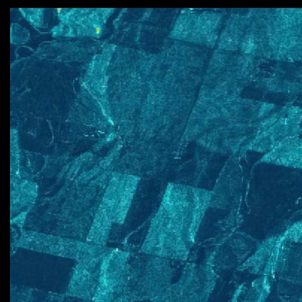
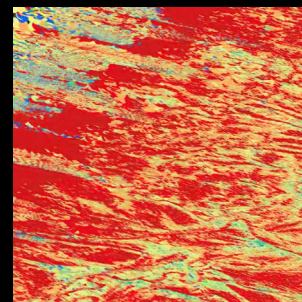
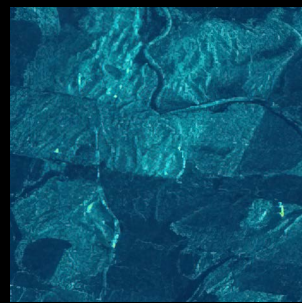
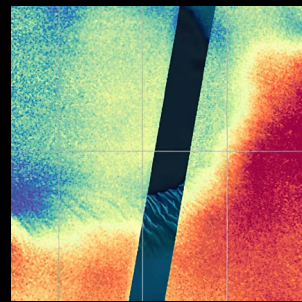
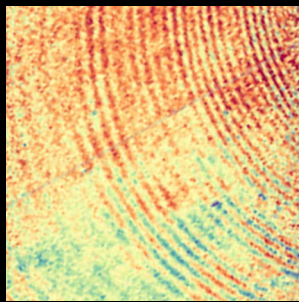
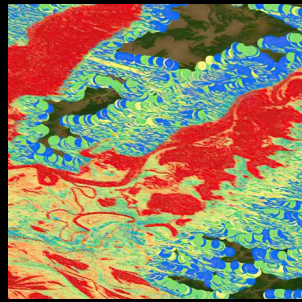
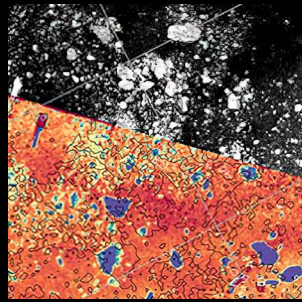


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A vibrant sampling of first images from the Ka-Band Radar Interferometer on the Surface Water and Ocean Topography satellite. SWOT uses variations in how radar scatters from Earth's surface to measure sea levels and to map most of the world's lakes and rivers.

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Director's Message



Reflecting on 2023, this was a foundational year for JPL as we launched signature initiatives that will position the Lab to succeed and lead well into the future.

We updated and simplified our values — who we aspire to be — to Bold, Inclusive, and Trusted. We established seven strategic imperatives that will guide our focus as we prepare for our next century of groundbreaking innovation and exploration. Most importantly, we navigated challenges and celebrated successes that are only possible because of our shared passion for imagining and then achieving what others think impossible.

Among the most thrilling milestones of the year was the flawless takeoff and early operation of the Psyche mission, now on its way to explore a metal-rich asteroid in search of clues about the origins of rocky planets in our solar system. Riding aboard the Psyche spacecraft is the Deep Space Optical Communications experiment, the first demonstration of the technology beyond the Earth-Moon system. DSOC is already setting distance and data-rate performance records as it paves the way for future robotic and human missions to Mars and beyond.

On the Red Planet, the Perseverance rover continued caching samples of the

Martian landscape for eventual return to Earth, and the Ingenuity Helicopter — originally planned to complete only five flights — soared higher and faster than ever, completing 70 flights by the end of 2023.

Peering deeper into the universe, JPL made contributions to the European Space Agency's Euclid space telescope, which is investigating the mysterious nature of dark matter and dark energy. We also completed assembly and entered functional testing of the Coronagraph Instrument for NASA's Roman Space Telescope, which will complement Euclid's findings and image mature exoplanet systems.

Our Earth-observing missions are delivering unprecedented views of our home planet — from a composite of global sea level heights created with data from the Surface Water and Ocean Topography satellite, to maps of surface minerals and methane super-emitters from the Earth Surface Mineral Dust Source Investigation.

Demonstrating our unique capability of communicating with spacecraft in deep and interstellar space, our Deep Space Network celebrated 60 years of critical support to an astounding array of NASA-wide missions. The stunning James Webb Space Telescope images, the cutting-edge science data from Perseverance, and the historic images of the far side of the Moon from Artemis I all reached Earth thanks to DSN's international network of antennas.

Closer to home, we launched the Lab's first-ever diversity, equity, inclusion, and accessibility strategy, re-established the

ombuds office, and hosted community-building events celebrating long-standing traditions and establishing new ones — all with the goal to build a workplace where everyone can thrive.

As we look to the year ahead, more innovative missions that expand the edge of possibility await us as our teams work tirelessly to prepare missions to leave the launch pad in 2024. NASA and the Indian Space Research Organisation (ISRO) are readying the NASA ISRO Synthetic Aperture Radar satellite to observe Earth's most complex natural processes and help us better understand the effects of climate change. Later in the year, we will launch Europa Clipper toward Jupiter's icy moon, which could host the ingredients to support life.

The work we're doing now will lead to transformational scientific and technological discovery beyond what we can imagine for decades to come. My hope for the years ahead is that we can dream fearlessly, act boldly, and keep daring mighty things together.

Laurie Leshin
Director, JPL

ASTRONOMY & PHYSICS

JPL missions are redrawing the limits of the physically possible, from the quantum to the barely quantifiable. A giant light filter will unmask planets circling other stars, a near-infrared observatory will take snapshots of the kinetic cosmos, and a collaboration with the European Space Agency has started to expose the hidden forces scattering the visible universe.

Left: Euclid's snapshot of the Horsehead Nebula is among the space telescope's first images. Scientists will use Euclid to create the most extensive three-dimensional map of the universe to date.

Right: Scientists examine major components of the SPHEREx telescope in a lab at Caltech's Cahill Center for Astronomy and Astrophysics.



Three of a Kind

A new extraordinary space-based observatory, SPHEREx, aims to map the entire sky in unprecedented detail and color.

Over two years, SPHEREx will map the sky four times, including over 450 million galaxies and 100 million stars, creating a huge database of celestial objects.

The observatory's three science objectives are to look at three main periods of the lifetime of the universe.

The first goal is to gain a better understanding of where water and other ingredients necessary for life originated

by measuring the abundance of water ice in interstellar clouds of gas and dust, places where new stars form and where planets are eventually created.

The second will be to study the cosmic history of galaxies, learning more about when they began to form and how they've changed over time.

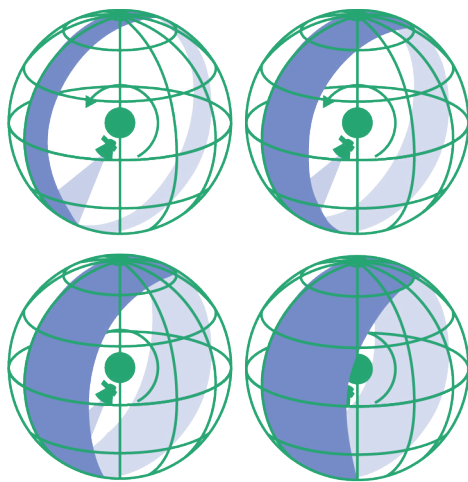
Thirdly, scientists will use SPHEREx's maps to find out more about how the rapid expansion of the universe occurred a fraction of a second after the Big Bang.

Scientists at JPL have been assembling the telescope, joining its various components together into its final form. Some, however, may think this telescope looks a bit odd. Its cone shape looks more like something you may find around a dog's head after going to the vet.

SPHEREx's main telescope uses three mirrors and six detectors shielded by three nested cones. Without this shielding, SPHEREx would be blinded from the light and heat of the Sun and Earth.

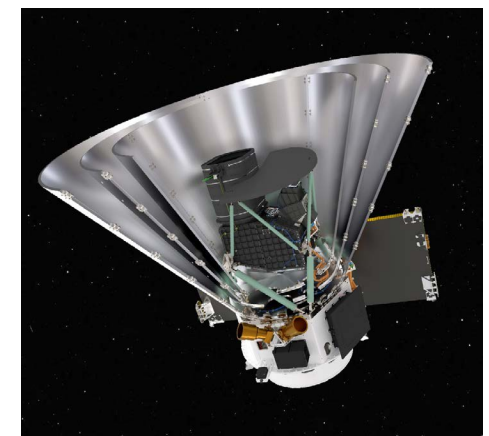
SPHEREx is scheduled to launch aboard a SpaceX rocket from Vandenberg Space Force Base in California by April 2025.

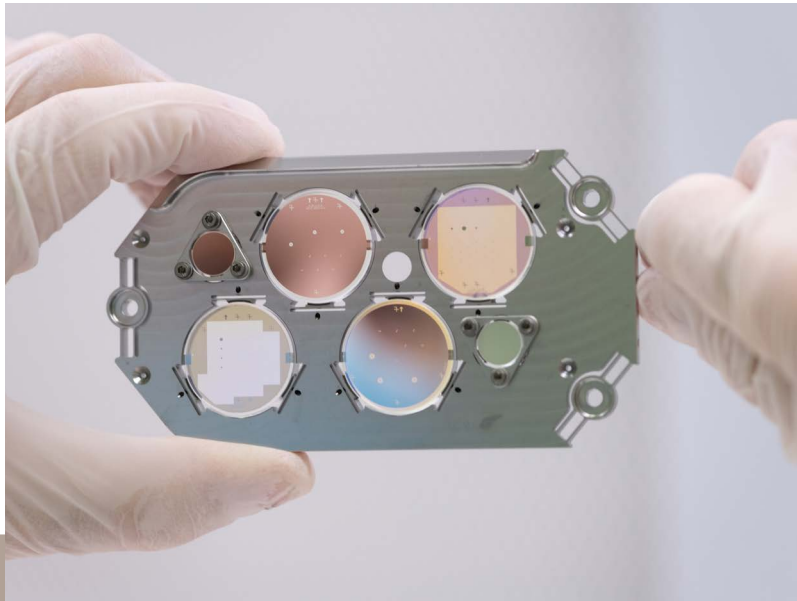
Right: SPHEREx captures multiple successive exposures in a circular sequence, producing a complete spectral sampling of the entire sky twice a year.



Above: A scientist assembles SPHEREx's Medium Wave InfraRed focal plane array.

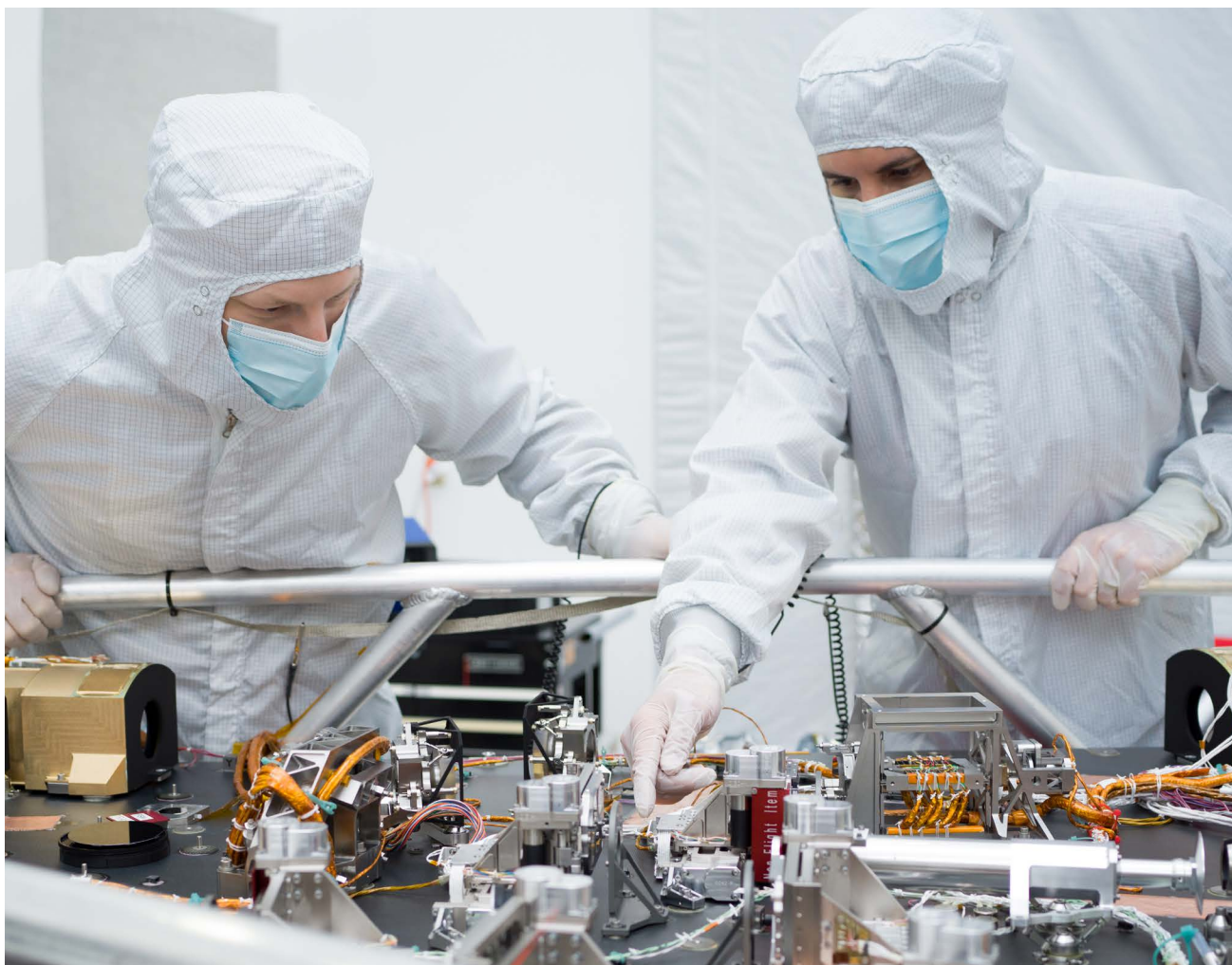
Right: An artist's concept of a cross-section of the SPHEREx telescope in space.





Left: The focal plane mask for the Coronagraph Instrument on NASA's Nancy Grace Roman Space Telescope suppresses starlight, making it possible to see planets orbiting a star.

Below: Members of the Roman Coronagraph Instrument team collaborate on assembling the components of the instrument's optical bench.



A Piano-sized Instrument to Orchestrate Discovery

Scientists have discovered more than 5,000 planets outside our solar system. However, these exoplanets are difficult to directly image for signs of life because light from their host star hides them with its glare.

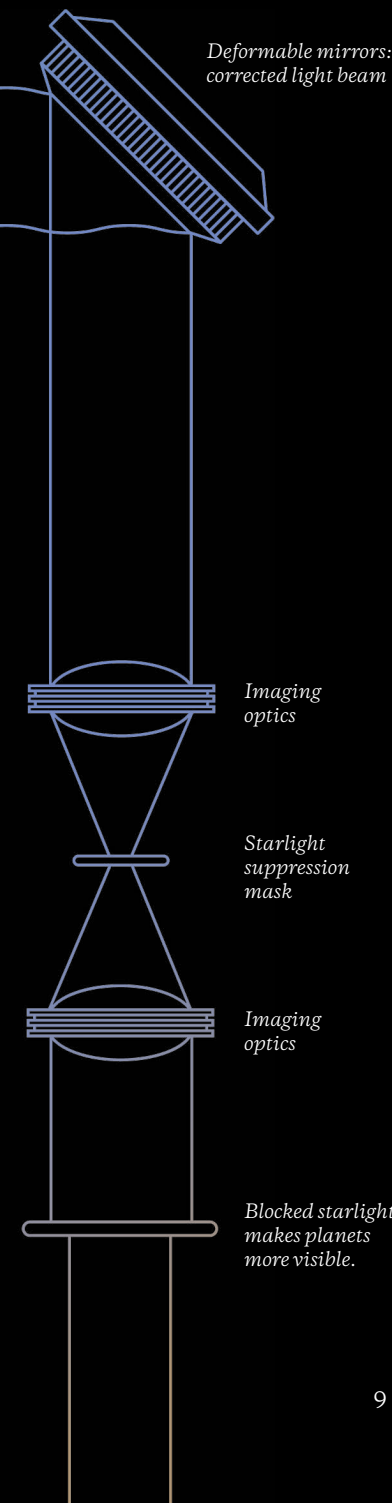
Distorted starlight beam

To block that light, a new instrument is in development: the coronagraph. Roughly the size and shape of a baby grand piano, its deformable mirrors are essential to seeing planets just one ten-billionth the brightness of their Sun.

The Coronagraph Instrument team has already designed the cutting-edge instrument and built the components. With all the pieces assembled, the team kicked off testing the instrument in late 2023 at JPL to make sure all of its components operate as intended. Over the next year, ongoing testing will resemble a well-choreographed ballet that involves heavy duty cranes, lasers, and vacuum chambers the size of buses.

Once complete, the Coronagraph will be shipped to the Goddard Space Flight Center and incorporated into NASA's Roman Space Telescope, which will launch by May 2027, to test this next-generation technology. Following the recommendations of the 2020 Astrophysics Decadal Survey, NASA is laying the groundwork to develop this technology further to enable the Habitable Worlds Observatory mission concept, a telescope that would be as large as Webb, operating in the same wavelengths as Hubble — but designed to find Earth-like exoplanets around other stars and search them for signs of life.

Finding and studying Earth-like planets orbiting nearby stars is critical to understanding whether we are playing life solo or if there are potential duets or more across the universe.



Right: The journey of light through a coronagraph

The Dazzling Edge of Darkness



Above: JPL detectors shown integrated on Euclid's Near Infrared Spectrometer and Photometer instrument

Photo credit: Euclid Consortium/CPMM/LAM

The European Space Agency's latest space telescope, Euclid, released its first five science images in November 2023.

Euclid is the first space telescope dedicated to dark matter and dark energy studies.

Dark matter, an invisible substance five times more common in the cosmos than "regular" matter, can only be observed by its gravitational effect on objects around it, like stars, galaxies, and planets.

Dark energy is the mysterious driver behind our universe's unexplained accelerating expansion. While gravity should pull everything in the universe together, everything instead is moving apart faster and faster.

The new images include views of a large cluster of thousands of distant galaxies, close-ups of two nearby galaxies, a gravitationally bound group of stars called a

globular cluster, and a nebula (a cloud of gas and dust in space where stars form), all depicted in vibrant colors. These targets were chosen to demonstrate the full potential of Euclid's two instruments.

JPL supplied detectors and other critical hardware for Euclid's planned six-year mission to produce the most extensive three-dimensional map of the universe yet, covering nearly one third of the sky and containing billions of galaxies up to 10 billion light-years away from Earth.

In addition, NASA has established a U.S.-based Euclid science data center and is also providing science teams to the mission.

Euclid was scheduled to start routine observations in early 2024, collecting vast amounts of dazzling data on dark matter and dark energy.

Right: Euclid's view of globular cluster NGC 6397 — one of the telescope's first images



Pulling Apart Gravity's Pull

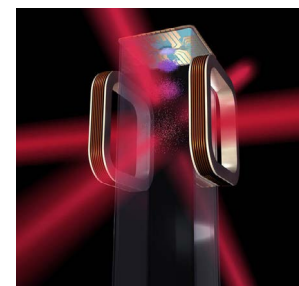
The physical world around us depends on atoms and molecules staying bound together, according to an established set of rules.

But a mystery in modern physics is why the laws of gravity don't seem to match up with the laws of quantum physics, and physicists have been unable to unite them into a single description of the universe.

In August 2023, NASA sent a major update to its Cold Atom Laboratory on the International Space Station. About the size of a small refrigerator, the lab enables dozens of scientists on Earth to do experiments in quantum science, the study of the fundamental behaviors of atoms and molecules. The upgrade will produce two to three times more atoms: That's like upgrading a telescope with higher resolution.

With more atoms, scientists will have new ways of testing theoretical concepts such as the equivalence principle, part of Einstein's general theory of relativity, the backbone of modern gravitational physics. The famous principle holds that gravity and an equivalent constant acceleration are indistinguishable in their effect on objects. An astronaut in a windowless room on Earth or in a spaceship accelerating at a force of 1g would perceive no difference.

This new capability marks the start of an era where it is possible to study not only the quantum properties of atoms, but also quantum chemistry, which focuses on how isotopes of different atomic elements interact and combine with each other in a quantum state. That knowledge will be essential for harnessing the one-of-a-kind facility to develop new space-based quantum technologies.



Top: NASA astronauts (from left) Jasmin Moghbeli and Loral O'Hara work on the Cold Atom Lab aboard the International Space Station.

Bottom: An artist's concept of a magneto-optical trap and atom chip used by Cold Atom Lab

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 met-

als 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.

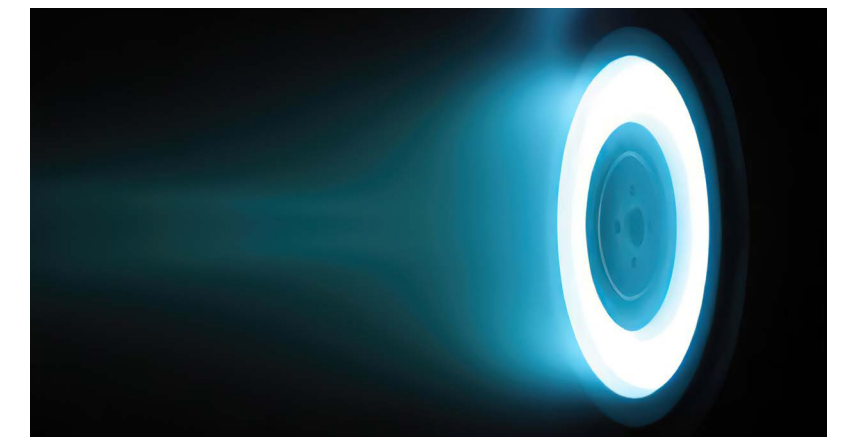
Scientists expect an asteroid belt's worth of surprises when the mission reaches Psyche in August 2029. The spacecraft will orbit at different distances — coming as close as 47 miles — to map the metal world's shape and decipher its internal structure and composition.

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.

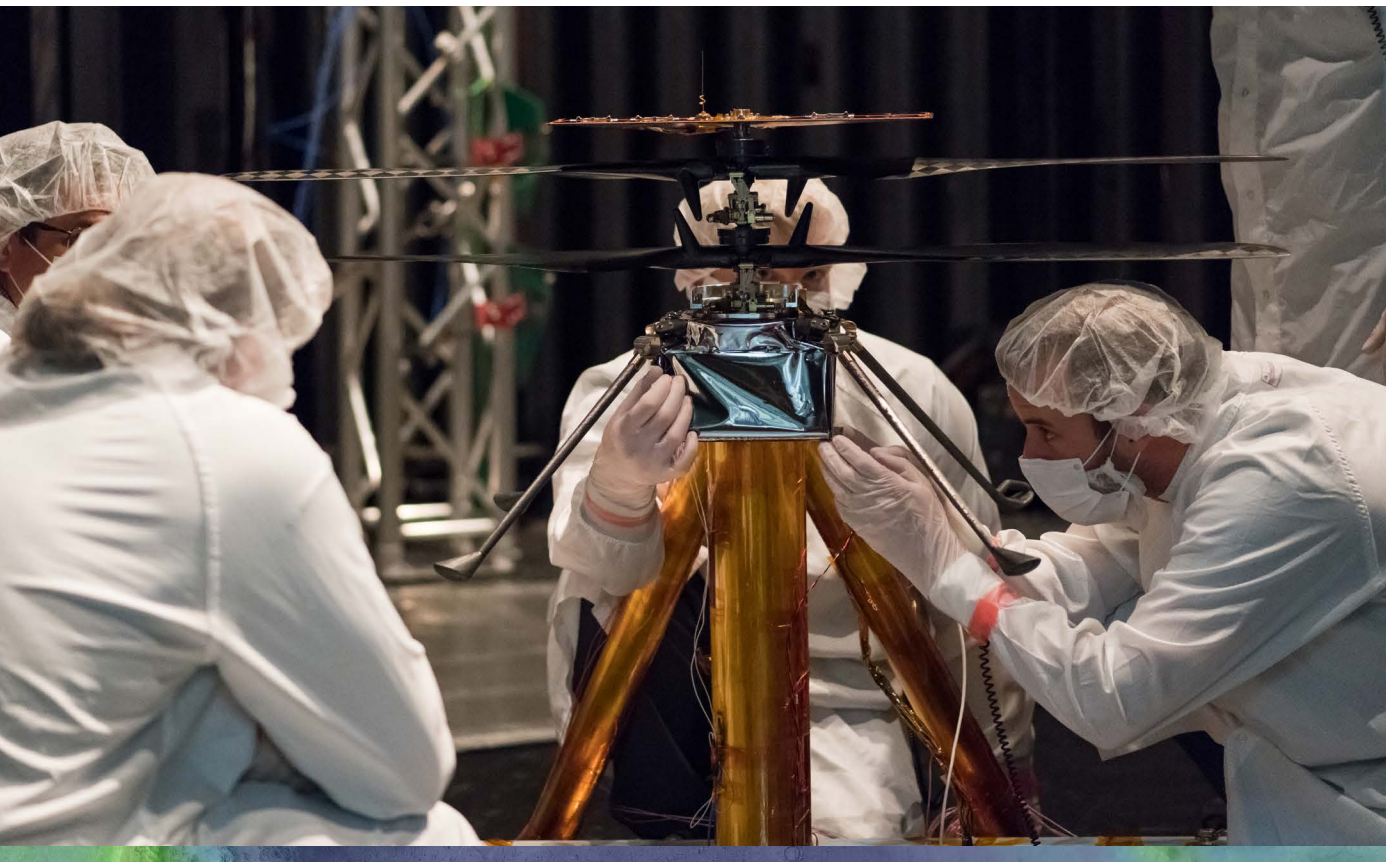
Top: NASA's Psyche spacecraft, atop a SpaceX Falcon Heavy rocket, lifts off from Kennedy Space Center's historic Launch Complex 39A in Florida on Oct. 13, 2023.

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.

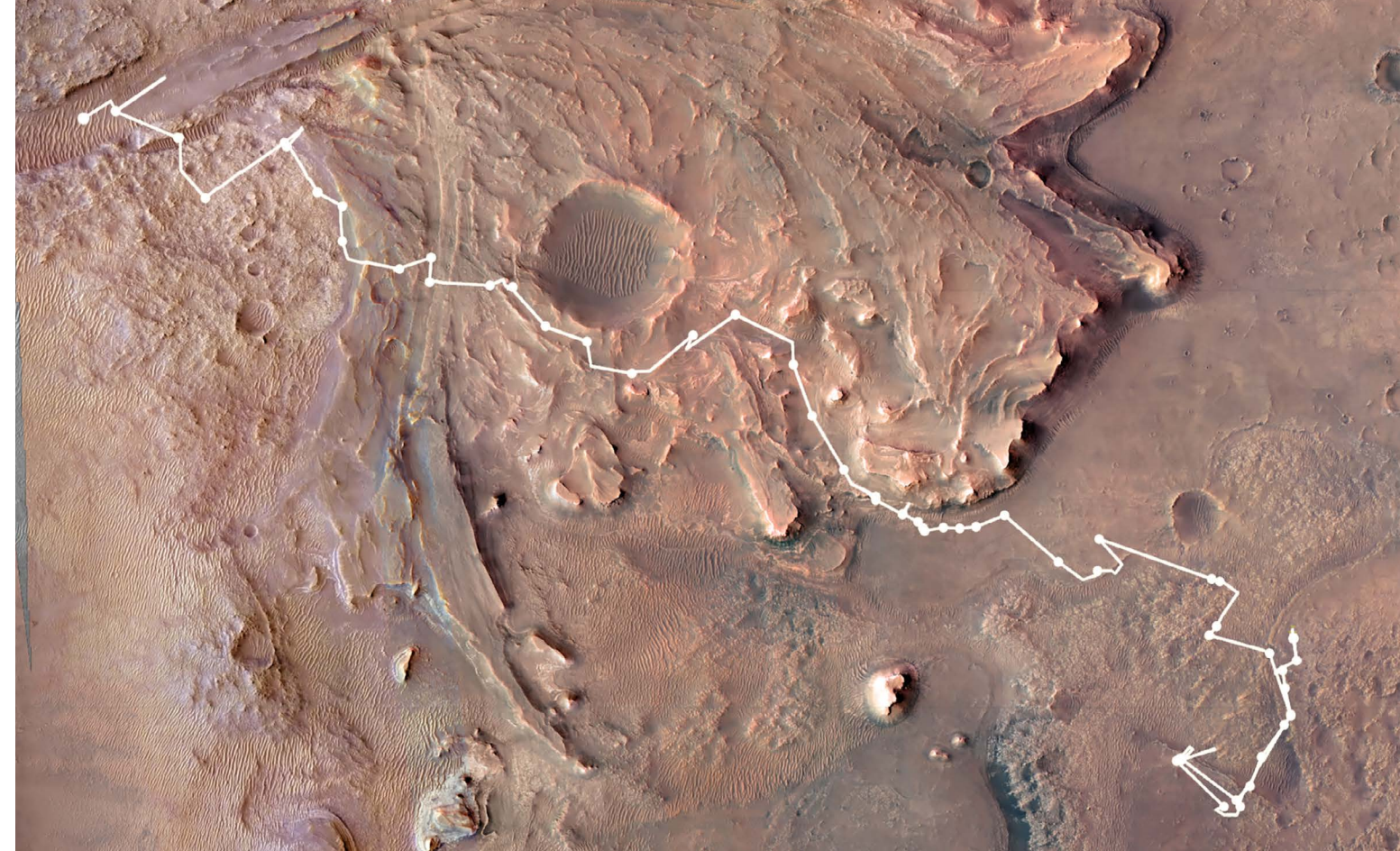
NASA's Ingenuity Mars Helicopter, a 19-inch tall, 4-pound wonder, arrived on Mars in 2021 as a barnacle on the belly of NASA's Perseverance Rover. The little chopper's primary goal was to demonstrate that powered flight is possible on Mars despite the planet's wispy atmosphere, which is 100 times thinner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

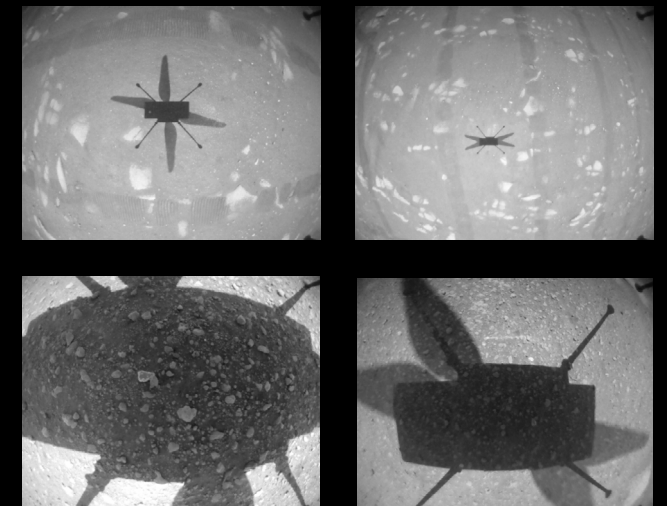


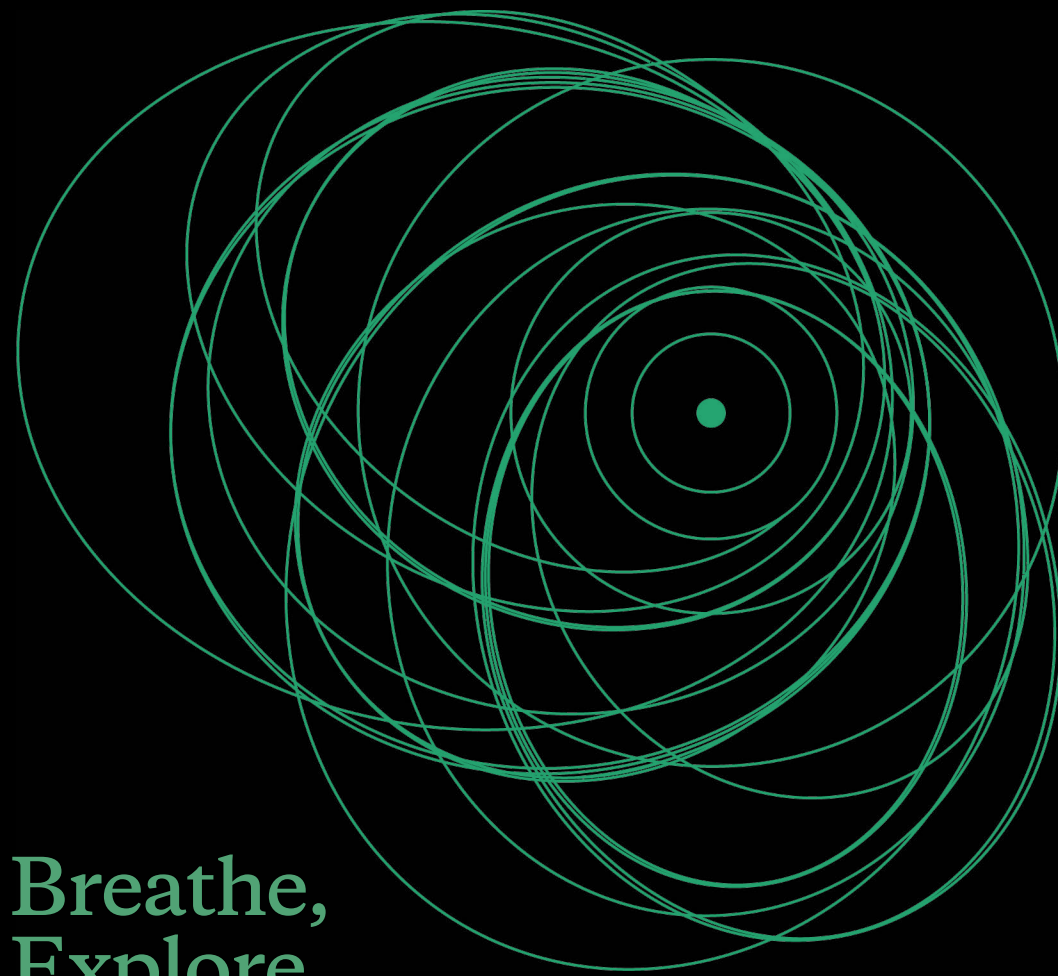
Flight Log

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.

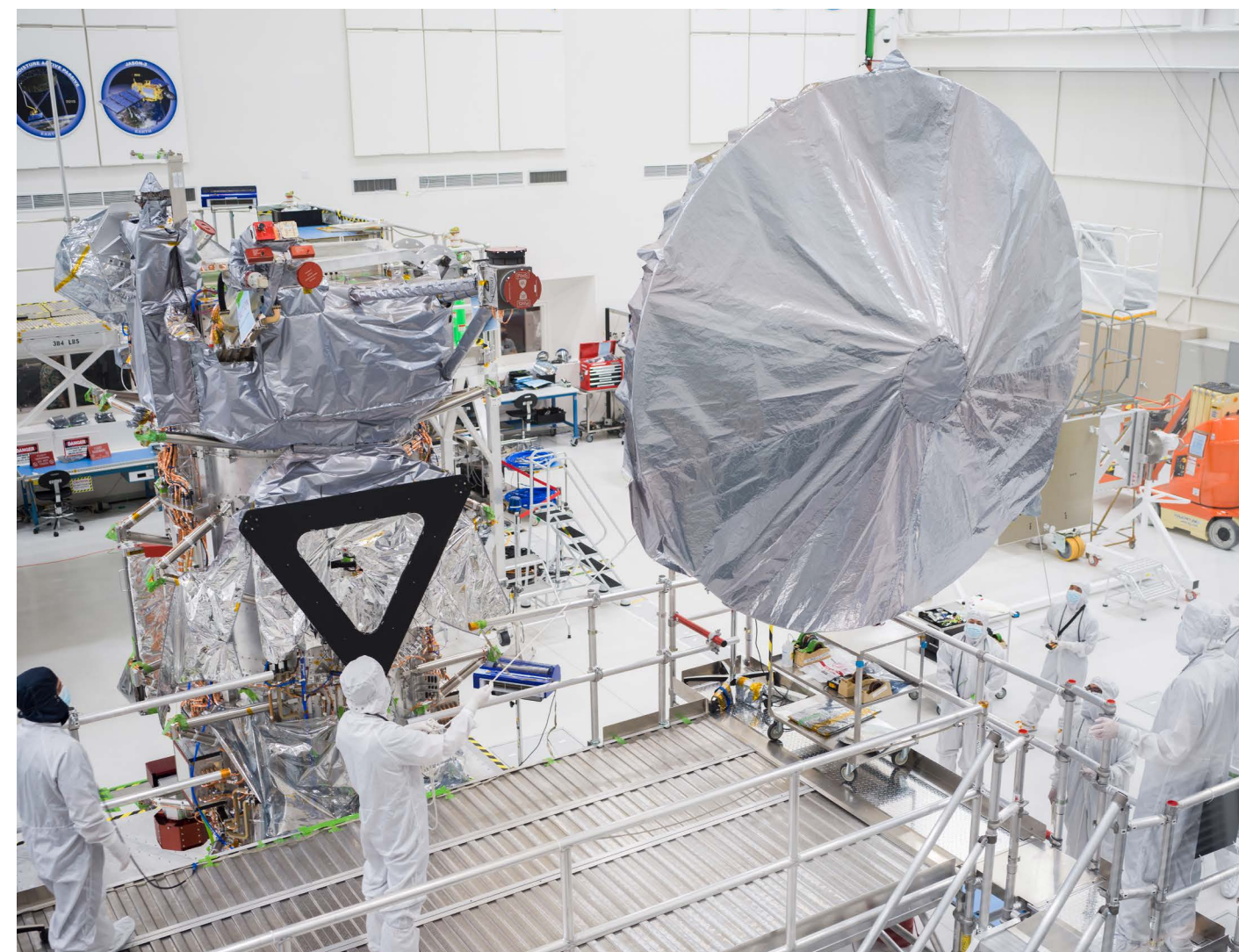
In October 2024, the Europa Clipper spacecraft is scheduled to blast off from the Kennedy Space Center in Florida, reaching its destination in 2030. Once

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.

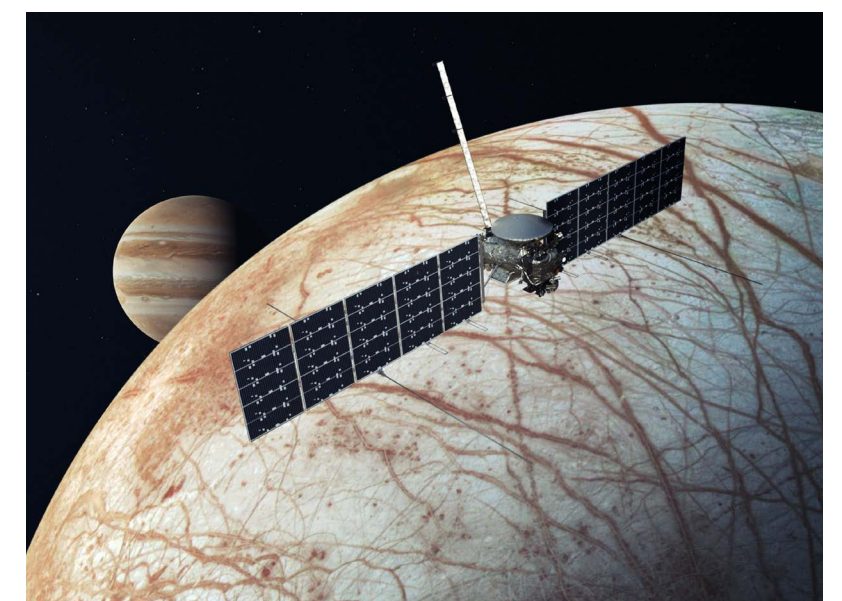
But there's one major obstacle: Jupiter is home to the harshest known radiation belts in our solar system. That's why NASA scientists and engineers designed custom flybys to deal with Jupiter's radiation belts.

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.

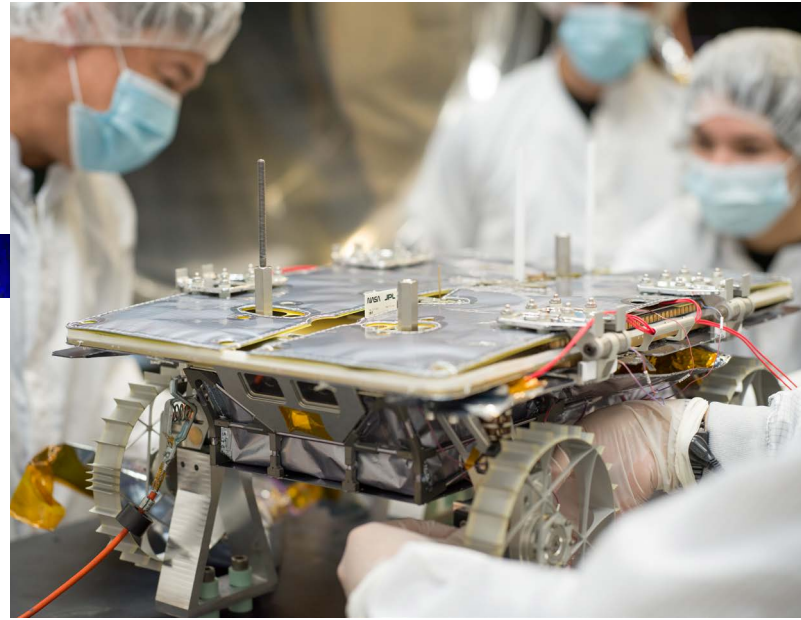
If confirmed to exist, habitable environments on Europa would forever alter the probability of life in the cosmos.



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 can brave the lunar landscape.



Follow the Leader

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

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.

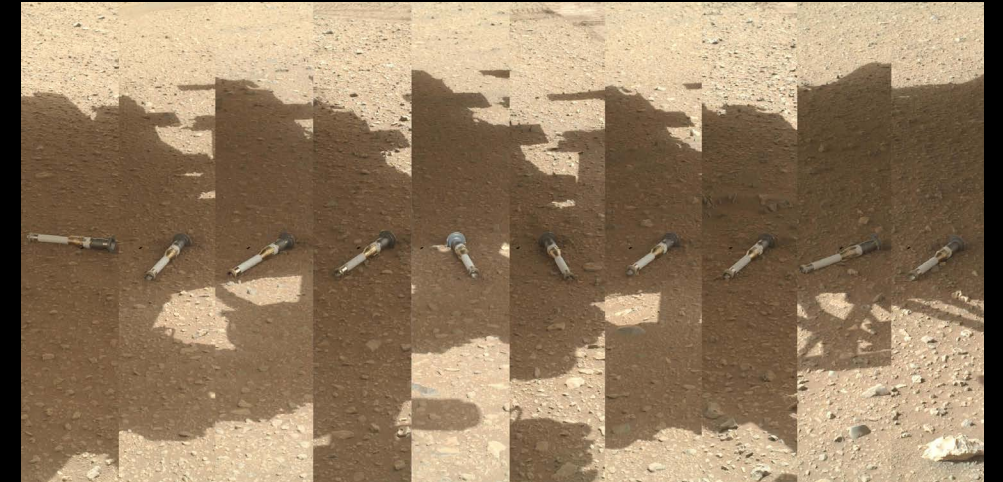
Currently slated to arrive in 2025, the trio will spend about 14 Earth days — the daylight hours of a single lunar day — to carry out experiments on the Moon. In particular, their ground-penetrating radars will work together to create a three-dimensional map of the subsurface beyond the capability of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

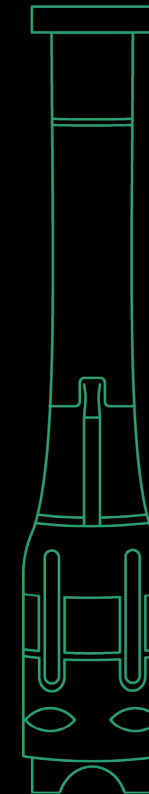
When they simultaneously awaken, they'll share their health status with one another and once again elect a leader based on which is most fit for the task at hand. Then off they'll go for another round of lunar exploration.

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.

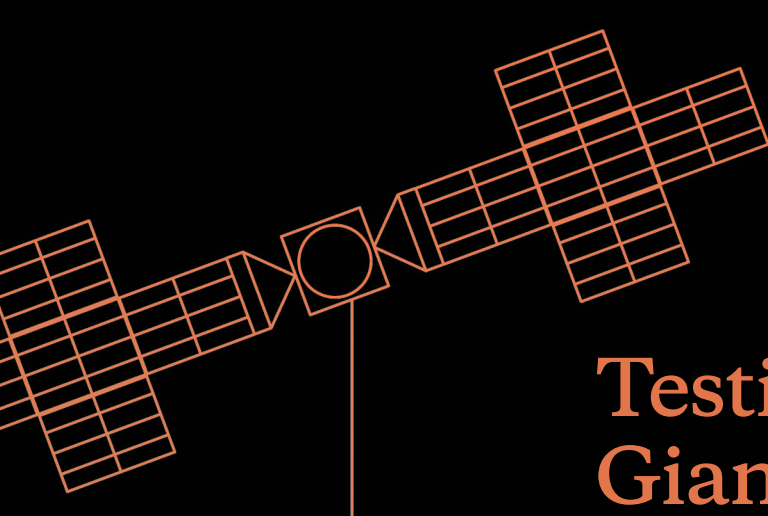
A Mars Sample Return campaign would fulfill one of the highest priority solar system exploration goals identified by the National Academies of Sciences, Engineering, and Medicine in the past three decadal surveys. Returning samples would revolutionize our understanding of Mars by bringing scientifically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

INTER-PLANETARY

As humanity once again seeks to plant its flag on the Moon, return samples from across our solar system, and push farther out into the stars, gentle giants at home — and the engineering experts behind the antennas — help ensure we make the right moves to achieve mission success.

Left: Deep Space Station-14, a 70-meter-wide antenna dish at the Deep Space Network's complex in Goldstone, California





Testing 1, 2, 3... Giant Leap

Until 2023, NASA had used only radio waves to communicate with missions traveling beyond the Moon.

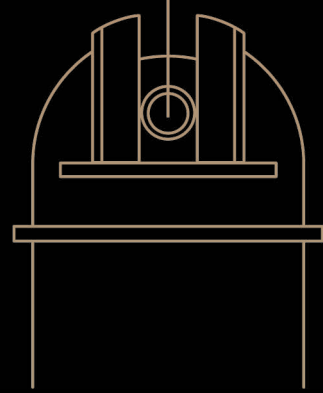
Now, as with the transition from copper phone lines to fiber optics on Earth, the leap from radio to optical communications in space will vastly increase data rates. Multiplied bandwidths will enable more powerful human and robotic missions for probing our universe.

Launched in October 2023 aboard the Psyche mission, NASA's Deep Space Optical Communications experiment is the agency's first demonstration of the technology beyond the Earth-Moon system. DSOC achieved "first light" in the early hours of Nov. 14, successfully beaming test data nearly 10 million miles to Earth. It was the farthest optical transmission in the history of space exploration. But what really got the world's attention? Less than a month later, the farthest video transmission (*see sidebar*).

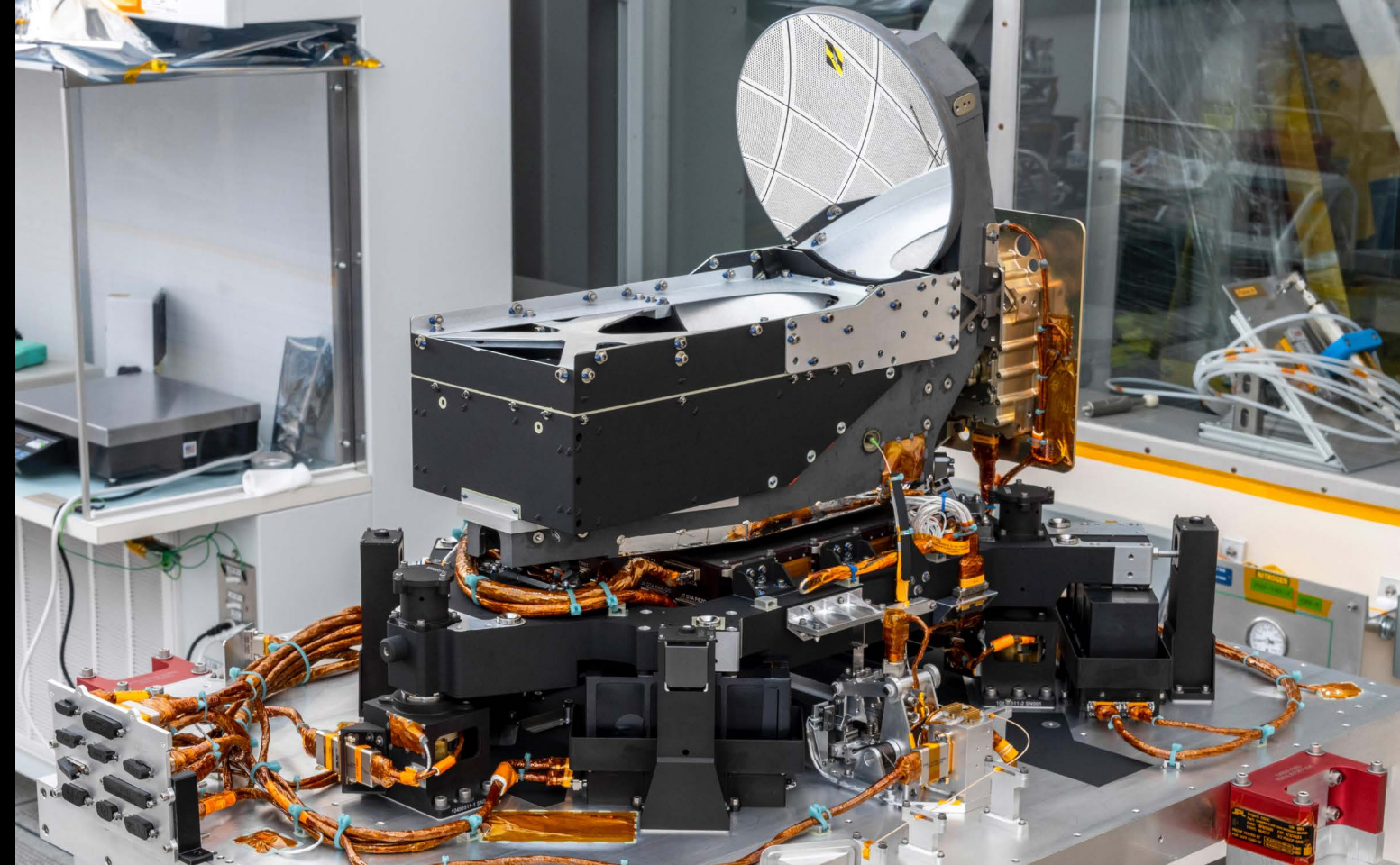
DSOC is forecast to achieve high-rate transmissions over distances up to 240 million miles — comfortably farther than the average distance to Mars of 140 million miles — during the first two years of Psyche's six-year journey to the asteroid belt.

Supported by the Deep Space Network in JPL's Interplanetary Network Directorate, DSOC consists of a flight laser transceiver, a ground laser transmitter, and a ground laser receiver. With first light, the DSOC team is working on refining the system to demonstrate high-bandwidth data transmission at steadily greater distances from Earth.

If it performs as expected, the technology will enable high-rate communications with streaming high-definition imagery to support humanity's next giant leap: setting foot on Mars.

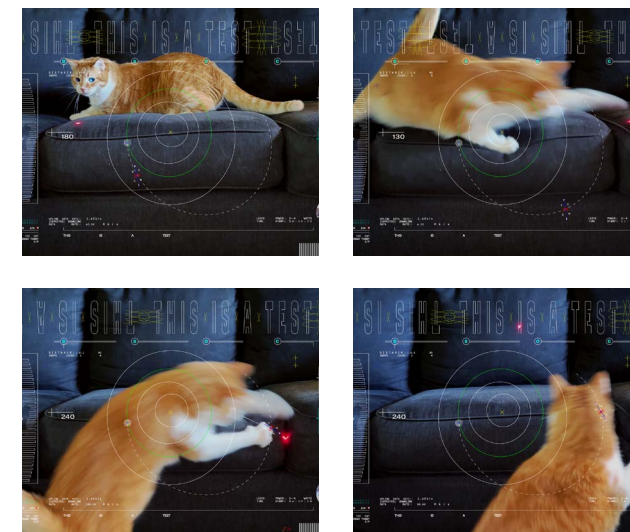


Left: Illustration of Psyche communicating via laser with the Palomar Observatory



Above: DSOC's flight laser transceiver before being integrated with Psyche

Ad Astra, Taters!



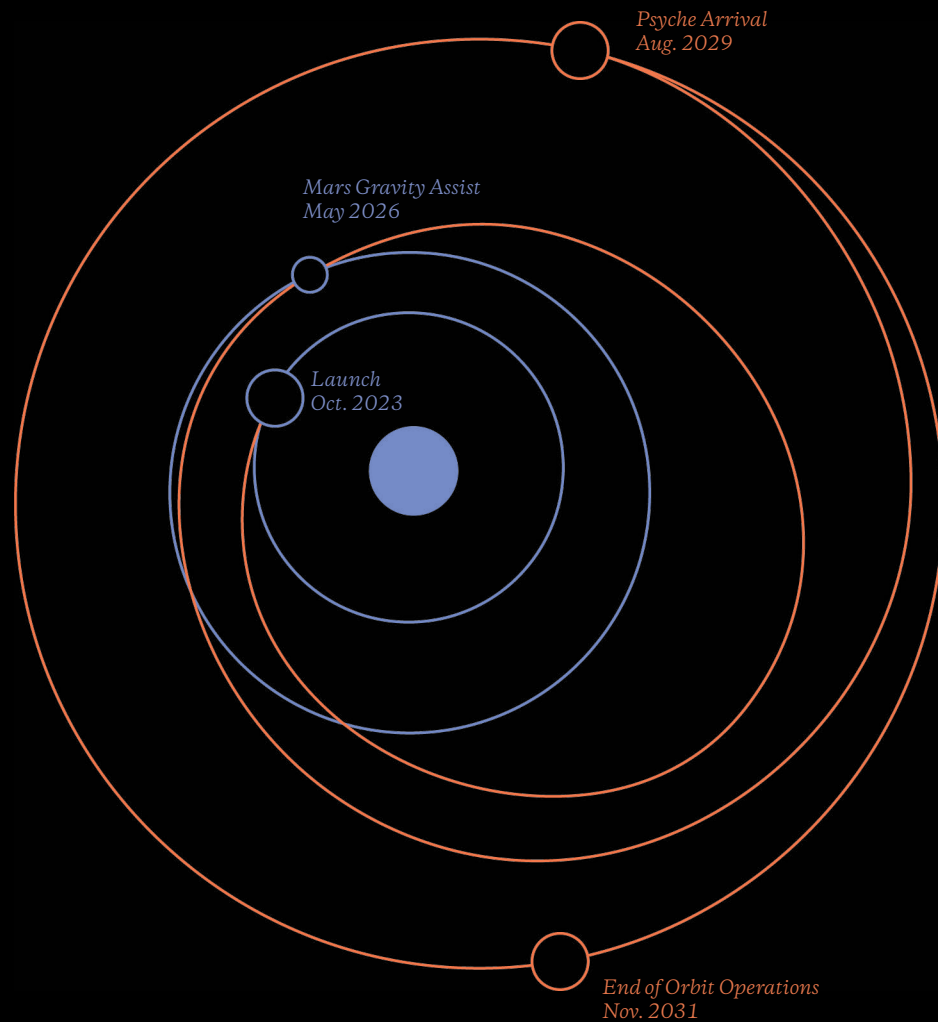
On Dec. 11, DSOC went viral with — what else? — a cat video. That day, a DSN antenna on Earth received an ultra-high definition streaming video from DSOC as an optical transmission from a record-setting 19 million miles away. Uploaded before launch, the 23-second video featured an orange tabby cat named Taters, the pet of a member of the JPL design team that came up with the idea, chasing a laser pointer with overlaid graphics.

The graphics illustrated several features from the tech demo, such as Psyche's orbital path, Palomar's telescope dome, and technical information about the laser and its data bit rate. Tater's heart rate, color, and breed were also on display.

History, as much as popularity, inspired the choice of video subject. In 1928, RCA and NBC tested an invention called television with broadcasts of a small statue of the cartoon character Felix the Cat.

Right: An illustration of Psyche's orbital plan and trajectory

Psyche Orbit ●
Planetary Orbits ●



DSN Tracks Course for Asteroid Prospector

For many nineteenth-century American prospectors, the hope was to strike it rich. The Psyche asteroid mission is banking on a goldmine of insights into planetary evolution and our own world's core.

As it does with all NASA interplanetary missions, the DSN will receive data and send commands to Psyche. Those commands will chart a spiral path to the asteroid that will begin with a ride-along with Mars in May 2026. Psyche will ride along briefly on the Martian orbit, harnessing the Red Planet's gravity, to increase the

spacecraft's speed and adjust its direction toward the asteroid belt.

Psyche will then travel into the main asteroid belt, where the gravity of its namesake asteroid is expected to capture the spacecraft in July 2029. The spacecraft's orbital operations will start in Aug. 2029.

Psyche's cruise, arrival, and orbital paths will accelerate the potential of striking it rich in our understanding of our solar system, our home planet, and the elements common to rocky planets.

NASA Deputy Notches DSN Hat Trick

Below: NASA Deputy Administrator Pam Melroy and NASA Administrator Bill Nelson in front of a giant antenna dish at DSN's Goldstone site

Top right: The massive DSS-23 antenna dish was fabricated in Aviles, Spain, before being shipped to Goldstone.

Bottom right: An antenna dish at DSN's Canberra site in Australia

In summer 2023, NASA's Deputy Administrator Colonel (USAF, Ret.) Pamela Melroy toured all three DSN locations in the U.S., Spain, and Australia, walking amongst the giant antenna dishes that support all of NASA's human and robotic missions.

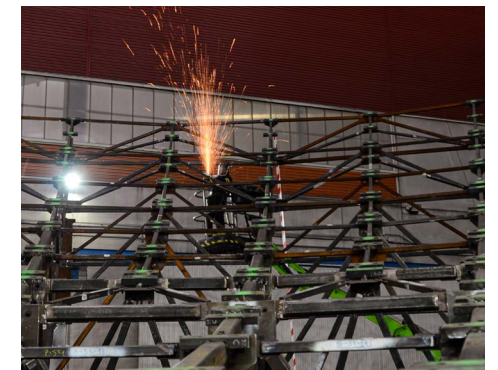
Melroy learned of the improvements DSN will undergo in the next few years to ensure it has the capability to support the human phases of the Artemis program to the Moon and the robotic ventures to explore ever deeper into space. Those improvements include the addition of K-band transmission to two antennas, a necessary upgrade for lunar exploration that is expected to be complete in 2025.

The DSN is also adding a new 34-meter (112-foot) antenna at the Goldstone site in

California. Scheduled to begin transmissions in 2026, the antenna structure and its 3,000 pieces were fully fabricated in Aviles, Spain, with electronics scheduled for installation in 2024.

When these antennas fix their focus on the incoming signal — be it from humans, robots on the surface of other worlds, or spacecraft sailing through the solar system and beyond — they will continue to give the world front-row seats to some of the greatest events in history.

The DSN's silent giants connect us to humanity's reach for the stars and allow us to imagine where we, as a species, go next.



All the Right Moves



Above: OSIRIS-REx sample return capsule shortly after touching down in the desert at the Department of Defense's Utah Test and Training Range

Opposite, top: An artist's concept of OSIRIS-REx landing on the asteroid Bennu

Opposite, bottom: A training model of the sample return capsule parachuting down to Earth during a drop test in preparation for retrieval of the capsule

Seven years after launching to space, the OSIRIS-REx spacecraft flew by Earth in Sept. 2023 to deliver a pristine sample from the near-Earth asteroid Bennu.

Since OSIRIS-REx lifted off in 2016, the DSN team has communicated with the spacecraft through several correctional moves to ensure the success of the mission.

The first move took place three months after launch in Dec. 2016 with the successful firing of its main engines, increasing its velocity by 964 miles per hour and setting up the spacecraft for its gravity-assisted ride in Earth's orbit.

Almost a year later, OSIRIS-REx got its gravity assist, gaining about 8,500 mph to

begin its two-year journey to the asteroid Bennu. Then in 2018, the spacecraft aced its next move with its arrival at Bennu, where it set two records: the smallest body ever orbited (diameter of 1,640 feet), and the closest orbit of a small body, at just 1 mile from the surface.

The spacecraft collected its sample with a flawless touchdown in Oct. 2020 that lasted just six seconds. In May 2021, it set off on a return trip to Earth, traveling 3.86 billion miles in total to Bennu and back.

In its final mission move in Sept. 2023, the spacecraft successfully dropped the sample capsule — containing an estimated 8.8 ounces of asteroid rocks and soil — to Earth a few minutes ahead of schedule.



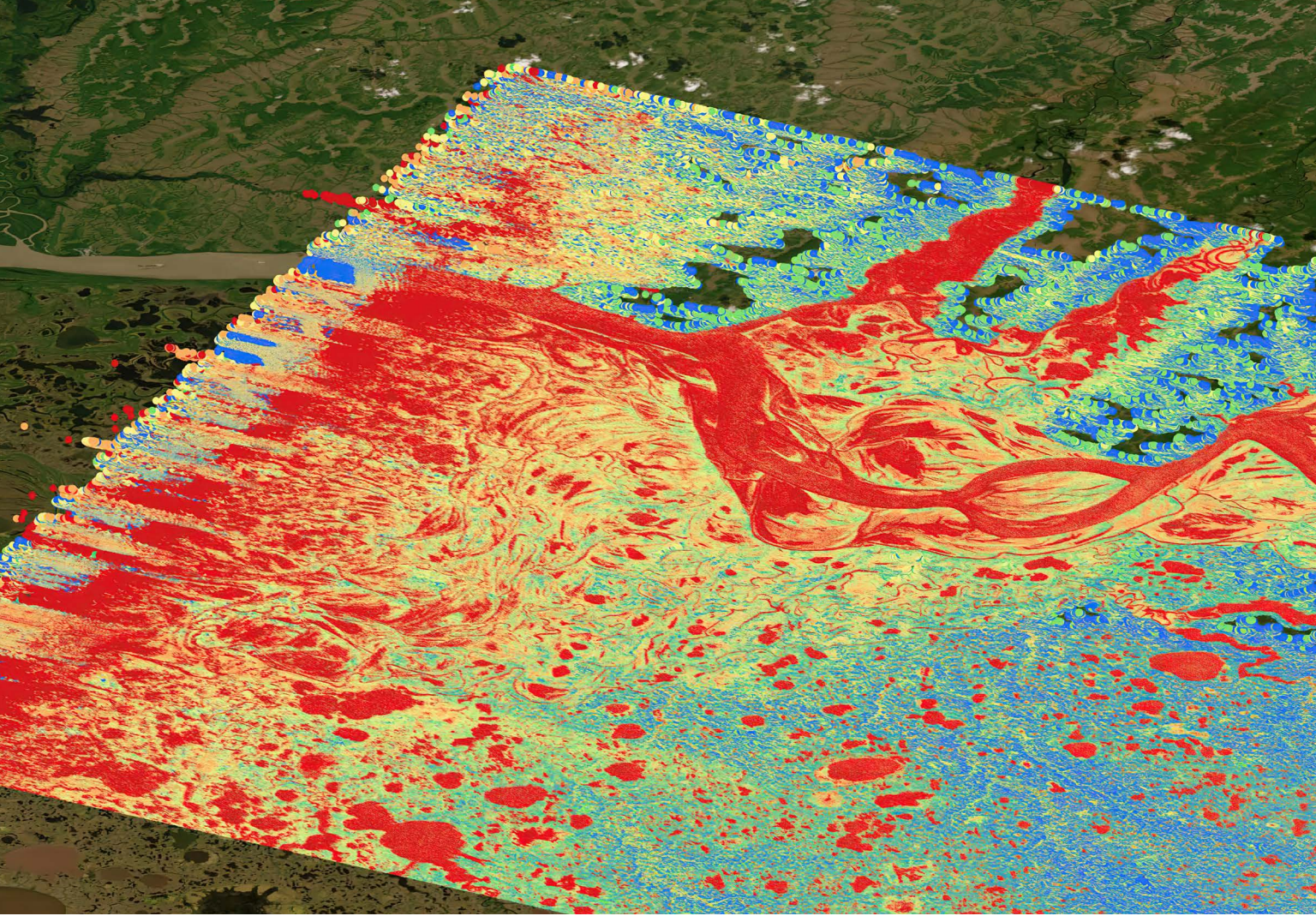
Right: The SamCam imager's view as OSIRIS-REx approached asteroid Bennu's surface to collect a sample

EARTH SCIENCE



Left: An artist's concept of the Surface Water and Ocean Topography spacecraft orbiting Earth

Climate change is here now, impacted by and impacting every population on the planet. Measurement and analysis are critical to adaptation and mitigation. A new JPL mission surveys nearly all the world's lakes and large rivers. Another has spotted hundreds of methane sources. And a future mission will monitor land movements with game-changing frequency.



Raise a Glass... of Water

As the Earth's climate changes, the distribution of water on the planet is also changing.

This is leading to changes in water availability, especially in areas subject to frequent drought or flooding.

The Surface Water and Ocean Topography mission, a collaboration between NASA and the French Space Agency, launched in Dec. 2022 to achieve the first global survey of Earth's surface water, namely rivers, lakes, and oceans, with unprecedented accuracy. Surface water is essential for human consumption, household use, agriculture, hydroelectric power, and many industries.

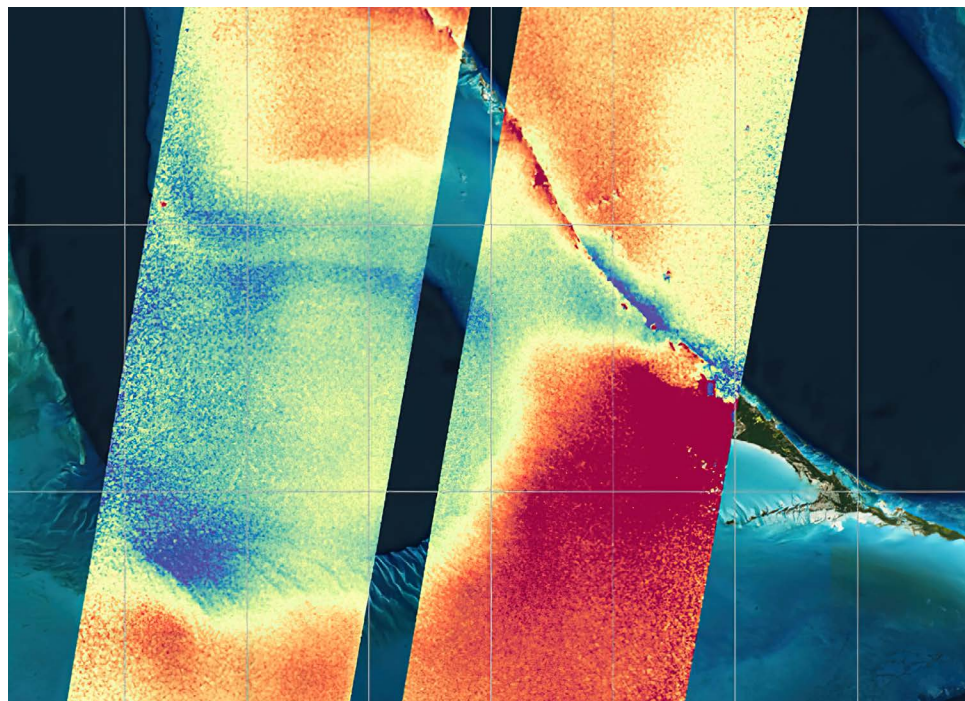
SWOT's performance, as seen in images and data, is already exceeding expectations. Using radar technology, the solar-powered spacecraft scans over 90 percent of the planet every 21 days. It measures 95 percent of the world's lakes larger than 15 acres and gathers data on rivers wider than 330 feet, allowing researchers to better understand how climate change is affecting the planet's water cycle.

The mission's instruments also monitor the oceans, allowing scientists to better track sea level changes. The information will help societies better understand the consequences of sea level rise and develop strategies that support worldwide coastal community and ecosystem planning and

management in the face of increasing tides and surges. With its enhanced spatial resolution, SWOT is also observing finer features in the ocean, providing oceanographers with profound new insights into the transport of energy and nutrients around the globe.

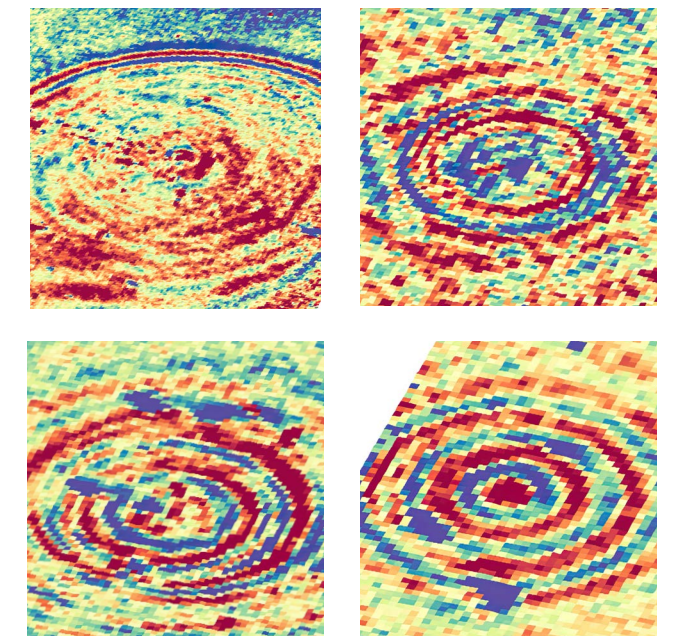
SWOT is expected to continue collecting data for at least three years, delivering the most comprehensive view of the world's surface water. The mission will help improve our ability to predict and respond to natural disasters, such as floods and droughts, and its findings will benefit all decision-making that involves water management.

Next time you raise a glass of drinking water, consider: SWOT has most likely surveyed it and will be back to check on its health.



Above: SWOT passed over the Yukon River in Alaska and recorded this data during a period of calibration and validation, when a mission tests the reliability and precision of its instruments. The satellite aims radar beams at Earth and measures how they scatter off the surface. Backscatter from water tends to be stronger than from solid ground, enabling SWOT to distinguish the two with high accuracy.

Left: The mission also measures variation in sea surface height. These two swaths show the fine details of sea levels in the Caribbean Sea, with red areas representing higher elevations.



Right: SWOT observed circular waves forming around icebergs in polar oceans.

A Side Hustle on the ISS

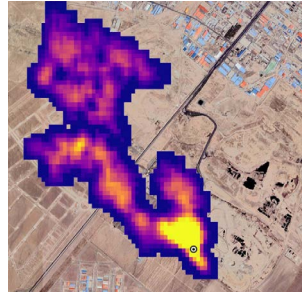
NASA's plan for its Earth Surface Mineral Dust Source Investigation instrument was to focus on the climate impacts of lofted dust particles. But since docking to the International Space Station in July 2022, EMIT has become an unlikely climate hero for a different reason.

EMIT was born from a desire to track Earth's mineral dust cycle. Winds in our atmosphere kick up dust from arid regions and carry the particles elsewhere. These opaque air currents can have significant and predictable long-term climate effects on regions far from the dust source.

The spectrometer on EMIT detected the dust as expected. Unexpectedly, the instrument also showed extraordinary sensitivity to large and small methane emissions, from tens of thousands to just hundreds of pounds per hour. Within weeks of entering orbit, EMIT had become a "super-emitter" detector. It has already identified over 750 point-source emissions, including from landfills, agricultural sites, and oil and gas facilities.

Methane detection is crucial in addressing the climate crisis due to its potent greenhouse effect. Methane is up to 80 times more effective at trapping heat than carbon dioxide. By pinpointing methane emission sources, EMIT enables operators and agencies to mitigate the emissions.

EMIT is still performing its original duties, it's just picked up another climate change fighting side hustle.



Above: EMIT spotted a plume of methane rising from a landfill.

Below: EMIT attached to the ISS in the bottom left of the lattice framework in front of the solar panels



Locking Eyes with Cyclones

The Compact Ocean Wind Vector Radiometer instrument, launched to the International Space Station in late 2021, is delivering critical forecast information for the most devastating of storms: tropical cyclones.

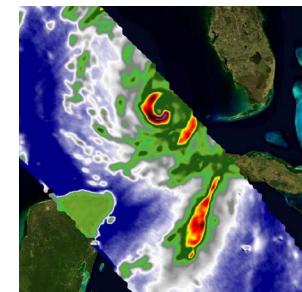
COWVR, approximately the size and weight of a mini fridge, gathers data by measuring microwave emissions from the Earth's atmosphere and surface. The data lets forecasters peer inside the center of storms and understand the processes that generate them.

The eyewall packs the strongest winds within a storm, and as the eye dilates or contracts, the wind speed can change accordingly. Reliable, frequently updated information on wind speed is crucial to tracking storms as they move between Africa's east coast and the west coast of the Americas.

COWVR incorporates technology and designs developed at JPL for the Jason series of ocean-observing satellites. Like Jason, COWVR uses a radiometer built with spinning dishes to enable broader coverage than that provided by an instrument that points straight down. For COWVR, JPL engineers managed to simplify the design, making it more power-efficient without compromising its capabilities.

To date, COWVR data are available for evaluation by forecasters at the U.S. National Hurricane Center. In addition, the Joint Typhoon Warning Center intends to take a closer look at COWVR's surface wind speed and direction data to see how they may improve tropical cyclone forecasts.

All from staring a challenge right in the eye.



Top: COWVR weather instrument aboard the ISS

Bottom: COWVR's view of Hurricane Idalia as it approached Florida's Gulf Coast

Ecosystem Equalizer

NASA and the Indian Space Research Organisation are putting the finishing touches on the NASA ISRO Synthetic Aperture Radar satellite.

NISAR will scan Earth's surface every 12 days, observing the many complex natural processes of our planet — including ecosystem changes, the movements and melting of glaciers and sea ice, and the motion of the land — to better understand earthquakes, volcanic eruptions, and landslides.

The satellite carries two different synthetic aperture radars: one by NASA (the L-band SAR), and one by ISRO (the S-band). NISAR marks the first time the two space agencies are collaborating to develop an Earth-observing mission.

A main focus for NISAR will be Earth's forests and wetlands as they serve as vital carbon sinks, hoarding carbon that might otherwise float in the atmosphere as carbon dioxide and other greenhouse gases.

Forests hold carbon in the wood of their trees. NISAR's data from often cloud-covered rainforests — such as those in the Congo and Amazon basins, which lose millions of wooded acres every year — will improve our understanding of how that loss contributes to global warming.

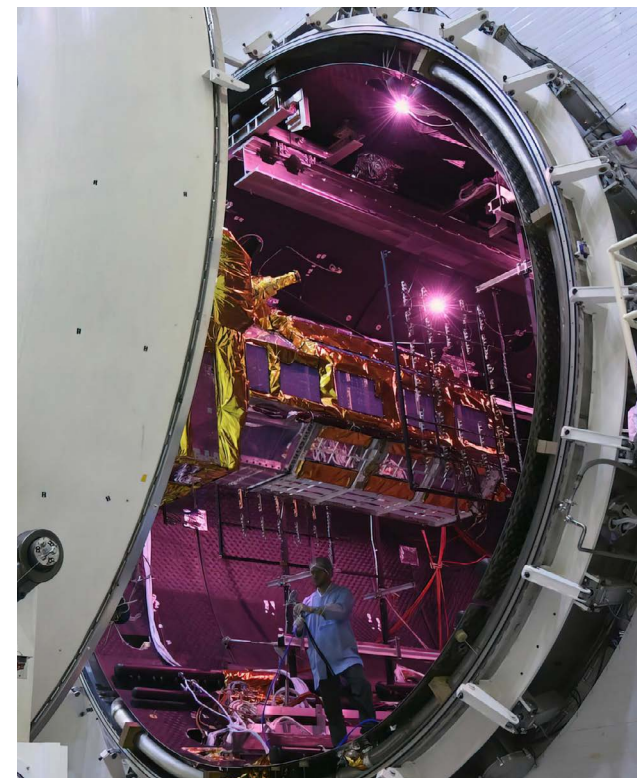
Wetlands present another carbon puzzle: Swamps, bogs, peatlands, inundated forests, marshes, and other wetlands hold

20 to 30 percent of the carbon in their soil, despite constituting only 5 to 8 percent of the land surface.

Tracking these ecosystem changes on a global scale will help researchers understand the impacts on the carbon cycle — the processes by which carbon moves between the atmosphere, land, ocean, and living things.

NISAR is set to launch in 2024 from southern India.

NISAR marks the first time the two space agencies are collaborating to develop an Earth-observing mission.

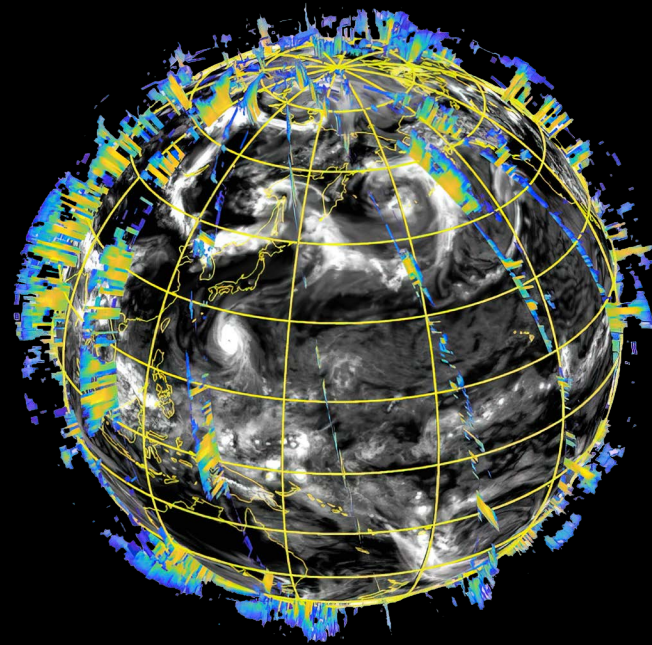


Right: The NISAR satellite enters the thermal vacuum chamber for three weeks of testing at an ISRO facility in Bengaluru, India.



Above: At JPL, the NISAR science payload is packaged for shipment to ISRO headquarters in Bengaluru.

Right: A simulation showing the kind of images that data from the NISAR satellite will produce



Skies Clear over Climate Change

Above: Radar data gathered by NASA's CloudSat satellite on July 31, 2007

Opposite, top: Rendering of the CloudSat spacecraft above Earth's surface

Opposite, bottom: Data collected by the CloudSat spacecraft, which was often combined with other satellites

Clouds once clouded our understanding of climate change.

Clouds exert an enormous influence on our weather and climate and represent a key element in Earth's water cycle, bringing water from the air to the ground and from one region of the globe to another. Clouds also dominate Earth's energy budget through their effect on the exchange of solar and thermal energy.

Because of these factors, even small changes in cloud abundance or distribution can influence the climate. The extent of that influence was a matter of significant scientific debate in the 1990s and early 2000s. Then came CloudSat.

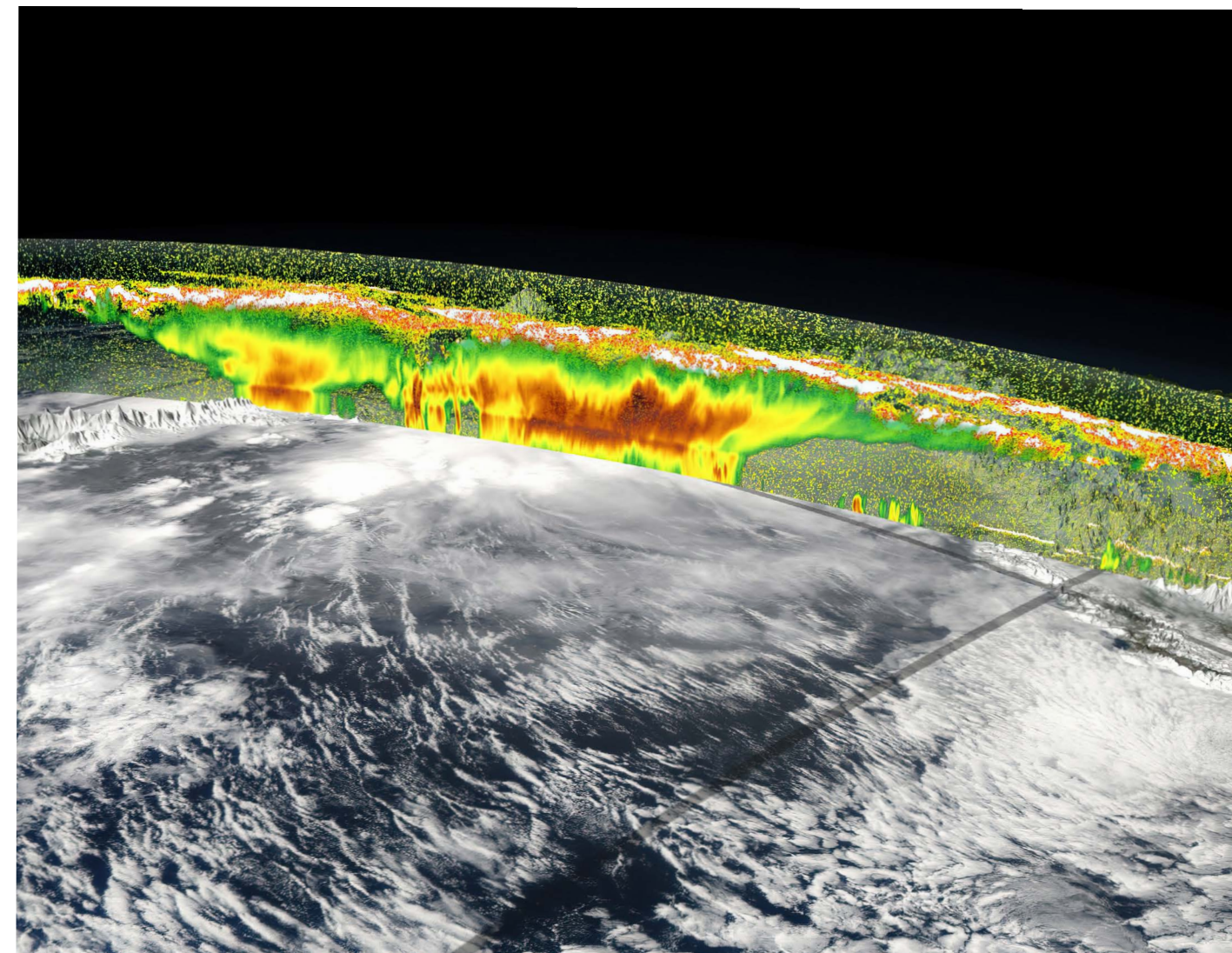
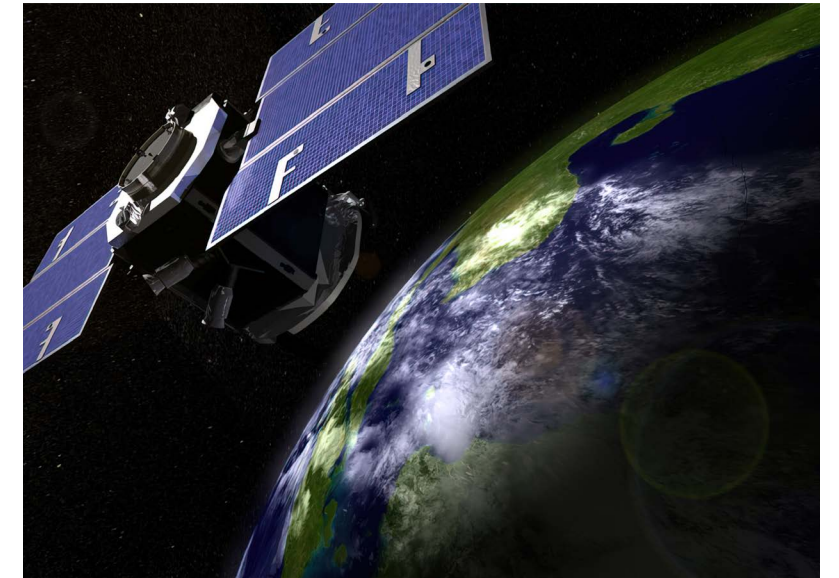
Since 2006, CloudSat has been clearing the clouds on climate change by flying the first "cloud radar" — a millimeter-wavelength radar 1,000 times more sensitive to cloud properties than existing spaceborne radars — to provide the first direct global survey of cloud systems.

For 17 years, CloudSat has presented an unprecedented view of our Earth system that scientists had been long hoping for. Its observations have enabled climatologists to build more sophisticated models with better representations of clouds needed in predicting the effect of climate change and reducing uncertainty in forecasts of the global extent of warming.

CloudSat ran far past its design life, ending its run in Sept. 2023. The project delivered many firsts, including: determining how often clouds rain and snow, how much ice and water are contained in clouds globally, and how clouds heat or cool the atmosphere.

CloudSat has also fostered a global scientific community that will continue to clear our thoughts on how clouds influence the climate.

For 17 years, CloudSat has presented a view of our Earth system that scientists didn't have before.



TECHNOLOGY



Determining the composition of Earth's surface minerals from space, mining and caching Martian rock, detecting single photons from the depths of the cosmos, and expanding the Lab's world-leading store of space navigational knowledge: newly developed JPL technology vaulted from promising to proven in 2023.

Left: JPL sample handling lead observes the mechanisms designed to core, cache, and store future Mars rock samples

Minerals Detective Lifts Prints from Space

High above Earth, a sharp-eyed instrument takes the fingerprints of molecules in Earth's system with exquisite precision.

EMIT, the Earth Surface Mineral Dust Source mission, uses spectroscopy to determine the composition and location of minerals on the surface that can be blown as dust particles into Earth's atmosphere. The sources of mineral dust in arid land regions are poorly understood, but the effects of transported dust in the atmosphere are well-documented, influencing radiation, clouds, terrestrial/aquatic ecosystems, snow, and human health.

EMIT is enabled by new optical technologies from JPL's Microdevices Laboratory. The core of EMIT's unmatched capability is the shaped-groove diffraction grating, written with electron beam lithography, that creates the spectrum (rainbow) in the heart of the spectrometer. These grooves

are precisely shaped to produce tailored diffraction efficiency that keeps the instrument's performance optimal over a broad spectral range, despite solar irradiance, Earth reflectance, and detector quantum variations. EMIT's grating is MDL's largest to date at 92 mm (nearly four inches) and achieves the highest performance, with a straylight control of 1 part in 10,000.

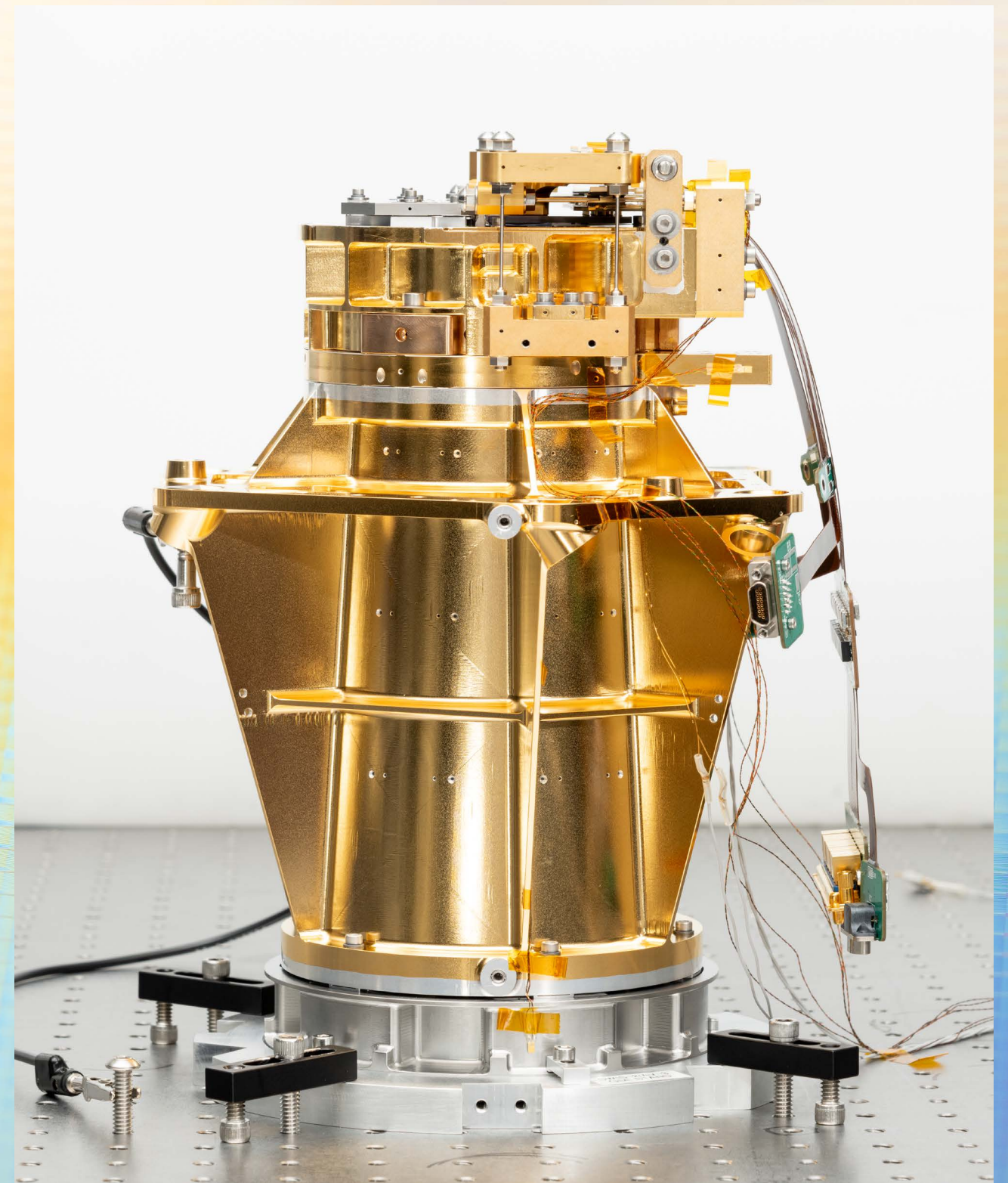
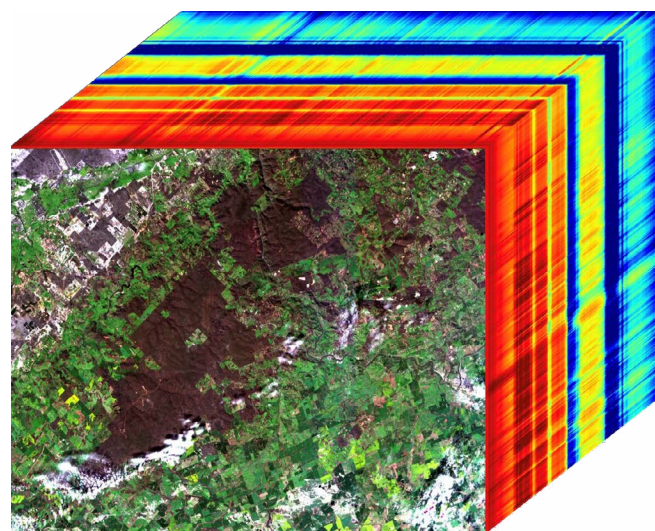
MDL also developed two supporting technologies: a micromachined black silicon slit and a zero-order light trap.

The ideal slit lets light pass in a specified wavelength range without unwanted reflection and misdirection of photons around the slit's edges. The MDL team used a custom process based on electron beam patterning and plasma etching to transform the reflective surface around the slit into a forest of silicon needles that absorbs nearly all light. With this technology, only the photons intended to reach the detector make it to their target.

The same process was used to fabricate a zero-order light trap to absorb un-diffracted light from the grating and prevent it from bouncing around inside the spectrometer.

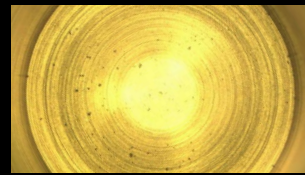
For over three decades, JPL has been perfecting electron-beam lithography techniques for fabricating optical components used in instruments across the solar system. The result, as shown in the Earth Science section of this annual report, is the most advanced and precise imaging spectrometer in Earth's orbit.

Below: EMIT's first measurements as it passed over Western Australia



Above: EMIT's imaging spectrometer contains the grating, slit, and light trap enabled by JPL-invented technology.

The Intricate Sequence before Sample Return



Roubion
Aug. 6, 2021



Montdenier
Sept. 6, 2021



Montagnac
Sept. 8, 2021



Salette
Nov. 15, 2021



Coulettes
Nov. 24, 2021



Robine
Dec. 22, 2021



Malay
Jan. 31, 2022



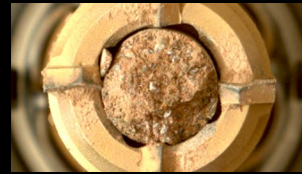
Ha'ahóni
March 7, 2022



Atsá
March 13, 2022



Swift Run
July 7, 2022



Skyland
July 12, 2022



Hazeltop
July 27, 2022



Bearwallow
Aug. 3, 2022



Shuyak
Oct. 2, 2022



Mageik
Nov. 16, 2022



Kukaklek
Nov. 29, 2022



Atmo Mountain
Dec. 2, 2022



Crosswind Lake
Dec. 7, 2022



Melyn
March 30, 2023



Otis Peak
June 23, 2023



Pilot Mountain
Sept. 15, 2023



Pelican Point
Sept. 25, 2023



Lefroy Bay
Oct. 21, 2023

Samples collected by the Perseverance rover through the end of 2023. These samples record the history of the Jezero Crater landing site and may preserve signs of ancient life.



Above: A tray holding 39 of the 43 sample tubes was installed into the Perseverance rover before its journey to Mars in May 2020.

Any samples from Mars returned to Earth in the coming years will owe their existence to JPL developments for drilling, retrieving, and storing Martian rock free of direct human assistance.

The Mars 2020 Sample Caching System allows the Perseverance rover to acquire grainy regolith and solid rock cores for eventual scientific analysis on Earth. A percussive drill is mounted on the end of the rover's long robotic arm, and at the tip of the drill, the teeth of the bit encircle the opening to a sample tube. As the drill sinks into the rock, the core and loosened material collect in the tube.

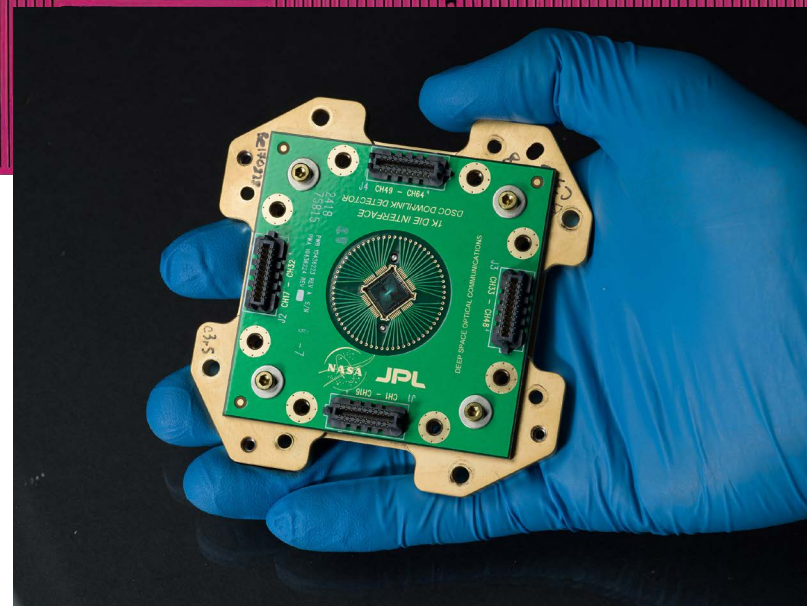
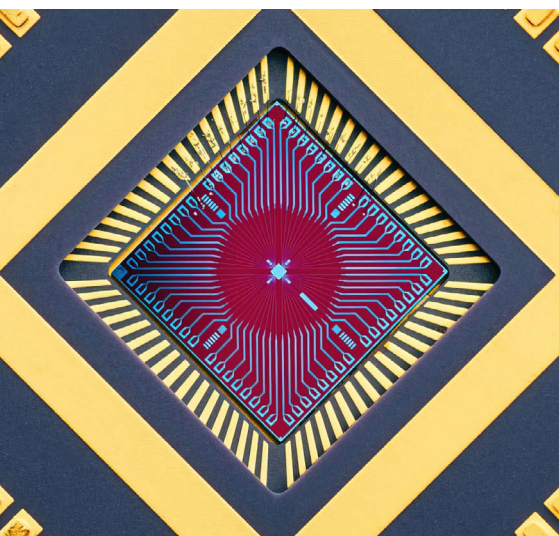
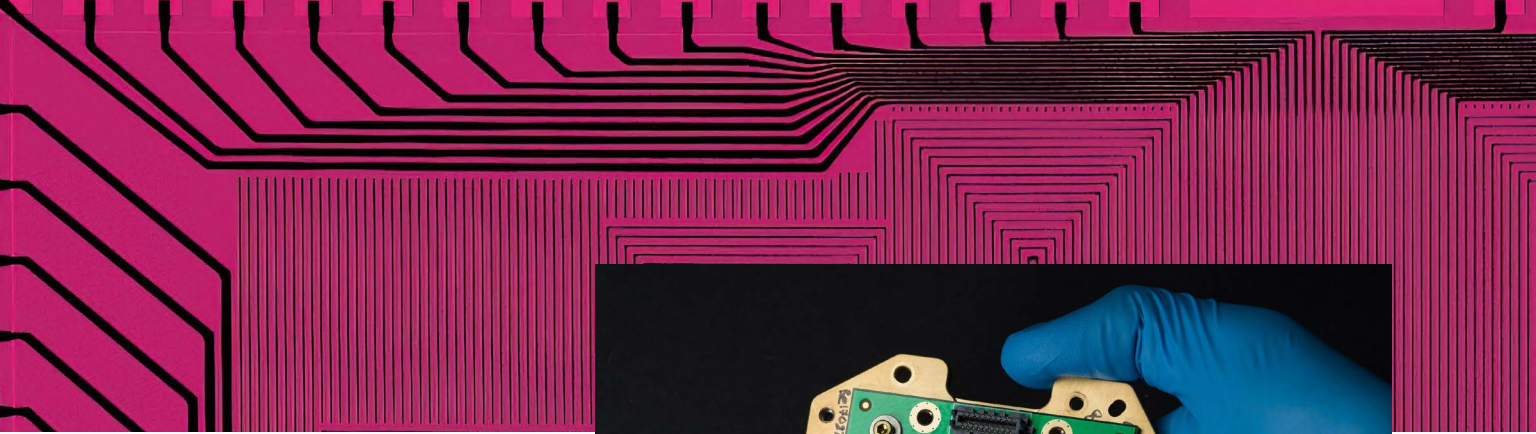
The arm then retracts, docks with the rover, and transfers the tube and surrounding drill bit to an Adaptive Caching Assembly for processing. A small arm within the ACA removes the filled tube from the drill bit and moves the tube through a series of steps

to image the sample, measure its length, hermetically seal the tube, and cache the sealed tube either onboard the rover or on the surface of Mars.

The system comes with six core drill bits, a regolith bit, and two abrading bits for removing weathered outer layers of rock and enabling on-site experiments by the rover's other instruments.

New technologies developed for the system include sample acquisition directly into a tube, tube/bit drop-off, tube sealing and on-board tube storage, along with control algorithms.

Few industrial systems on Earth could carry out this kind of complex sequence with no manual intervention and no maintenance. By the end of 2023, the sampling system did so 23 times, depositing scientific treasures on the surface of Mars and aboard Perseverance.



When Discovery Turns on a Point of Light

Top: Scanning electron microscope image of Superconducting Nanowire Single Photon Detectors array wires

Left: A 64-pixel array of SNSPDs can count over 1 billion photons per second. The array is mounted in a chip carrier and can be efficiently coupled to a 5-meter telescope.

Right: DSOC's SNSPD is coupled to Caltech's 200-inch Hale Telescope. It is designed to receive near-infrared laser signals from the DSOC flight transceiver traveling with NASA's Psyche mission.

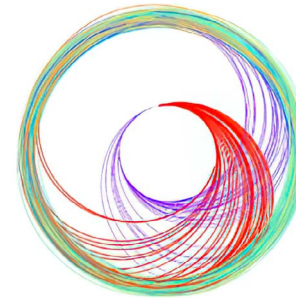
In a *Nature* paper published in 2023, JPL and the National Institute of Standards and Technology announced the development of a single-photon detector 20 times larger than its predecessors and potentially capable of detecting light from planets outside our solar system.

The thermally-coupled imager is an example of a superconducting nanowire single-photon detector. SNSPDs are the highest-performing light sensors available, with efficiency as high as 98 percent in the near-infrared, stray pixel activation (dark count) probabilities under 1 in 100,000, and sensitivity across the spectrum from the ultraviolet to the mid-infrared. The detectors are currently deployed at the Palomar Observatory to receive laser signals from NASA's Deep Space Optical Communication technology demonstration on the Psyche spacecraft.

Further development of the technology is focused on demonstrating SNSPD arrays with broadband efficiency from the far-UV to the near-infrared, as well as raising the technology readiness level of detectors through radiation, vibration, and lifetime testing.

The detectors could figure in planned future missions, such as the Habitable Worlds Observatory, and also serve a critical role in quantum communication and computing, as well as in biomedical imaging.

JPL Cuts to the Chase in Navigation Contest



Above: The graphic trajectory plots of the winning solution to the GTOC 2023 "nearly impossible" problem of interplanetary trajectory

It's not enough to forge a new path. In the forbidding void of space, it has to be the best possible path.

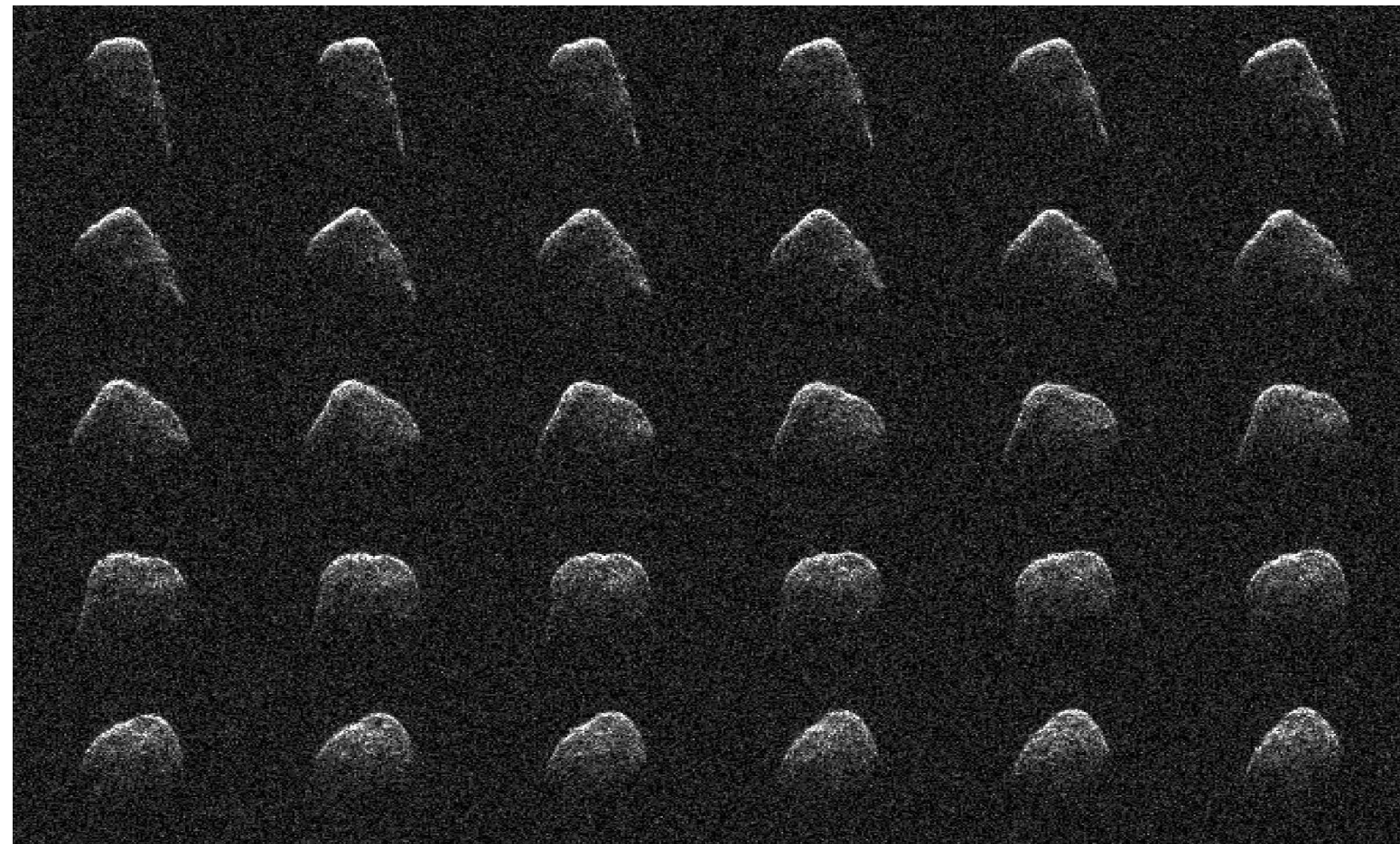
A JPL team in 2023 won the latest edition of the Global Trajectory Optimization Competition. Created by the European Space Agency's Advanced Concepts Team, GTOC is so demanding that only 28 of 100 registered teams submitted solutions in the latest round. Of the 12 competitions held to date, JPL has won five of seven entered and hosted four others.

The 2023 challenge was to maximize the mass of asteroid material brought to Earth over a 15-year time span by a fleet of cooperating spacecraft. Teams had 60,000 asteroid candidates from which to choose. Using electric propulsion, spacecraft had to rendezvous with each chosen asteroid twice: first to drop off a mining craft, then to retrieve the collected mass. Final solutions

were due within one month after the problem statement's release. The JPL solution, involving 35 spacecraft, collected nearly 60,000 pounds of asteroid material, well ahead of the nearest competitor.

Participating in GTOC over the years has prompted innovation in the development and use of JPL trajectory design tools and algorithms. In 2023, the JPL team developed a mixed integer linear programming tool to optimize the asteroid groupings and encounter sequences. This capability, along with well-honed search and preliminary trajectory design capabilities and some experienced insight, allowed JPL to pull ahead of the competition.

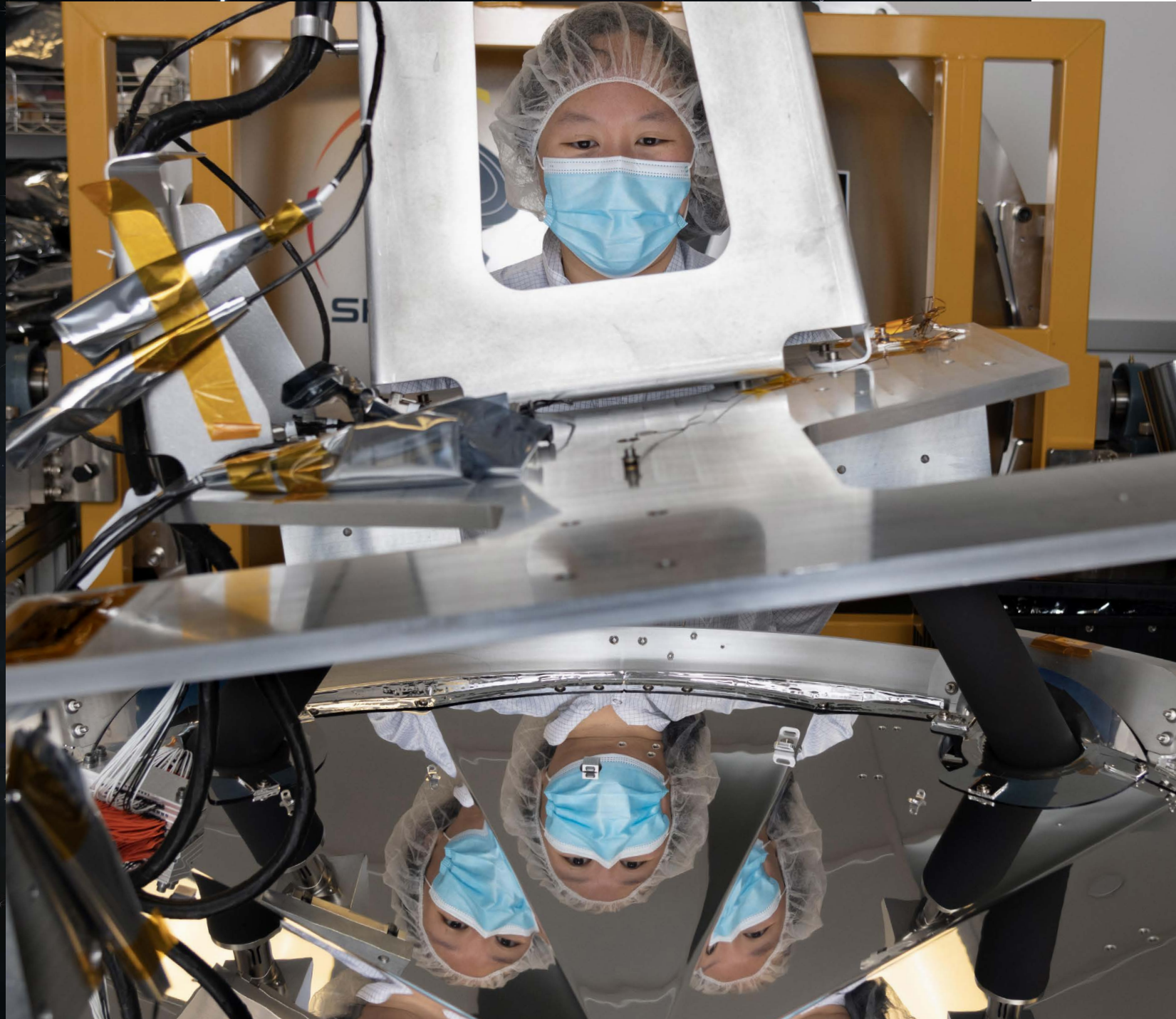
More importantly, these capabilities are used to explore complex trade spaces for new mission concepts, enabling JPL to maximize science while minimizing cost and risk.



"The ingenuity and perseverance necessary to explore the outer reaches of our solar system, to track the changes wrought by a warming climate on our home planet, and to peer deep into the cosmos, can only be achieved by scientists, engineers, and staff who think big, are dedicated to the long term, and work together seamlessly as a team. This is the JPL that inspires all of us at Caltech and uplifts billions of people across the globe."

*Thomas F. Rosenbaum
President, Caltech*

CAMPUS & LAB



Left: To ready SPHEREx for its journey, scientists and engineers at Caltech and JPL have been busy testing the spacecraft's detectors and optics at Caltech's Cahill Center for Astronomy and Astrophysics.

Whether testing the first telescope to map the near-infrared universe, catching a star swallowing a planet, planning to map deposits of water on the Moon, or discovering the true extent of local methane emissions, researchers on campus and on Lab worked together in 2023 to enable the fundamental leaps in knowledge for which Caltech and JPL are known worldwide.

Right: SphereX during testing at Caltech



Mixology for SPHEREx

SPHEREx is getting something like the martini treatment from a grumpy bartender: shaken violently and chilled aggressively.

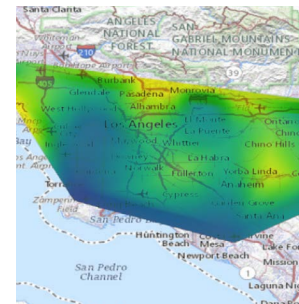
The future space telescope has been shuttling between JPL and campus for hardness testing: bolted to a large mechanical shaker on Lab to mimic the vibrations of launch, and cooled to minus 350 degrees Fahrenheit in an SUV-sized chamber at Caltech's Cahill Center for Astronomy and Astrophysics to simulate the permafrost of space.

Once thoroughly tested, the telescope will be shipped back to Ball Aerospace in Boulder, Colorado, where it was built, for integration with the rest of the spacecraft in March 2024. Launch is scheduled for no later than April 2025.

The bullhorn-shaped telescope will create the first map of the entire sky that extends into the near-infrared spectrum, capturing both visible images and unseen structural details for hundreds of millions of stars and galaxies. The telescope also will study the abundance of water and other ices in regions where stars and planets form — to better understand how water arrived on Earth.

SPHEREx is managed by JPL for NASA's Astrophysics Division within the Science Mission Directorate. Mission data will be processed, archived, and made available to scientists and the public by Caltech's IPAC.

Local Methane Emissions Far Greater than Estimated



Above: Map of average methane enhancements from local emissions in the Los Angeles Basin from January-March, 2023

Below: The CLARS facility overlooks the Los Angeles basin.

Photo credit: R. Duren

You can try to measure gas emissions in a city by adding up all the leaks you find, or you can go to an overlook and sweep the whole basin. Caltech and JPL researchers have found that counting leaks misses a ton — or many tons — of methane emissions.

Their study, published in *Nature Communications* in September 2023, shows that methane emissions in the Los Angeles region have decreased 1.6 percent per year over the past decade. The local gas company had estimated that emissions were going down nearly 6 percent a year, but that estimate was based on ground-level measurements that likely missed many sources.

The discrepancy matters not only for environmental reasons, but because a 2014 California law requires a 40 percent reduction in statewide methane emissions by 2030 from 2013 levels. The study shows that the measurement method is of critical importance in determining compliance with the law.

Caltech and JPL researchers used the California Laboratory for Atmospheric Remote Sensing-Fourier Transform Spectrometer to scan the atmosphere over the Los Angeles basin from the Mount Wilson Observatory. Seeking to identify molecular signatures in the air, CLARS-FTS spent the last decade collecting data on the area's fluctuating levels of methane, a powerful greenhouse gas and key contributor to climate change.

By measuring methane levels across the whole basin from a higher vantage point, the researchers were able to provide a powerful check on the sum of ground-station point measurements.

"It's not enough for an industry to regulate itself," the researchers concluded. "As the country's leader in setting environmental standards, the state needs to expand its current work in the measurement, reporting, and verification of natural gas emissions from all sectors of the economy."



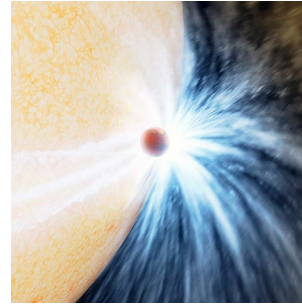
An Interstellar Feast

For the first time, astronomers have caught a star in the act of swallowing a planet whole. The sun-like star lies about 12,000 light-years away in our galaxy and appears to have engulfed a Jupiter-sized gas giant.

The star was spotted by the Zwicky Transient Facility, which scans the skies every night from Caltech's Samuel Oschin Telescope at Palomar Observatory near San Diego. ZTF observations showed that the star brightened greatly and then began to fade in a matter of days. Parallel observations on JPL's NEOWISE space observatory showed that the star's infrared radiance increased steadily about nine months before ZTF caught the visible flash of light.

The astronomers realized that NEOWISE was detecting dust created as a planet spiraled into the star's atmosphere and skimmed the star's surface, pulling hot gas off the star that drifted outward and cooled. The planet then plunged into the core of the star, triggering the flare of optical light registered by ZTF. NEOWISE is still detecting the infrared glow of the new dust, which continues to escape the star.

Astronomers had theorized that older stars could swallow their inner orbiting planets, but direct evidence for such an event had been lacking. The confirmation helps clarify scientists' understanding of the fates of solar systems, including our own.



Above: This artist's impression shows a doomed planet skimming the surface of its star.

Below: In 2017, ZTF team members installed the 605-megapixel, wide-field camera at the prime focus of the 48-inch Samuel Oschin Telescope at Palomar Observatory.



Left: Lunar Trailblazer undergoes testing at Lockheed Martin

Photo credit: Lockheed Martin Space

Lunar Trailblazer to Lead Humans to Water

NASA's Lunar Trailblazer mission will fill out the sparse inventory of water ice on the Moon, potentially aiding future explorers and settlers.

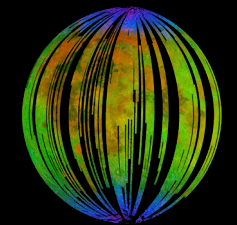
The small satellite will carry two instruments: JPL's High-resolution Volatiles and Minerals Moon Mapper, and the Lunar Thermal Mapper, built by the University of Oxford and contributed by the U.K. Space Agency. Once orbiting the Moon, Lunar Trailblazer will use HVM³ to map the spectral fingerprints of the different forms of water over the lunar landscape. LTM will scan those regions to characterize their surface temperatures. Together, the instruments will enable scientists to determine the abundance, location, and form of lunar water, building upon current knowledge of the presence and distribution of water on the Moon.

Scientists will also use Lunar Trailblazer to detect other potential icy volatiles. The chemical makeup of these ices could provide additional clues about the origin of the Moon's water.

Applications from any obtainable water would range from purifying deposits for drinking to processing them for fuel and breathable oxygen.

Having undergone final assembly and system-level testing at Lockheed Martin Space in Littleton, Colorado, Lunar Trailblazer is on schedule to ship to Florida for final preparations and launch in late 2024.

Lunar Trailblazer is one of five missions of NASA's Small Innovative Missions for Planetary Exploration. SIMPLEX selects high-risk, low-budget small spacecraft to explore other planets, moons, and asteroids. The mission is managed by JPL, and its science investigation and mission operations are led by Caltech. JPL also provides project systems engineering, as well as mission assurance, trajectory design, and navigation.



Above: NASA's Moon Mineralogy Mapper found small amounts of water and hydroxyl (blue) on the surface of the Moon.



Above: Illustration of the type of orbit paths Lunar Trailblazer will take over the surface of the Moon

COMMS & EDUCATION



When NASA decided to improve the visitor experience in its physical and virtual lobbies, the agency turned to JPL's Communications and Education Directorate. The Lab also dove into home improvement, hosting thousands of visitors and completing a monument to its founders. Students descended on JPL for prestigious competitions, and the Lab's missions inspired fans, creators, and even a poet laureate.

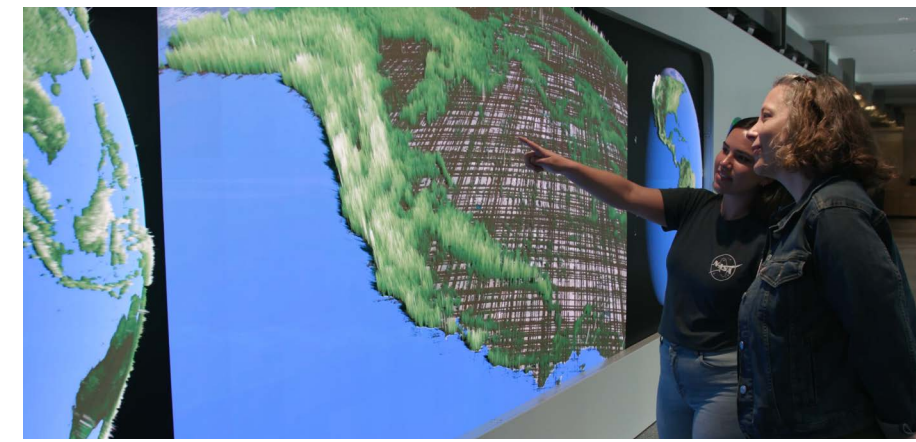
Left: Summer interns gathered for a group photo by the JPL sign located on the Mall.



Above: Visitors to the Earth Information Center in Washington D.C. experienced the “Space for Earth” exhibit.

NASA Makeover Made in Pasadena

Communications and Education Directorate teams championed NASA initiatives from the front door of the agency’s head office to the lowest level of its virtual home.



Top: EIC visitors viewed the large hyperwall that displays real-time Earth data.

Bottom: NASA Administrator Bill Nelson spoke before the EIC ribbon-cutting ceremony at NASA Headquarters on June 21.

Inside the lobby of NASA’s D.C. headquarters, the Earth Information Center opened in June 2023, realizing NASA Administrator Bill Nelson’s dream of building a “mission control” center for Earth. The exhibit offers public access to real-time Earth science and climate data in an immersive design that lets visitors engage with data-driven artistic representations of Earth’s interconnectedness and changing vital signs. A DesignLab team partnered with NASA Headquarters and Goddard Space Flight Center’s Science Visualization Studio for many components of the EIC, with JPL designing and developing the Earth Pulse sculpture, the hyperwall, the “Space for Earth” experience, the “Eyes on Earth” kiosk, and the 16-foot red NASA worm logo outside the lobby doors.

Other crucial support for the agency’s mission took place mostly out of public view. Another DesignLab team — working with partners across NASA — led an extensive transformation of NASA’s web presence. This multiphase effort involved gathering more than 23,000 web pages under a single architecture and rebuilding all content behind the browser into a JPL-configured management system. The first beta sites launched in July, followed by the September launch of the flagship nasa.gov and science.nasa.gov domains.

The Lab Reopens and Inspires

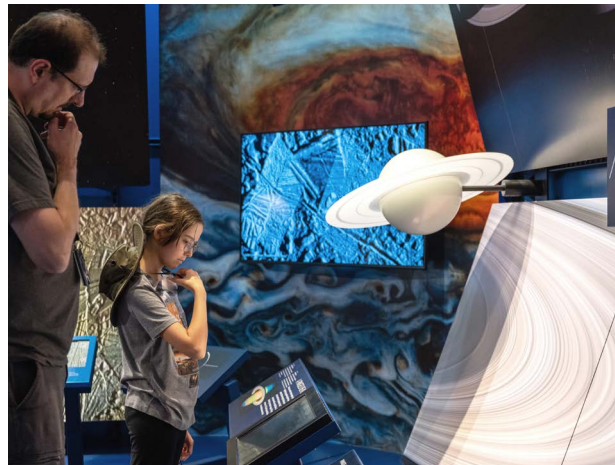
Open for Exploration

After more than three years of pandemic-imposed restrictions, the Lab again welcomed crowds of space fans for Explore JPL. More than 600 red-shirted JPLers spread out to greet, guide, and educate 23,000 visitors over the span of a weekend in April. In nearly every nook and cranny on Lab, guests enjoyed displays, models, robots, science exhibits, and the opportunity to speak with scientists, engineers, researchers, and other JPL employees.



Kids at Work

Late summer brought another wave of curious onlookers when more than 650 young enthusiasts took part in activities across the Lab for Take Our Children to Work Day. Kids enjoyed stomp rockets, inflatable planetariums, robot races, and a group photo with Director Laurie Leshin as they learned about the projects and missions their family members were working on at JPL.



Reevaluating our Origins

A year of return to tradition also brought reevaluation of JPL's origins. In May, Director Laurie Leshin, Deputy Director Larry James, Chief Inclusion Officer Neela Rajendra, and the Asian American Council unveiled a physically and metaphorically transparent update to the 1968 Founders' Plaque. Created by the Lab Engagement team, the glass overlay contextualizes and names all founders and supporters involved in the rocket tests of 1936 that established the Lab. The overlay includes the previously omitted names of theoretician Qian Xuesen, funder and photographer Weld Arnold, and observer Jeanne Bollay.

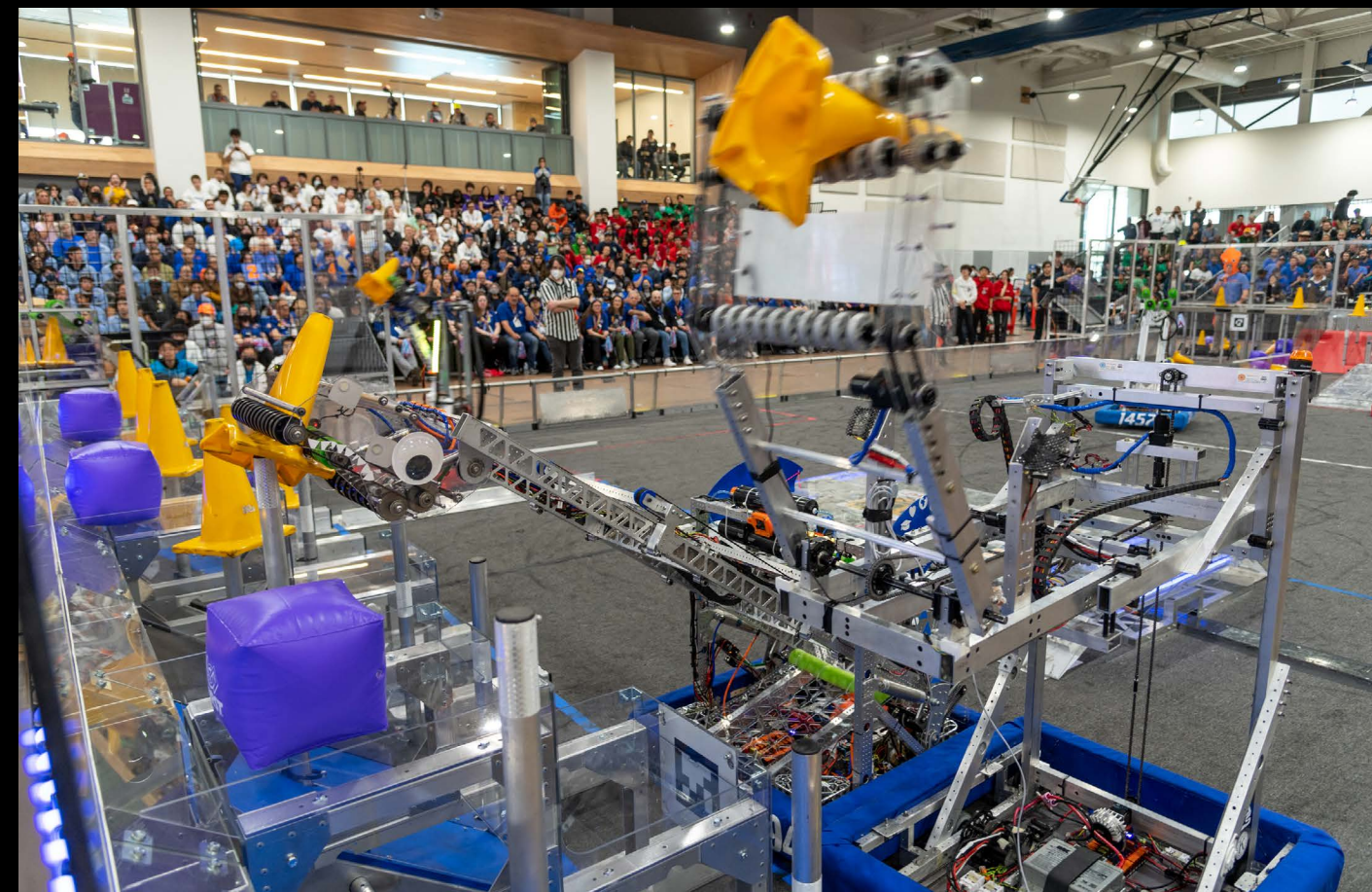


Future Scientists Make Their Mark on Lab

More than 700 college and high school students spent summer 2023 on Lab for Education Office and Human Resources internships supporting nearly 500 mentors in 265 groups.

In February, JPL hosted its 31st regional National Science Bowl — a nationwide contest challenging student teams in a wide range of science disciplines. The following month, JPL hosted its 24th regional Ocean Sciences Bowl — a competition focusing solely on ocean sciences and environmental stewardship. Also in March, JPL sponsored seven local teams in the 22nd annual Los Angeles FIRST Robotics competition, an event in which high school students design and construct a task-oriented robot to meet a unique set of game challenges. And at year's end, JPL hosted its annual Invention Challenge, in which high school teams and JPLers compete to accomplish a specified engineering task. As in years past, the high schoolers (and potential future JPLers) beat out the seasoned engineers.

Below: Students test their robotic creations at the JPL-sponsored FIRST Robotics competition.



Missions and Imaginations Take Flight

Media Relations and Public Engagement outreach teams took part in sharing the Lab's key initiatives with the world, from mission media days, to long-awaited launches, to hosting a panel at L.A. Comic-Con, to public calls for mission-inspired art, and even to a literary event at the Library of Congress.

In October, mission members and their families gathered in von Kármán Auditorium to watch the 6,000-pound Psyche spacecraft launch aboard SpaceX's Falcon Heavy, beginning its six-year, 2.2-billion-mile journey to our solar system's main asteroid belt. The Psyche mission is the first to explore a world made mostly of metal in an effort to solve the mysteries of planetary cores similar to our own. Media Relations, Public Engagement, DesignLab, and Education teams were tapped to support this mission through a mix of print and digital posters, stickers, and public outreach campaigns like the #PsycheSpaceCRAFTY call for artistic submissions from the public.

JPL attracts the nation's finest space scientists and engineers. But poets? When Europa Clipper's "Message

Below: U.S. Poet Laureate Ada Limón visits Europa Clipper in High Bay 1 at JPL.



in a Bottle" campaign started to gain traction, the Public Engagement team enlisted the 24th U.S. Poet Laureate, Ada Limón, as the mission's public voice. As part of her commission, Limón wrote "In Praise of Mystery: A Poem for Europa" exclusively for the mission. The poem links Earth to Europa via their shared life-harboring ingredient: water. In June, Limón presented the poem at the Library of Congress, and its words — along with the names collected for the Message in a Bottle campaign (well over two million) — will be engraved upon Europa Clipper's casing before it makes its 1.8-billion-mile journey toward the Jupiter system.

Media Relations and Public Engagement also supported outreach for ongoing Mars missions in 2023. Model replicas of

NASA's Perseverance rover and Ingenuity Mars Helicopter have been touring museums across the U.S. as part of the "Roving With Perseverance" roadshow. In 2023, the models traveled to museums in six states, giving visitors a full-scale representation of the size and function of each Mars craft.

As Ingenuity's mission began to spin down, the directorate looked toward a farewell announcement in early 2024. The mighty little chopper was sent to Mars to determine if powered, controlled flight on the Red Planet could be possible. It was proven possible, by year's end, 70 times over.

Considering only five flights were expected or even hoped for, Ingenuity's success was out of sight.

Top left: Family and friends gathered in the Von Kármán auditorium to watch the Psyche mission launch.

Top right: Life-size models of the Perseverance rover and Ingenuity Mars Helicopter at the Museum of Science in Boston

Bottom left: Comic-Con participants sign up to send their names to Jupiter with Europa Clipper.

Bottom right: A Media Relations host prepares for a Psyche news conference.



Left: Laurie Leshin with
Deputy Chief Technologist
Charles Norton

JPL TODAY & TOMORROW

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Dare Mighty Things Together:

A Plan for JPL 2023-2026

In 2023, Director Laurie Leshin unveiled a new three-year plan for the Lab along with a set of simplified values, introducing the initiative by pointing to the rapid evolution of JPL's core business.

“While JPL literally pioneered much of the space-exploration ecosystem, at this essential moment in time, the world around us is changing at an accelerated pace, and space exploration continues to evolve in reach, scope, and complexity. These changes present enormous and exciting opportunities, but they also can make the future feel somewhat less certain and harder to see. The purpose of this plan is to help us focus on actions that enable JPL to have an expanded positive impact on the space ecosystem in the coming years,” said Leshin.

“Dare Mighty Things Together: A Plan for JPL” runs to JPL's 90th birthday in October 2026 and serves as an aspirational and actionable roadmap to the future. Visible and shaped by people across the Lab, it ensures JPLers are working toward common goals that will position the Lab for success for many years to come.

The plan opens with JPL's North Star followed by the three new values of Bold, Inclusive, and Trusted, which condense and replace the former five.

Our North Star

Drive the forefront of scientific discovery and extraordinary benefit to humanity through innovative mission technology and research

Inspire people everywhere to think bigger and imagine what is possible

Leverage our unique capabilities to advance the broader space-exploration ecosystem

Create a safe, inclusive, exciting workplace where all can thrive

Strategic Imperatives

The Plan lays out a set of seven Strategic Imperatives that will serve as the foundation of much of JPL's work over the next three years, advancing its ability to succeed, seed, and lead well into the future. The imperatives look beyond what the Lab is currently doing to drive more transformational science, infuse more technology into missions, expand JPL's reach to spark imaginations everywhere, engage new partners, and operate as a more integrated and strategic Lab.

World Class Workforce

1 Create and enable the best workforce to deliver JPL's and NASA's mission

Position for Performance

2 Sharpen processes to drive excellence and accountability in delivering our flight missions

Transformative Science and Technology

3 Pursue leading-edge science questions and boldly drive innovation and technology into flight missions

Lab-wide Planning and Prioritization

4 Forecast and prioritize new work across JPL to align with our capabilities and goals

Industry Leading Workplace Culture

5 Create an inclusive, collaborative, and engaging workplace culture that serves as a role model for the space industry

Global Inspiration

6 Catalyze a global community to share compelling stories about space and Earth exploration that are synonymous with the future of humanity

2036 and Beyond —
Launching JPL's Next Century

7 Envision and position JPL for a bright long-term future in the space ecosystem

Our Values

BOLD

We are courageous explorers, driven by our conviction to take informed risks and expand the edge of possibility. We build and manage complex missions designed to tackle the most challenging scientific questions and address global challenges. We are motivated by building first-of-a-kind systems and by knowing that our discoveries will advance knowledge and drive positive change in society.

INCLUSIVE

We create a collaborative culture where our teams, colleagues, and partners feel valued and empowered to innovate. We appreciate excellence, expertise, and experience across all disciplines. We embrace difference with respect and curiosity. We create environments where teams can achieve things not thought possible. We take pride in the breadth of our reach, engagement, and impact.

TRUSTED

We operate with integrity and the highest professional standards. We do the right thing. We honor our commitments. We work to advance our relationships. We share information and expertise with each other, with partners, and with the world. We work together toward ambitious common goals and outcomes.



Above: Unwrapping the updated Founders' Plaque shortly before its formal presentation to the Lab on May 23

Projects in Flight

Total Projects in Flight

37

PROJECTS BY TARGET OF STUDY*

25 Earth

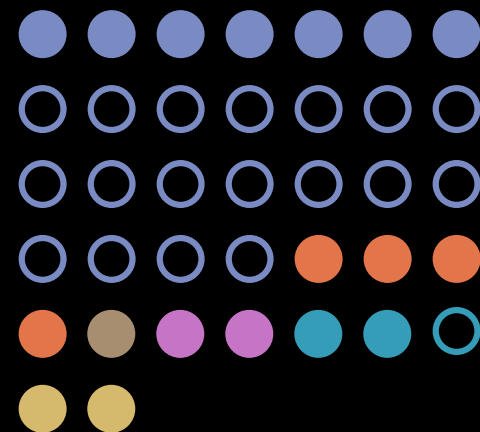
4 Mars

1 Jupiter

2 Asteroids & Comets

3 Stars & Galaxies

2 Interstellar Space



Key:
 ● Mission
 ○ Instrument

* As of Dec. 31, 2023

Earth

Missions

- Jason-3
- GRACE-FO
- Sentinel-6
- SWOT
- SMAP
- CloudSat
- OCO-2

Instruments

ON THE INTERNATIONAL SPACE STATION

- ECOSTRESS
- EMIT
- OCO-3
- Tempest-H8
- COWVR
- Cold Atom Laboratory

ON NON-JPL SPACECRAFT

- AIRS (Aqua)
- MISR (Terra)
- MLS (Aura)
- ASTER (Terra)
- TGRS (COSMIC-2)

AIRBORNE

- AVIRIS
- HyTES
- PALS
- AirMSPI
- DopplerScatt
- PRISM
- UAVSAR

Mars

Missions

- Mars Odyssey
- Mars Reconnaissance Orbiter
- Mars Science Laboratory (Curiosity)
- Mars 2020 (Perseverance)

Jupiter

Missions

- Juno

Asteroids and Comets

Missions

- Psyche
- NEOWISE

Stars and Galaxies

Missions

- NuSTAR
- Euclid (ESA mission with NASA-JPL contributions)

Instruments

ON NON-JPL SPACECRAFT

- MIRI (James Webb Space Telescope)

Interstellar Space

Missions

- Voyager 1
- Voyager 2



Above: Psyche team members pass around the lucky peanuts prior to launch as part of a JPL tradition.

Leadership

Executive Council

Laurie Leshin

Director

Larry D. James

Deputy Director

Leslie Livesay

Associate Director for Flight Projects and Mission Success

David Gallagher

Associate Director for Strategic Integration

Richard Cook

Program Manager for Mars Sample Return

Tom Cwik

Chief Technologist

Matthew Decker

Chief Data & Information Officer

Suzanne Dodd

Director for Interplanetary Network

Roger Gibbs

Director for Engineering and Science

James Graf

Director for Earth Science and Technology

Michael Greene

Director for Communications and Education

Martin Herman

Director for Safety and Mission Success

Sammy Kayali

Chief Financial Officer, Manager of Operations Integration

Jennifer Lum

General Counsel, Caltech

Rebecca Macko

Director for Human Resources

Susan Owen

Acting Chief Scientist

Keyur Patel

Director for Astronomy and Physics

Neela Rajendra

Chief Inclusion Officer

Matthew Wallace

Director for Planetary Science

JPL Advisory Council

Maria Zuber (Chair)

Vice President for Research, MIT

Waleed Abdalati

Director, Cooperative Institute for Research in Environmental Sciences at the University of Colorado Boulder

Ambassador**Barbara M. Barrett**

Former United States Secretary of the Air Force

Antonio J. Busalacchi

President, University Corporation for Atmospheric Research

Philip Christensen

Regents Professor, School of Earth and Space Exploration, ASU

France Córdova

President, Science Philanthropy Alliance

Pascale Ehrenfreund

Former President of the International Astronautical Federation and former Chancellor of the International Space University

Fiona Harrison

Chair of the Division of Physics, Mathematics and Astronomy, Caltech

Steve Isakowitz

President, The Aerospace Corporation

Kent Kresa

Chairman Emeritus, Northrop Grumman Corporation

Jonathan Lunine

Chair of the Astronomy Department, Cornell University

Ellen Ochoa

Astronaut & Former Director, Johnson Space Center

Janet Vertesi

Associate Professor of Sociology, Princeton

Tom Young

Former Director, Goddard Space Flight Center
Former Vice President, Lockheed Martin

Caltech Board of Trustees JPL Committee

Jon B. Kutler (Chair)

Chairman and Chief Executive Officer, Admiralty Partners, Inc.

Ambassador**Barbara M. Barrett**

Former United States Secretary of the Air Force

Admiral Bobby R. Inman

Emeritus Professor, The University of Texas at Austin

Kent Kresa

Chairman Emeritus, Northrop Grumman Corporation

Taylor**W. Lawrence**

Former President, Raytheon Missile Systems

David Li Lee

Managing General Partner, Clarity Partners, L.P.

Deborah**D. McWhinney**

Former Chief Executive Officer, Citi Enterprise Payments & Citi Group

Ex Officio Members:**Thomas****F. Rosenbaum**

President, Caltech

David**W. Thompson**

President and Chief Executive Officer (Retired), Orbital ATK

David E.**I. Pyott, CBE**

Entrepreneur

Workforce Demographics

Lab Population* by Gender

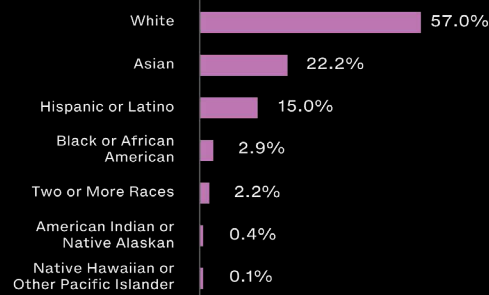
31.4%

Female

68.6%

Male

Lab Population by Ethnicity

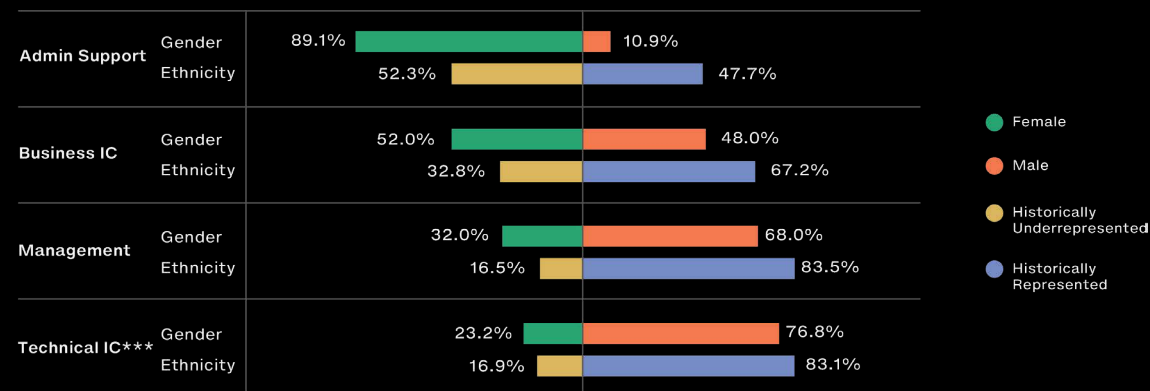


Lab Population by Ethnicity & Gender

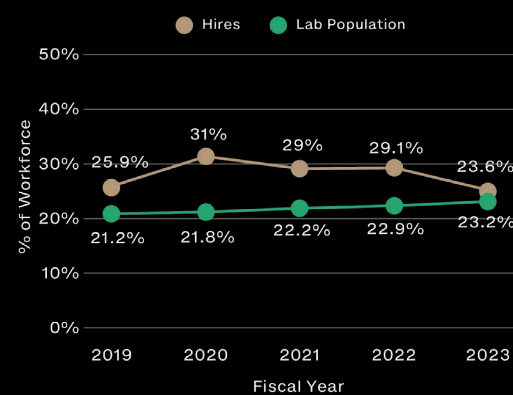


A small percentage of employees (less than 1%) chose not to identify as one of the ethnicities.

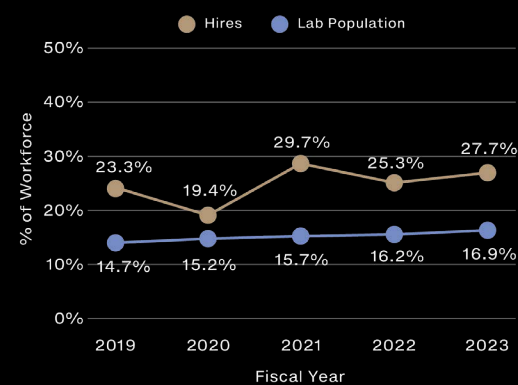
Lab Population by Job Type, Gender, and Ethnicity Group**



Female Employees in Technical Roles, FY19-FY23



Employees from Historically Underrepresented Groups in Technical Roles, FY19-FY23



Inclusion: A JPL Core Value

JPL is committed to leveraging evidence-based, science-informed interventions designed to create more equitable systems that ensure all employees can reach their full potential. To that end, 2023 marked the release of JPL's first Diversity, Equity, Inclusion, and Accessibility Strategic Plan. Developed by the Office of Inclusion, the plan lays out four strategic goals:

Diverse Community

Seeking connections across difference and building broad networks; ensuring our workforce is representative of the qualified U.S. labor force.

Equitable Opportunities

Increasing the equity of our systems and processes; ensuring every employee has what they need to reach their full potential.

Accessible Workplace

Ensuring employees with disabilities are valued and included in accessibility-related decisions and using systems and tools in an equally integrated and effective manner as a person without a disability.

Trust & Accountability

Cultivating a culture of mutual trust and accountability between our employees and our leaders through transparency in our policies, decision-making, and demographic data.

Key accomplishments since the plan's release include:

- Launching the DEIA Manager's Toolkit, a compendium to the strategy to help managers advance the strategic goals
- Establishing two working groups to address physical and digital accessibility at JPL, and providing related educational events and resources in partnership with other organizations across Lab
- Creating the Polaris Award, the first centralized JPL award for DEIA efforts
- Establishing three new Employee Resource Groups, bringing the total to ten:
 1. Advisory Council for Women
 2. Amigos Unidos
 3. Asian American Council
 4. BEST (Black Excellence Strategic Team)
 5. Disability Advocacy Networking Group****
 6. Foreign National Advocacy Network****
 7. NEBULA (Native Engagement in Building a Unified Leadership Alliance)
 8. Neurodiverse Laboratory Network****
 9. Spectrum
 10. JPL Vets

* Lab Population: The population consists of JPL employees in the core workforce (excluding students, part-time, and temporary workers) on active or paid leave status.

** Ethnicity Group - Historically Underrepresented Groups: This population consists of JPL employees in the core workforce who identify as an ethnicity other than White or Asian.

*** Technical: This population consists of JPL non-management employees in the core workforce whose assignment is in the following job families: Engineering, Institutional Leadership, Lifecycle Program Project Leadership, Research, and Software and Computing Systems.

**** Established in 2023

Sustainability

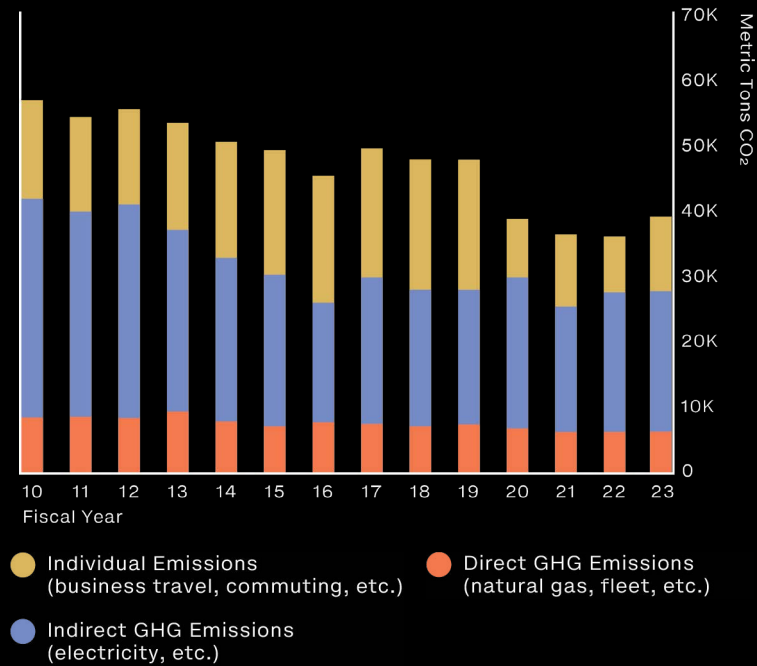
Greenhouse Gas Emissions

Sustainable Buildings

In FY23, 620,222 (24%) of JPL square footage met sustainable building criteria.

Fleet Management

NASA's goal is to reach 100% zero-emission government vehicles by 2035. JPL has plans for FY24-FY35 to expand its electric vehicle charging station infrastructure to meet this goal.



Energy Efficiency

NASA's goal is to meet or exceed a 30% reduction in Btu/GSF from the FY03 baseline and reduce energy intensity each year.

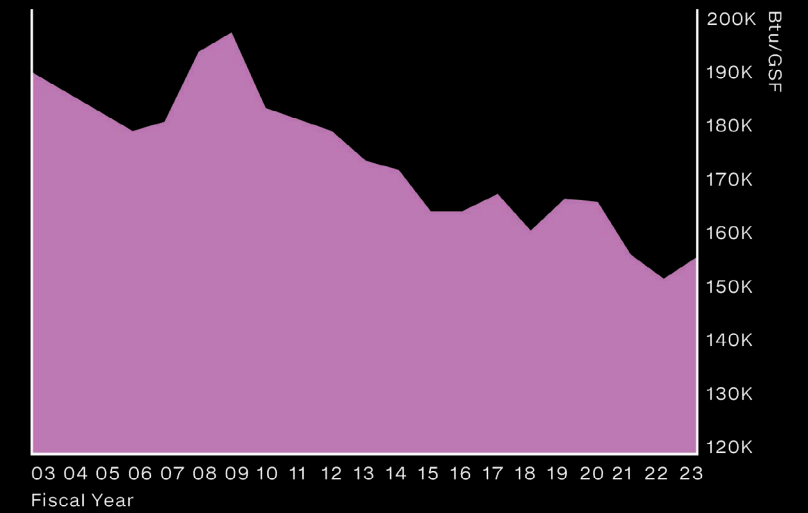
Energy Intensity

Decreased energy intensity by 14% in FY23 compared to baseline FY03.

Increased energy intensity by 3% in FY23 compared to FY22.

Renewable Energy

2% of electricity was sourced from on-Lab renewable sources in FY23.



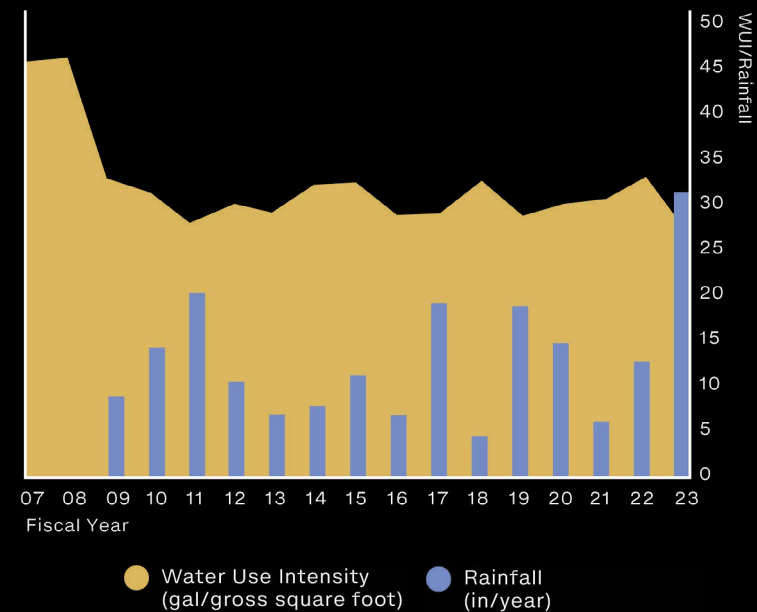
Water Efficiency

NASA's annual goal is to achieve a 20% reduction relative to FY07 and reduce water use intensity each year.

Water Use Intensity

Decreased water use intensity by 40% in FY23 compared to baseline FY07.

Decreased water use intensity by 17% in FY23 compared to FY22.



Waste Reduction and Diversion

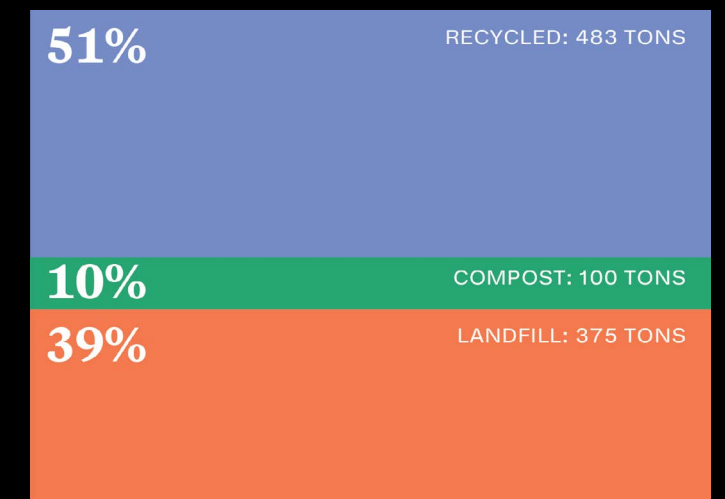
NASA's goal is to divert 50% of construction and demolition debris waste and 50% of non-C&D solid waste from landfills.

Waste Diversion

61% diversion of non-C&D solid waste

85% diversion of C&D waste (not shown)

65% overall waste diversion rate in FY23 (not shown)



Major External Awards

Farah Alibay

Honorary Ph.D. (DSc) from the Gina Cody School of Engineering and Computer Science at Concordia University

Laurie Barge

Rosalind Franklin Society Award in Science for Astrobiology

Morgan Cable

2023 Scialog Collaborative Innovation Awards

Nacer Chahat

- WAMS Society, Life Fellow
- Class of 2024 American Institute of Aeronautics and Astronautics Associate Fellow

Goutam Chattopadhyay

Institute of Electrical and Electronics Engineers Microwave Theory & Technology Society

Communications & Education Directorate

- Webby People's Voice Awards:
- NASA's Eyes on Asteroids
 - NASA's Jet Propulsion Laboratory Website

Erik M. Conway

American Association for the Advancement of Science Fellow

Dariusz Divsalar

2023 Ellis Island Medal of Honor

Maksym Figat

- 2023 Poland Prime Minister Award
- 2023 Asea Brown Boveri Prize Competition (First Place)
- 2023 Young Innovators Award (First Place)

Sarath Gunapala

Quantum Devices Award

William Hart

Class of 2024 American Institute of Aeronautics and Astronautics Associate Fellow

Douglas C. Hofmann

Fellow of the National Academy of Inventors

Renyu Hu

2023 Scialog Collaborative Innovation Awards

Ingenuity Mars Helicopter Team

Milton Caniff Spirit of Flight Award

JPL

2023 US CIO 100 Award for IT Innovation and Leadership

Marie Levine

2023 Woman of the Year: From California's 30th Congressional District for the U.S. House of Representatives under Congressman Adam Schiff

David Miller

National Academy of Engineering

Angelyn Moore

The Association for Women Geoscientists 2023 Professional Excellence Award Winner for Government/Regulatory

MOXIE Team

TIME's Best Inventions of 2023

NASA's Global Climate Change Website

Anthem Award

Shouleh Nikzad

American Astronomical Society Joseph Weber Award on Astronomical Instrumentation

Charles D. Norton

Class of 2024 American Institute of Aeronautics and Astronautics Associate Fellow

PIXLISE, Accelerating Astrobiology Analysis

NASA, 2023 Software of the Year Award, Runner-Up

Adrian Tang

- Institute of Electrical and Electronics Engineers Region 6 Outstanding Engineer Award 2022
- Engineer's Council Outstanding Engineering Achievement Merit Award 2023
- National Academy of Inventors Senior Member

Babette Christelle Tchonang

2022 EuroGOOS Kostas Nittis Medal

Bonnie Teece

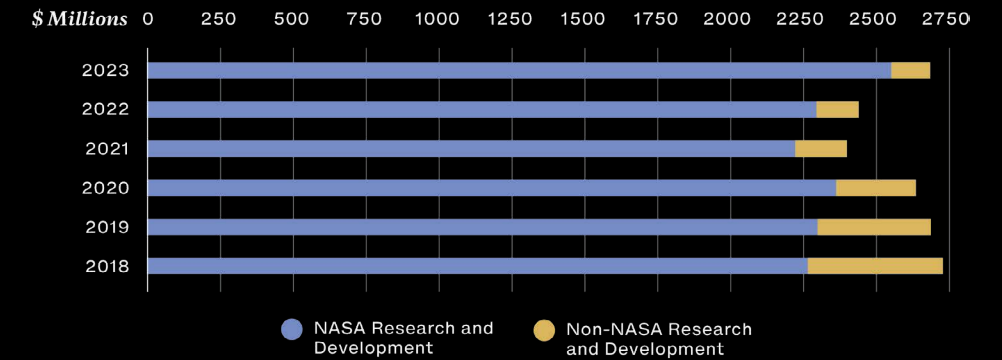
The Voisey Medal

Hemali Vyas

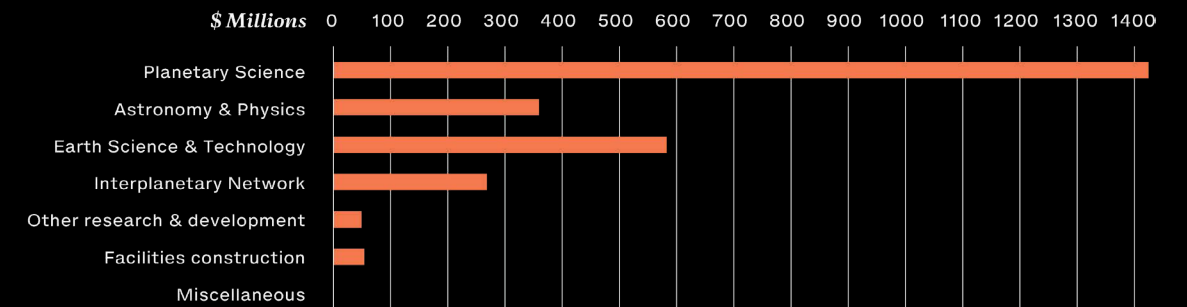
Class of 2024 American Institute of Aeronautics and Astronautics Associate Fellow

Budget & Workforce

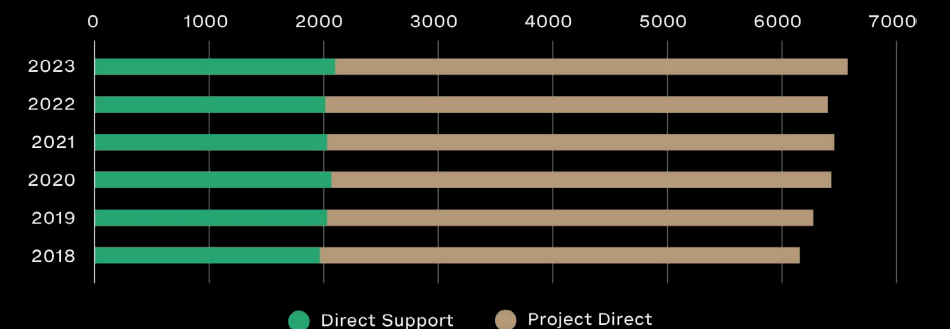
Annual Budgets



FY 2023 Budget



JPL Employees | Full-Time Equivalents



Major Contract Partners

Johns Hopkins University Applied Physics Laboratory

- Europa Clipper
- Mars Reconnaissance Orbiter
- Psyche

Ball Aerospace & Technologies Corporation

- CloudSat
- GRACE-C
- National Partnerships Office
- NEOSurveyor
- NEOWISE
- SPHEREx

ManTech Advanced Systems

- Institutional Computing

Peraton, Inc.

- Deep Space Network Operations
- Mars 2020

Raytheon

- Engineering, Implementation, Science, Operations and Communications (EISOC)
- ITSD Systems Administration

MORI Associates, Inc.

- Information Technology
- Infrastructure Support

EMCOR Government Services

- Facilities Maintenance and Operations

Lockheed Martin Corporation

- Engineering Support Services
- Europa Clipper
- Juno
- Mars Odyssey
- Mars Reconnaissance Orbiter
- Mars Sample Return
- VERITAS

Southwest Research Institute

- Europa Clipper
- Mars Science Laboratory

Airbus Defence and Space GMBH

- GRACE Follow-On
- GRACE-C
- NISAR



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