PLANETARY

From a journey to the core of planetary formation, to the search for life in hidden oceans, JPL spacecraft embody humanity's restless drive to explore, to understand, and to prove or disprove our singular standing in the universe.

Left: *A close-up of NASA's Ingenuity Mars Helicopter before it was sent to the Red Planet*

The Core of Discovery

Seeing what we have never seen before is the essence of exploration.

That essence forms the core of NASA's Psyche mission that successfully launched in October 2023 on a six-year, 2.2-billion-mile journey to the asteroid belt — between Mars and Jupiter — to visit 16 Psyche.

Discovered in 1852 by an Italian astronomer, 16 Psyche, named for the Greek goddess of the soul and the 16th asteroid to be catalogued, is believed to be the metal remnant of an ancient protoplanet stripped of its outer rocky layers.

Psyche appears to be an almost entirely metal world. Such worlds experienced high enough temperatures to cause denser metals to melt and fall to the center. Their makeup is believed to parallel that of Earth's core. It is impossible to explore our core — the 1,800-mile mass of minerals and magma beneath our feet — but the journey to Psyche may help uncover the secrets at the center of our home planet.

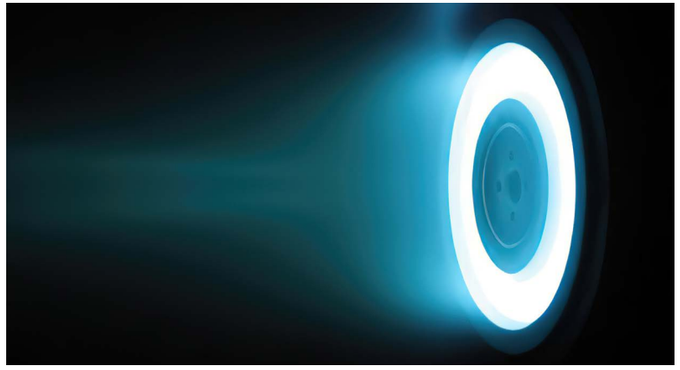
Scientists expect an asteroid belt's worth of surprises when the mission reaches Psyche in August 2029. The spacecraft will orbit at different distances — coming as close as 47 miles — to map the metal world's shape and decipher its internal structure and composition.

Psyche will also demonstrate two technologies to advance future missions. One is electric propulsion: The spacecraft will use solar power to excite and accelerate a stream of xenon gas to provide persistent thrust. The other involves the use of laser beams to increase the rate at which data can be transmitted (see the Interplanetary Network section for more on deep space communication and navigation).

Now and in the future, exploration is at Psyche's core.

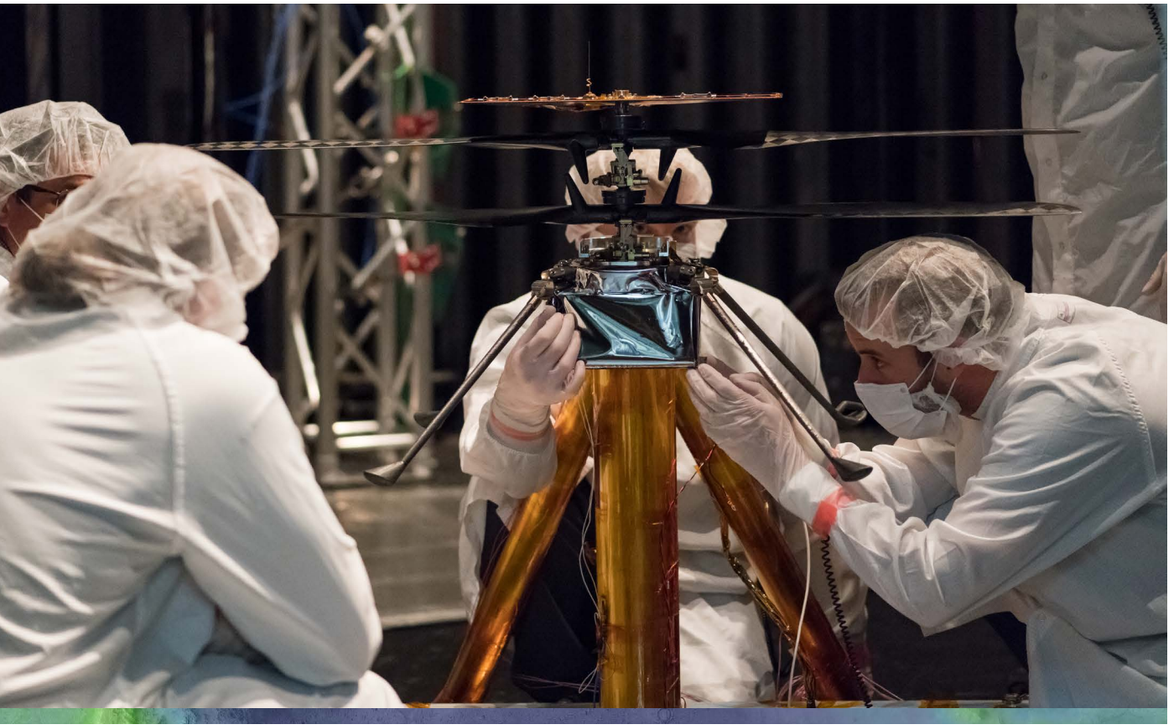
Top: *NASA's Psyche spacecraft, atop a SpaceX Falcon Heavy rocket, lifts off from Kennedy Space Center's historic Launch Complex 39A in Florida on Oct. 13, 2023.*

Bottom: *JPL's H9 Hall thruster during power testing*



Left: *Psyche team members celebrate a successful launch in the Space Flight Operations Facility at JPL.*

The Wright Stuff



Above: *The Mars Helicopter team assembles Ingenuity in a vacuum chamber at JPL in 2019.*

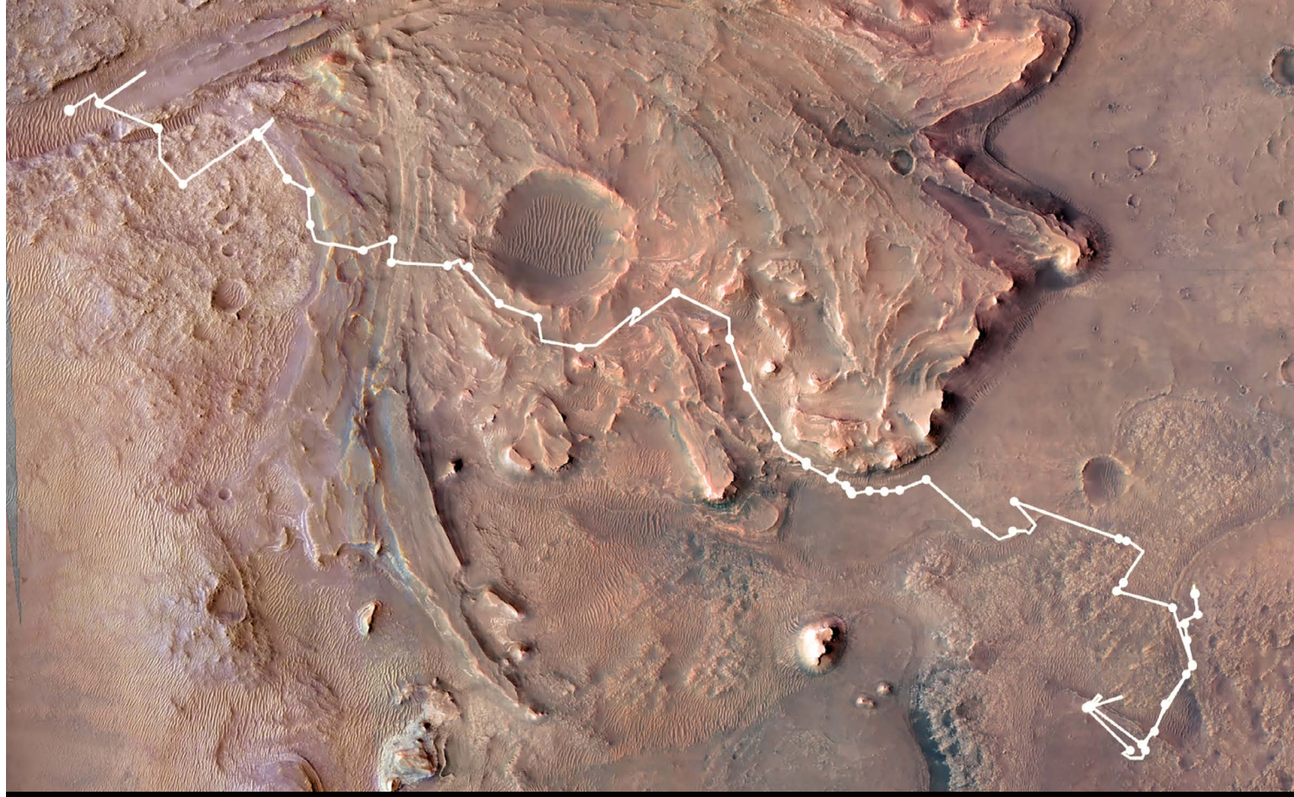
First controlled, powered flight on Earth: 120 years ago. First controlled, powered flight on another planet: three years ago.

NASA's Ingenuity Mars Helicopter, a 19-inch tall, 4-pound wonder, arrived on Mars in 2021 as a barnacle on the belly of NASA's Perseverance Rover. The little chopper's primary goal was to demonstrate that powered flight is possible on Mars despite the planet's wispy atmosphere, which is 100 times thinner than Earth's and is mainly composed of carbon dioxide, nitrogen, and argon gases.

Ingenuity aced that task, successfully completing its five planned flights in the spring of 2021.

NASA then granted the helicopter an extended mission on which Ingenuity would serve as a scout for Perseverance. In July 2021, Ingenuity logged its 10th flight. In April 2022, its 25th flight. A year later, its 50th flight. By the end of 2023, Ingenuity had logged its 70th flight, demonstrating controlled, powered air travel for a combined total of 11 miles and flight time of nearly 128 minutes.

Surpassing expectations like this comes at a cost, however. With some helicopter components showing signs of wear and the terrain becoming more challenging, the Ingenuity team recognized that its adventurous scout must eventually spin down. As 2023 came to a close, the team was preparing for the flying machine's end of mission.

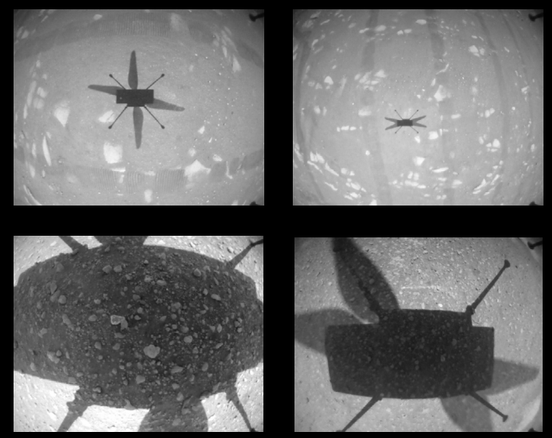


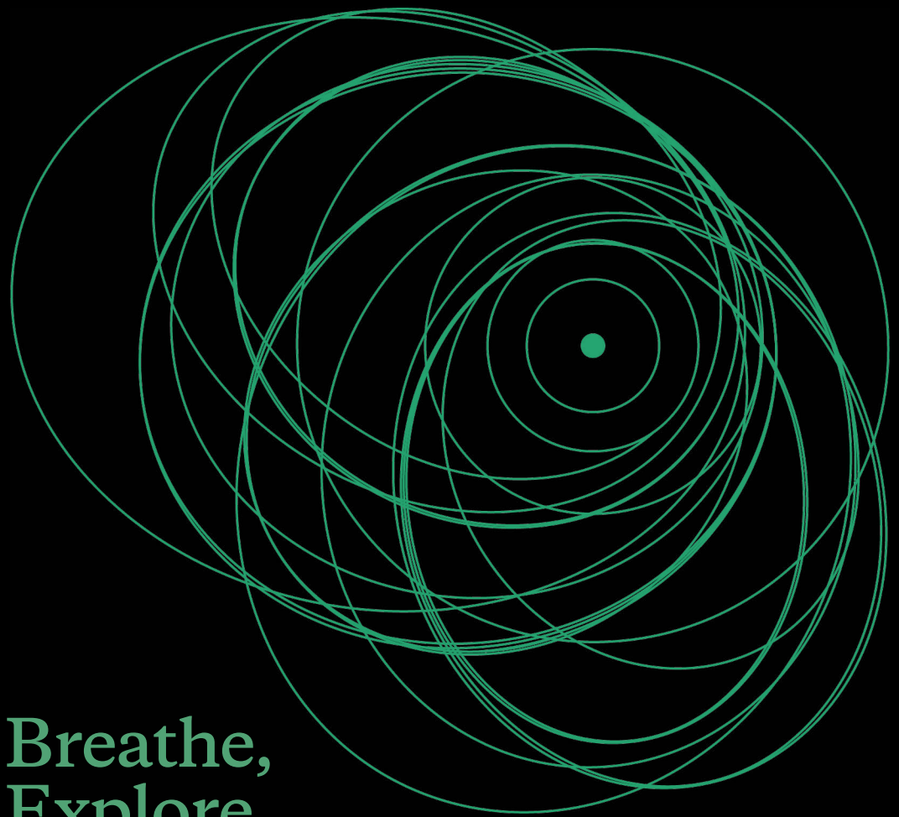
Flight Log

Above is Ingenuity's flight map, charting each of the helicopter's trips over Jezero Crater during its 70 flights through the end of 2023.

Ingenuity took its first flight on April 19, 2021, at a spot aptly named "Wright Brothers Field" and will take its last flight in early 2024.

Below: *Ingenuity captures its own shadow in a series of images taken during its first flight on April 19, 2021.*





Breathe, Explore, Repeat

Above: Illustration of Europa Clipper's planned orbital path around its eponymous moon

Opposite, top: In High Bay 1 of JPL's Spacecraft Assembly Facility, a team of engineers attaches a 10-foot high-gain antenna to the Europa Clipper spacecraft.

Opposite, bottom: Artist's rendering of the Europa Clipper spacecraft above Europa's surface.

If life exists elsewhere in the solar system, it may well reside in the ocean of Jupiter's icy moon Europa.

Europa is slightly smaller than Earth's Moon, and beneath its frozen exterior is a single body of water so deep that it may hold more liquid than all of the oceans on Earth. The mysterious sea, warmed by tidal forces, appears to have the necessary ingredients for life as we know it.

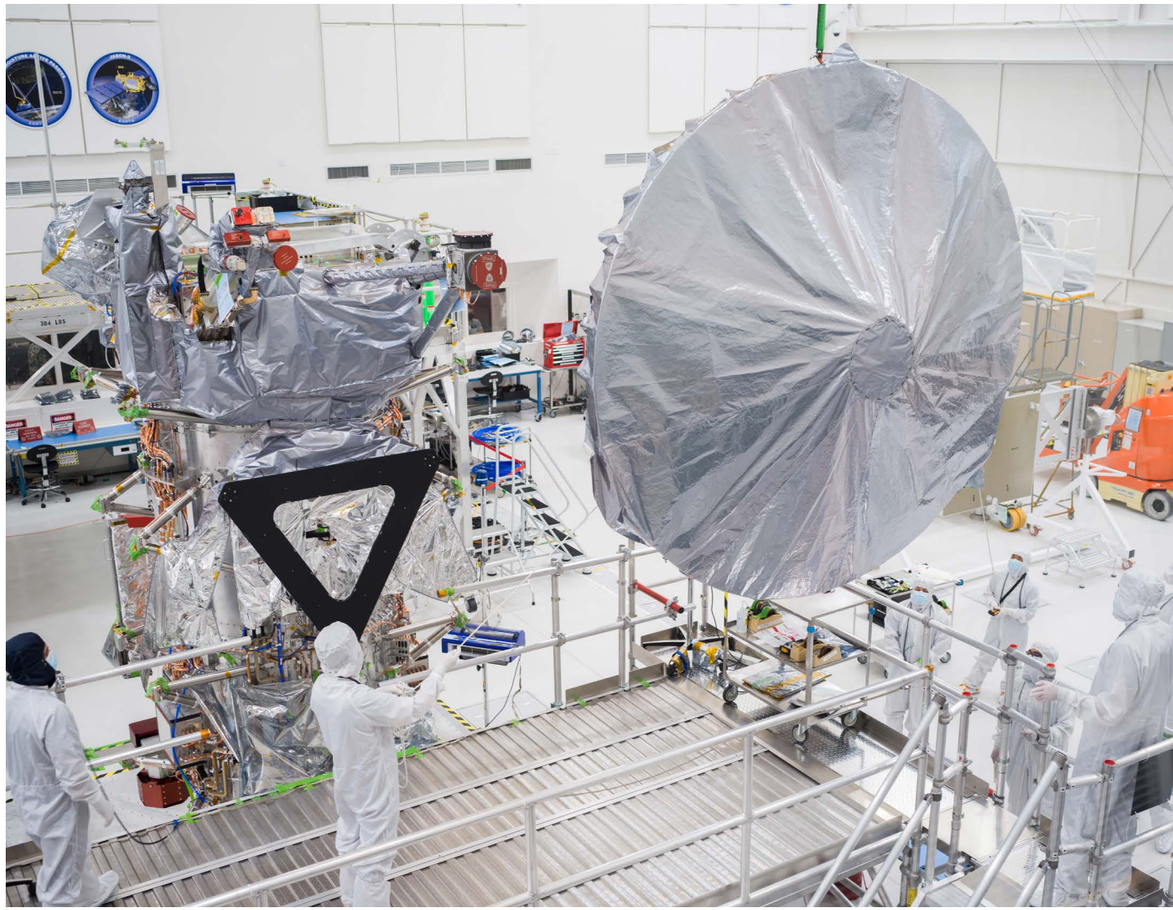
Speculation about Europa's potential habitability also got a boost from discoveries on Earth of unexpected organisms living near magma-fueled hydrothermal vents on the ocean floor.

In October 2024, the Europa Clipper spacecraft is scheduled to blast off from the Kennedy Space Center in Florida, reaching its destination in 2030. Once there, Clipper will fly past Europa nearly 50 times, coming as close as 16 miles to its icy surface to interrogate the moon with a sophisticated suite of nine instruments.

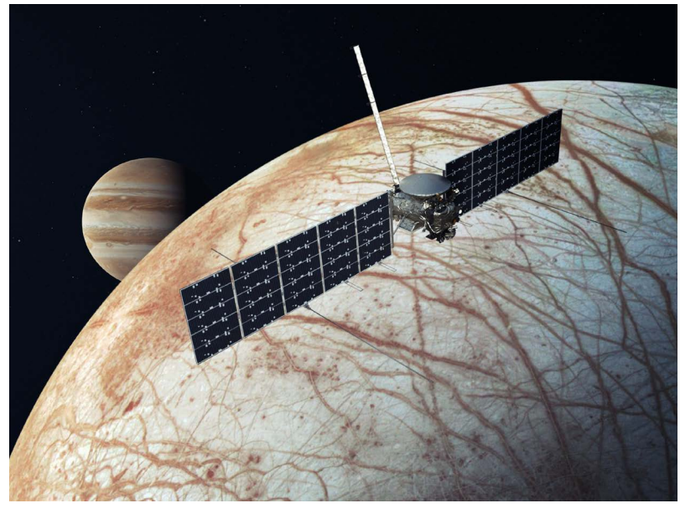
But there's one major obstacle: Jupiter is home to the harshest known radiation belts in our solar system. That's why NASA scientists and engineers designed custom flybys to deal with Jupiter's radiation belts.

On each flyby, Clipper will take a "deep breath," dive in and capture images and observations, and get out quickly. Then it will have a week or two to recuperate while the scientists back on Earth examine the data and come up with new commands for the next flyby.

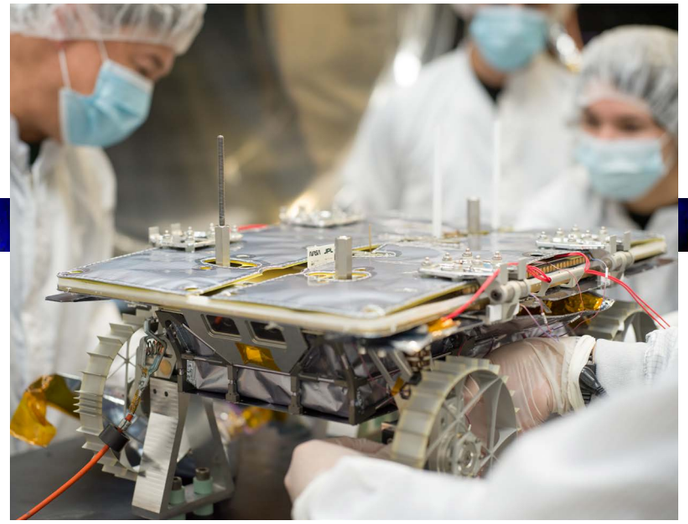
If confirmed to exist, habitable environments on Europa would forever alter the probability of life in the cosmos.



If confirmed to exist, habitable environments on Europa would forever alter the probability of life in the cosmos.



Right: *The CADRE team works on one of the three Moon rovers, ensuring that it canbrave the lunar landscape.*



Above: *One of the CADRE rovers is put to the test in JPL's Mars Yard, October 2023.*

Follow the Leader

NASA is sending a trio of miniature rovers to the Moon. Each about the size of a carry-on suitcase, the four-wheeled rovers will find a sunbathing spot, open their solar panels, and charge up. Mission controllers will provide a vague instruction, after which the rovers will choose a leader from among themselves. That leader will then break the broad directive into smaller tasks and assign them to the group.

A teamwork-minded experiment, CADRE (Cooperative Autonomous Distributed Robotic Exploration) marks another step toward developing autonomous robots that could potentially enable new science or support astronauts.

Currently slated to arrive in 2025, the trio will spend about 14 Earth days — the daylight hours of a single lunar day — to carry out experiments on the Moon. In particular, their ground-penetrating radars will work together to create a three-dimensional map of the subsurface beyond the capability of a single rover to achieve.

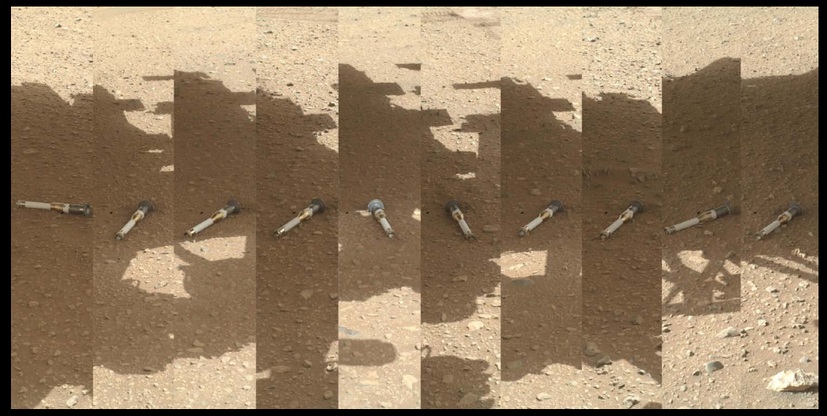
The hazardous lunar environment offers different challenges than Mars, with its especially high daytime temperatures of up to 237 degrees Fahrenheit (114 Celsius). To protect themselves, the rovers will shut down every 30 minutes, cooling off via radiators and recharging their batteries.

When they simultaneously awaken, they'll share their health status with one another and once again elect a leader based on which is most fit for the task at hand. Then off they'll go for another round of lunar exploration.

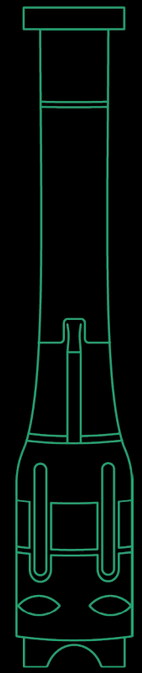
Someday, roving packs of robots may support humans in their exploration of the solar system, taking risks for science that a single explorer — human or robot — wouldn't dare attempt alone.

Right: *A photomontage of the sample tubes Perseverance deposited on the surface of the "Three Forks" location in Jezero Crater*

Below: *Line drawing of a Mars sample tube, similar to those aboard the Perseverance rover*



Independent Review Evaluates Mars Sample Return



An independent review board looked at NASA's current plans and goals of the first mission to return samples from Mars, and NASA established a team to respond.

In addition to bringing home the first sample collected from Mars, this highly complex mission would include the first launch from the surface of another planet, as well as the first in-orbit rendezvous at another planet. Mars Sample Return is a planned partnership with the European Space Agency.

"NASA has plans for a robust Moon to Mars exploration approach," said Nicola Fox, NASA's associate administrator for science. "Understanding the Red Planet supports the agency's Artemis program to ultimately send humans to Mars."

In its report to NASA in September, the board noted the scientific importance of returning samples from Mars but expressed concerns over the availability of sufficient funding to accomplish the mission in the proposed timeframe.

NASA established the IRB in May 2023 to evaluate the technical, cost, and schedule plans prior to confirmation of the mission's design. The board interviewed a wide variety of NASA and external experts to understand the program's scope and management, technical approach, schedule, and funding profile.

In response, NASA set up a team — led by Sandra Connelly, NASA's deputy associate administrator for science — to review the Mars Sample Return report. The team planned to make a recommendation by the second quarter of fiscal year 2024.

A Mars Sample Return campaign would fulfill one of the highest priority solar system exploration goals identified by the National Academies of Sciences, Engineering, and Medicine in the past three decadal surveys. Returning samples would revolutionize our understanding of Mars by bringing scientifically selected samples to Earth for study using the most sophisticated instrumentation around the world.