed this decade whereby science enables human exploration, and human exploration enables science."

Planetary defense

Major importance is also placed on international cooperative efforts to develop measures that will ensure planetary defense against potentially-hazardous near-Earth objects (NEOs). This refers to asteroids that periodically cross Earth's orbit and (on very rare occasions) collide with Earth. In the past, impacts from NEOs have caused extinction-level events (ELEs), such as the Chicxulub asteroid that killed the dinosaurs about 66 million years ago (aka. Cretaceous–Paleogene extinction event).

At present, NASA, the NSF, the ESA, and other government agencies worldwide play a leading role in developing the capacity to understand these asteroids and the long-term ability to prevent a potential impact. Therefore, the committee strongly recommends a robust program that enables the creation of a "U.S. planetary defense community" in the coming decade that will ensure detection, warning, and mitigation capabilities.

Two missions are prioritized to ensure this, including NASA's NEO Surveyor and Double Asteroid Redirection Test (DART) mission. Detailed assessments of these missions are provided in Chapters 19 and 22, respectively. The NEO Surveyor, which is currently pending Congressional approval, will consist of a dedicated space-based mid-infrared space survey telescope designed to discover and characterize most of the potentially hazardous NEOs.

The DART mission, which launched in November 2021, will rendezvous with the binary asteroid 65803 Didymos later this year. Once there, it with test what is known as the "kinetic impactor" method of planetary defense, where it will strike the Didymos' moonlet (Dimorphos) in an attempt to deflect it. A follow-up mission—the ESA's Hera spacecraft—will launch from Earth in 2024 and arrive around Didymos in 2027, at which point it will analyze Dimorphos for any changes in its orbit. As the committee recommends:

"The highest priority planetary defense demonstration mission to follow DART and NEO Surveyor should be a rapid-response, flyby reconnaissance mission targeted to a challenging NEO, representative of the population of objects posing the highest probability of a destructive Earth impact (~50-to-100 m in diameter). Such a mission should assess the capabilities and limitations of flyby characterization methods to better prepare for a short-warning-time NEO threat."

State of the Profession

Last, but not least, the committee made several recommendations regarding the State of the Profession (SoP), which includes the issues of diversity, equity, inclusivity, and accessibility in the planetary science enterprise (PSE). This included acknowledging the progress that has been made in recent decades and the efforts needed to build upon this during the next decade. As such, the committee made the following recommendations:

- Accurate and complete data concerning the size, identity, demographics of the PS&AB community, and workplace climate
- Identifying unintentional and pervasive bias and providing actionable steps to assist NASA in identifying where it exists and removing it from its processes
- Engage underrepresented communities at secondary and college levels
- Ensure that all community members are treated with respect, developing and enforcing codes of conduct

These measures are essential, they write, in order to "recruit, retain, and nurture the best talent, and to support continued American leadership in planetary science and astrobiology (PS&AB)."

Looking to the coming decade, there is no doubt that there is tremendous

potential for exciting missions and investigations. Even more exciting is the potential scientific discoveries these missions could reveal. These range from revelations about the history of the solar system, the formation and evolution of the planets, and enduring questions surrounding the emergence of life (and what forms it might take). But perhaps the most exciting thing is how these missions could enable the next generation to explore even farther, possibly to the edge of the solar system.

More information: Origins, Worlds, and Life (2022). DOI: 10.17226/26522

To read from or download a PDF copy of the Decadal Survey report, go to the NASEM page.

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