JUNO VISITS JUPITER'S LARGE MOONS GANYMEDE AND EUROPA (AND IO)

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JUNO VISITS JUPITER'S LARGE MOONS GANYMEDE AND EUROPA (AND IO)

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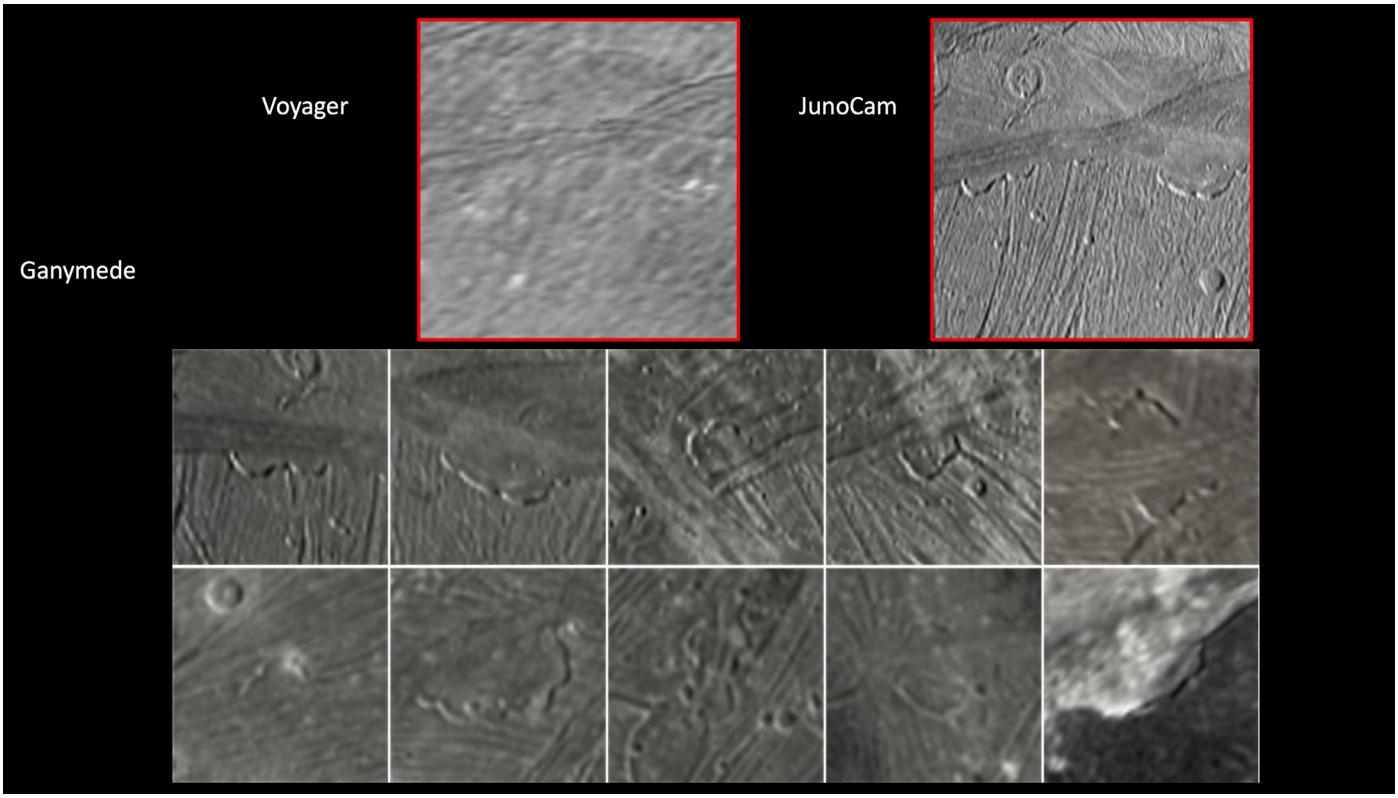
On June 7, 2021, NASA's Juno orbiter encountered Jupiter's largest moon Ganymede, the only moon with its own intrinsic internal magnetic field. The encounter at ~1046 kilometers (650 miles) altitude was part of Juno's extended mission, during which the most distant planetary orbiter will continue its investigation of the solar system's largest planet through September 2025 (or until the spacecraft's end of life, whichever comes first).

Proposed in 2003 and launched in 2011, Juno went into orbit around Jupiter on July 4, 2016. The prime mission was completed in July 2021. The extended mission involves 42 additional orbits, including close passes of Jupiter's north polar cyclones; flybys of Ganymede, Europa, and Io; as well as the first extensive exploration of the faint rings encircling the planet. Successful Ganymede and Europa encounters were achieved in June 2021 and September 2022 respectively and several visits to Io are in the planning stages over the next year.



In these images of Ganymede, JunoCam revealed 12 paterae — broad, shallow bowl-shaped features on a planetary body's surface — only two of which are evident in the Voyager data. These features were likely formed by late-stage volcanic processes. The top two views compare how well Voyager and Juno resolved one of these paterae. Credit: NASA/JPL-Caltech/SwRI/MSSS.

This image of the dark side of the jovian moon Ganymede was obtained by the Stellar Reference Unit star camera onboard NASA's Juno spacecraft during its June 7, 2021, flyby of the icy moon. Usually used to keep the spacecraft on course, the navigation camera was able to obtain an image of the moon's dark side (the side opposite the Sun) because it was bathed in the dim light scattered off Jupiter; the camera operates exceptionally well in low-light conditions. Credit: NASA/JPL-Caltech/SwRI.

"Since its first orbit in 2016, Juno has delivered one revelation after another about the inner workings of this massive gas giant," said principal investigator Scott Bolton of the Southwest Research Institute in San Antonio. "With the extended mission, we will answer fundamental questions that arose during Juno's prime mission while reaching beyond the planet to explore Jupiter's ring system and Galilean satellites."

"By extending the science goals of this important orbiting observatory, the Juno team will start tackling a breadth of science historically required of flagships," said Lori Glaze, planetary science division director at NASA Headquarters in Washington. "This represents an efficient and innovative advance for NASA's solar system exploration strategy."

Juno's close satellite encounters were the first since the end of the Galileo mission in 2003 and will be the last before the arrival of the next generation of missions to the jovian system: NASA's Europa Clipper and the European Space Agency's (ESA) JUpiter ICy moons Explorer (JUICE) mission. [New Horizons made important observations of these moons but was further away when it passed through the jovian system in 2007 (and Cassini from even further away in 2000).] Juno mapped parts of these satellites that were poorly observed by Voyager and Galileo and included science instruments not on either spacecraft, such as the Microwave Radiometer (MWR). Hence scientists and engineers were eager to see what Juno revealed. Juno's investigation of Jupiter's volcanic moon Io will also address many science goals identified by the National Academy of Sciences for a future Io explorer mission.

The extended mission's science campaigns will expand on discoveries Juno has already made about Jupiter's interior structure, internal magnetic field, atmosphere (including polar cyclones, deep atmosphere, and aurora), and magnetosphere, but the satellite observations are an unplanned science bonus given by the evolving nature of Juno's orbit.

The natural evolution of Juno's orbit around the gas giant provides a wealth of new science opportunities that the extended mission capitalizes on. Every science pass sends the spinning solar-powered spacecraft zooming low over Jupiter's cloud tops, collecting data from a unique vantage point no other spacecraft has enjoyed.

The point during each orbit where Juno comes closest to the planet is called perijove (or PJ). Over the course of the mission, Juno's perijoves have migrated northward, dramatically improving resolution over the northern hemisphere. This evolving geometry also brings the large moons into range on the inbound leg of Juno's orbits, which now cross the orbits of the satellites as Juno's orbit rotates. By adjusting the orbital trajectory Juno was able to be at their orbits when the moons were in the same position. The design of the extended mission takes advantage of the continued northward migration of these perijoves to sharpen its

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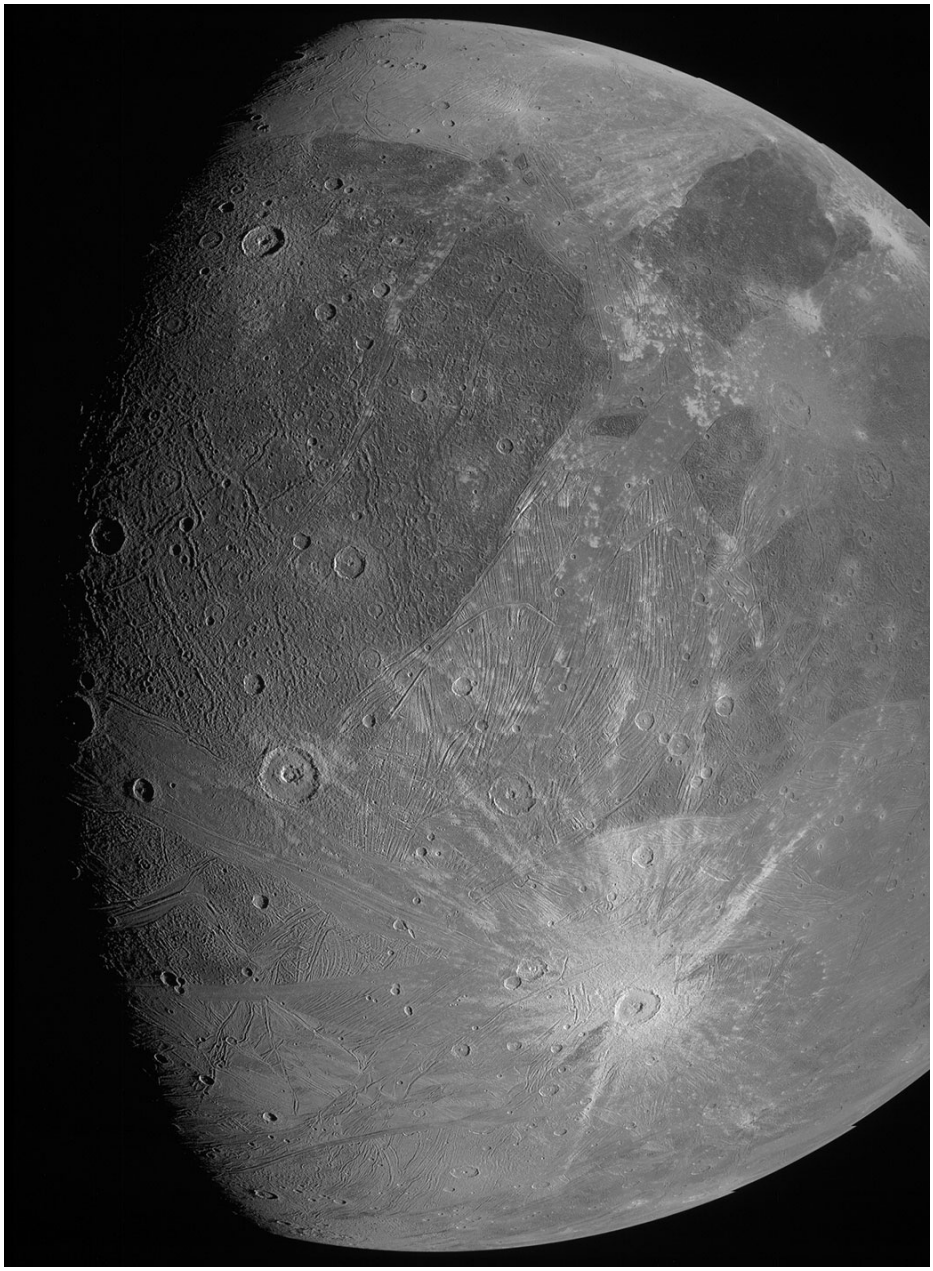


This image of the jovian moon Ganymede was obtained by the JunoCam imager onboard NASA's Juno spacecraft during its June 7, 2021, flyby of the icy moon. At the time of closest approach, Juno was within 1038 kilometers (645 miles) of its surface — closer to Jupiter's largest moon than any other spacecraft has come in more than two decades. This image is a preliminary product — Ganymede as seen through JunoCam's green filter. Credit: NASA/JPL-Caltech/SwRI/MSSS.

view of the multiple cyclones encircling the north pole while incorporating ring and Galilean moon flybys.

"The mission designers have done an amazing job crafting an extended mission that conserves the mission's single most valuable onboard resource — fuel," said Ed Hirst, the Juno project manager at the Jet Propulsion Laboratory (JPL) in Pasadena, California. "Gravity assists from multiple satellite flybys steer our spacecraft through the jovian system while providing a wealth of science opportunities." The satellite flybys also reduce Juno's orbital period, which increases the total number of science orbits that can be obtained."

The satellite encounters began with a low-altitude flyby of Ganymede on June 7, 2021 (PJ34), which reduced the orbital period from about 53 days to 43 days. (Callisto was never in the right place for Juno to get a close look.) The Ganymede flyby set up a close flyby of Europa on September 29, 2022 (PJ45), reducing the orbital period further to 38 days. A pair of close Io flybys, scheduled for December 30, 2023 (PJ57), and February 3, 2024 (PJ58), will combine to reduce the orbital period to 33 days.

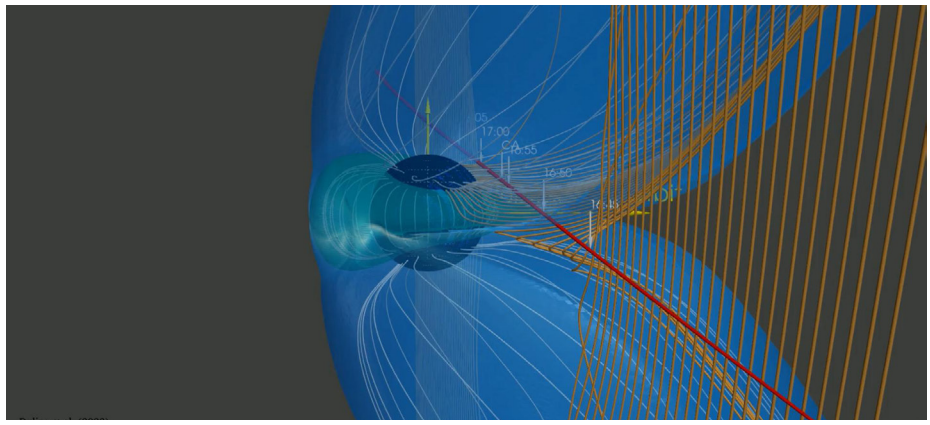
Juno will also fly through the Europa and Io tori — ring-shaped clouds of ions — on multiple occasions, characterizing the radiation environment near these satellites to better prepare the Europa Clipper and JUICE missions for optimizing observation strategies and planning, science priorities, and mission design. The extended mission also adds planetary geology and ring dynamics to Juno's extensive list of science investigations. "With this extension, Juno becomes its own follow-on mission," said Steve Levin, Juno project scientist at JPL. "Close-up observations of the pole, radio occultations [a remote sensing technique to measure properties of a planetary atmosphere or ring systems that uses the spacecraft radio waves], satellite flybys, and focused magnetic field studies combine to make a new mission, the next logical step in our exploration of the jovian system."

Citizen scientists have been processing the JunoCam images of Ganymede since they were released on the JunoCam website shortly after the encounter. The science teams and their affiliates have also been processing and analyzing the data from all the instruments and the first science findings from the Ganymede encounter were published in the journal *Geophysical Research Letters* in December 2022 and several additional articles are to be published early this year.

The close pass by the rotating spacecraft allowed for radio tracking that improved our understanding of the interior. The results suggest that Ganymede may be in hydrostatic equilibrium and appear to confirm that there are internal density variations of unknown origin. The Clipper and JUICE missions will be required to map out and resolve these variations in greater detail.

The MWR instrument performed the first resolved investigation of the subsurface ice for both Ganymede and Europa,

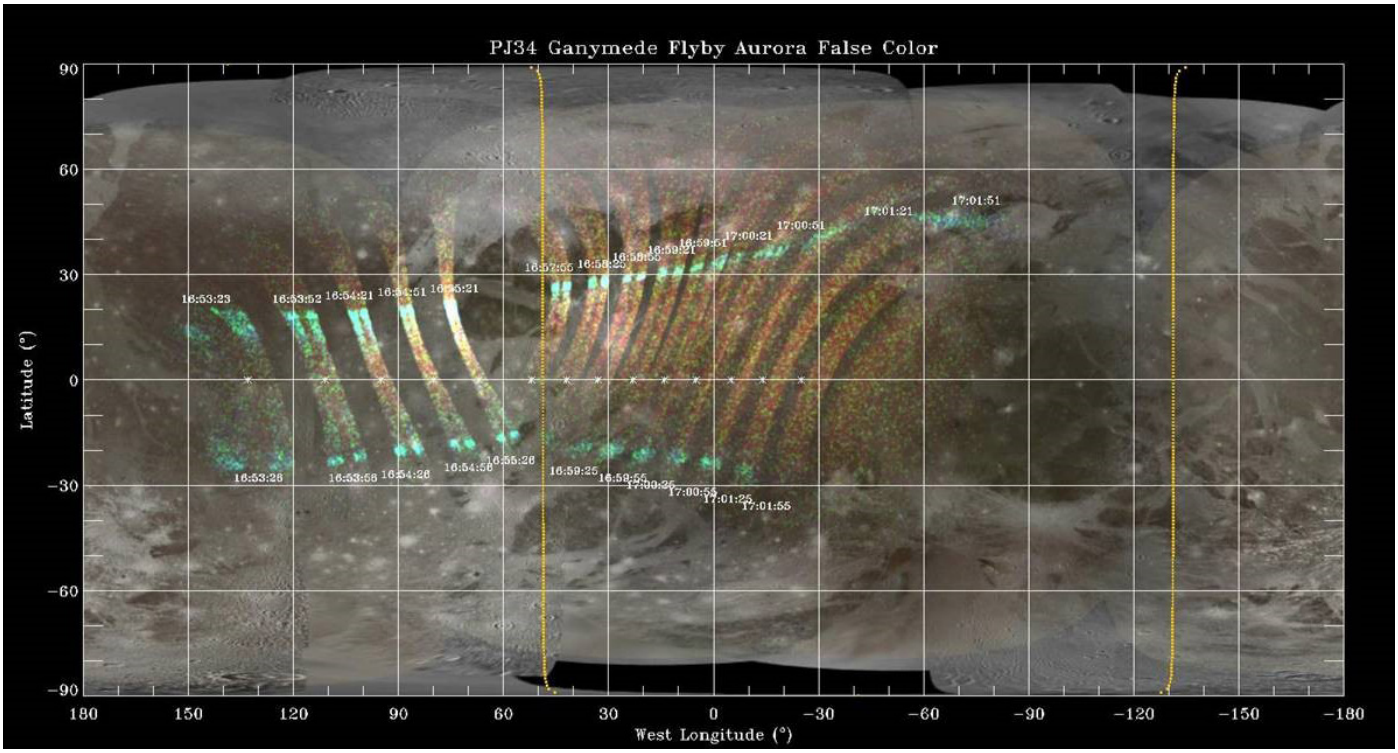
with the ability to compare subsurface characteristics of the two very distinct bodies. With six frequencies, MWR was able to analyze six depths and discern lateral and vertical variations in the subsurface thermal properties among older dark and younger bright terrains and with bright crater deposits such as at Tros. This type of instrument has never been flown to the outer solar system before. The Jovian InfraRed Auroral Mapper (JIRAM) also provided some of the highest-resolution infrared spectroscopy of Ganymede.



This animation (click image to start) illustrates how the magnetic field surrounding Jupiter's moon Ganymede (represented by the blue lines) interacts with and disrupts the magnetic field surrounding Jupiter (represented by the orange lines). During the June 2021 close approach to Ganymede by NASA's Juno spacecraft, the Magnetic Field (MAG) and Jovian Auroral Distributions Experiment (JADE) instruments onboard the spacecraft recorded data showing evidence of the breaking and reforming of magnetic field connections between Jupiter and Ganymede. Credit: NASA/JPL-Caltech/SwRI/Duling.

The 90-kilometer (56-mile) Tros crater was well resolved in the JunoCam stereo images, which reveal that it is ~1 kilometer (0.6 miles) deep. A total of 11 new paterae (features that resemble volcanic caldera or depressions on other planetary bodies) were identified in these new images. Stereo overlap of the four JunoCam mosaics allow for mapping of major topographic features and the only unusual feature was the 3-kilometer-high (1.9-mile-high) dome observed from Voyager data at the subjovian point. The JunoCam elevation map shows it to be oval in shape. The Stellar Reference Unit, an imager intended for navigation, also provided one image each of Europa and Ganymede in terrains poorly resolved in previous imaging, and both of these images were taken in reflected Jupiter light. This type of imaging was very successful at Saturn during the Cassini mission and should be equally successful during the Europa Clipper and JUICE missions.

Ganymede has a complex interaction with the jovian magnetosphere and the space environment due to its own internal magnetosphere. Juno's Ultraviolet Spectrograph (UVS) mapped out the location of Ganymede's northern and southern aurorae bands in greater detail than ever before, mapping the locations of the open and closed field lines. Juno crossed into this magnetosphere

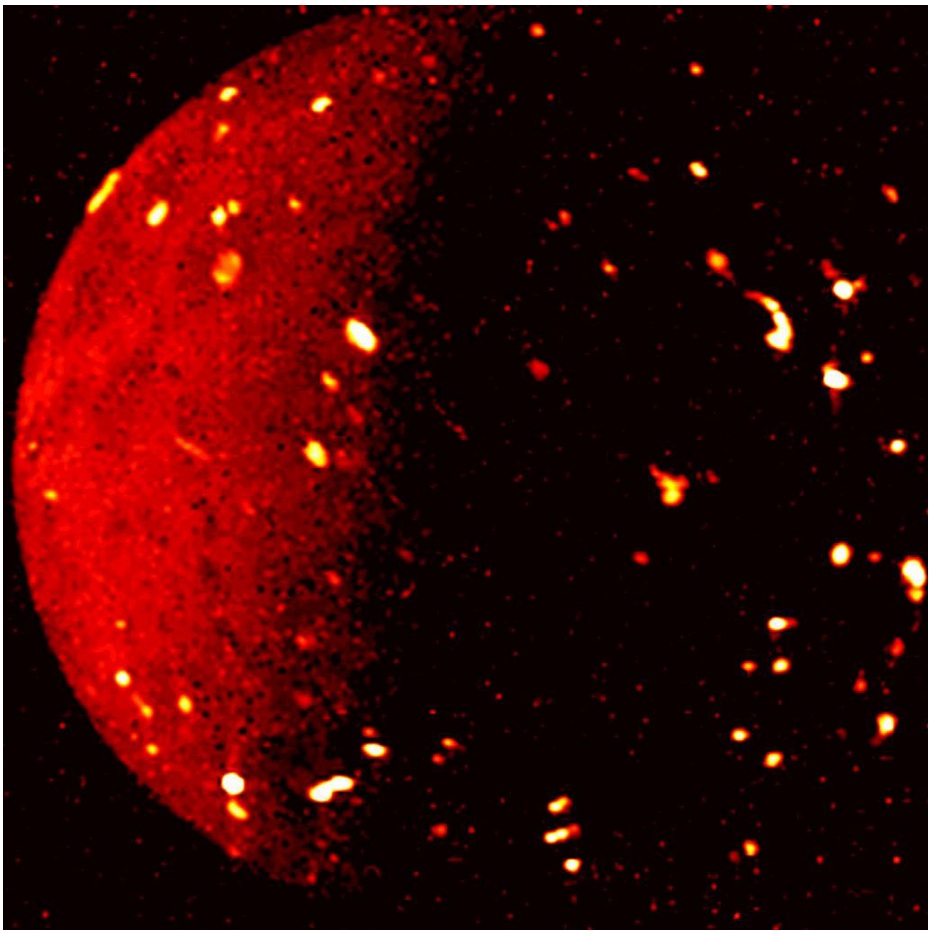


False color map of Juno-UVS Ganymede flyby observations, overlaid on a USGS geologic map. Auroral emissions of atomic oxygen at wavelengths of 130.4 and 135.6 nanometers are colored blue and green, respectively, while longer far-ultraviolet wavelengths (mostly from reflected sunlight) are colored red. The start and end times on (on June 7, 2021) for each UVS swath are indicated (Juno spins once every 30 seconds), along with the terminator in orange. From Greathouse T. K. et al. (2022) Geophys. Res. Lett., 49, e2022GL099794, doi.org/10.1029/2022GL099794.

and sampled the outflowing ion composition. Radio emissions were detected from the magnetosphere related to asymmetries and disturbances within this magnetosphere and in the charged particle environment around Ganymede. The extremely thin atmosphere around Ganymede is dominated by water products ejected from the surface by charged particles.

The data from the successful Europa encounter in September 2022 are also being analyzed and will be reported on at future science conferences, including the upcoming Lunar and Planetary Science Conference in March. While it is too early to report on those findings, the images reveal a landscape similar to that observed by Voyager and Galileo but with additional clusters of shallow depressions that might be associated with global features attributed to polar wander (of rotation) of Europa's icy shell. They also fill a gap in the Galileo mapping coverage and improve our understanding of the distribution of geologic units.

Observations from the MWR also suggest that Europa may have a different (and possibly more uniform?) structure within its outermost icy layers than does Ganymede. Other instruments will be looking to improve our understanding of Ganymede's surface composition, interactions with the jovian magnetosphere, and internal gravitational signature as it relates to internal density variations. Both Clipper and JUICE will be looking at these data to anticipate mission results and adjust mission plans as needed.



The volcano-laced surface of Jupiter's moon Io was captured in infrared by the Juno spacecraft's Jovian InfraRed Auroral Mapper (JIRAM) imager as it flew by at a distance of about 80,000 kilometers (50,000 miles) on July 5, 2022. Brighter spots indicate higher temperatures in this image. Credit: NASA/JPL-Caltech/SwRI/ASI/INAF/JIRAM.

The Io flybys in 2023/2024 will look for major surface changes due to ongoing volcanism, the composition of that volcanism, the distribution of Io's volcanoes, its internal structure, and the magnetospheric and particulate interactions with the surface. As Io is deep within the most intense radiation zones at Jupiter, scientists are hopeful that radiation-induced noise can be minimized. Regardless, Juno's encounters with the large Galilean satellites have already been a boon to our understanding of these enigmatic and dynamic objects. They are also important preludes to the mapping missions to Europa and Ganymede to be launched in 2023 and 2024.

"Juno's encounters with the large Galilean satellites have already been a boon to our understanding of these enigmatic and dynamic objects."

For an overview of the Ganymede science results, see Hansen C. et al. (2022) Juno's close encounter with Ganymede — An overview. *Geophys. Res. Lett., 49(23)*, e2022GL099285, doi.org/10.1029/2022GL099285.

Cover photo: On June 6, 2021, Juno encountered Jupiter's largest moon Ganymede at a distance of 1046 kilometers (650 miles). This view simulates the perspective of an observer near Juno as it passes by, using imaging acquired by the spacecraft and processed by Kalleheike Kannisto. Credit: NASA/JPL-Caltech/SwRI/K. Kannisto.

FROM THE DESK OF **LORI GLAZE**

INSIGHTFUL TO THE END

Lori S. Glaze

Director, NASA's Planetary Science Division, January 2023

Just before our break for the winter holidays, we said a fond farewell to one of our beloved Planetary Science Division (PSD) missions. With dust build-up on its solar panels, InSight's power levels had become precipitously low, and the spacecraft communicated with Earth for the final time on December 15, 2022. Although we had been anticipating losing contact with InSight for many months, and it was well into its extended mission, saying goodbye to one of our spacecraft is always sad — somewhat akin to losing a member of a family. I was glad, therefore, to spend time over the break relaxing and recharging with my own family and friends and reflecting on InSight's many successes.

InSight (short for Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) was the twelfth mission in the Discovery Program. It launched in May 2018, shortly after I started my tenure as Director of NASA's Planetary Science Division, so it has been especially meaningful for me to see this mission complete its whole "life." Unlike our rovers on Mars, which are sent to explore geologically and astrobiologically interesting locations, InSight's landing site in Elysium Planitia was specifically chosen to be pretty "boring" — but for good reason!

InSight's primary goal was to investigate the interior structure and composition of Mars. To do that, the lander needed to be at a site where it could remain as still and quiet as possible on the Mars surface for the entire mission. Elysium Planitia was therefore selected not for its geology and surface features, but rather for safety considerations. InSight touched down on November 16, 2018, in the western portion of the plane, less than 5° north of the equator, in an area that is characterized by flat topography and few large nearby rocks.

InSight carried three science instruments: the Seismic Experiment for Interior Structure (SEIS), the Heat Flow and Physical Properties Package (HP3), and the Rotation and Interior Structure Experiment (RISE). With this payload, the spacecraft was designed to address fundamentally important questions about the formation and evolution of Mars, such as the size and structure of the planet's core, mantle, and crust, the planet's heat flow, and the planet's current seismic activity.

During InSight's four-and-a-half-year sojourn on Mars, SEIS detected more than 1300 "marsquakes." Most of these quakes arose from activity on faults and rock fractures — caused by the buildup

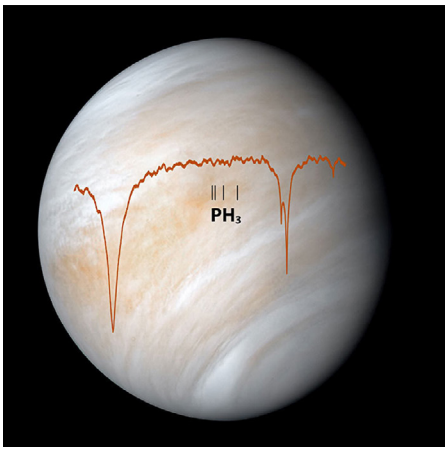
of stress as the planet continues to cool and slightly contract. In a surprise to the team, the majority of the largest quakes (up to about magnitude 5) can be traced to a region known as Cerberus Fossae, which is thought to be volcanically active enough to have had lava flowing within the last few million years. With these seismic data, the team has so far been able to confirm that the crust of Mars is between about 20 to 37 kilometers (12 to 23 miles) thick (thinner than expected) and may have two or three sublayers; that the mantle reaches to a depth of almost 1500 kilometers (about 1000 miles) below the surface; and that the core of Mars is molten, with a radius of about 1830 kilometers (1140 miles).

Despite the primary success in revealing the interior structure of Mars, InSight also faced its share of setbacks and challenges. Most significant were the valiant attempts to bury the HP^3 "mole." The heat probe had been intended to dig about 5 meters (16 feet) into the surface, via the self-hammering mole, and had been designed to encounter soil that was loose and sandy, like we have found at other mission landing sites. The ground at InSight's location, however, turned out to be unexpectedly clumpy, which scuppered the mole's burrowing progress. The valiant engineers at the Jet Propulsion Laboratory and the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, or DLR) devised several ingenious and innovative methods to further the mole's journey through the soil, but the probe was eventually buried only slightly below the surface. Nevertheless, the lessons learned and the data collected by HP^3 are still valuable for understanding the physical and thermal properties of Mars' soil and will be useful for future human or robotic missions.

In a case of appropriate celestial timing, InSight received one of its most exciting gifts on Christmas Eve (December 24), 2021. SEIS recorded a magnitude 4 quake, which the team later realized had been caused by a meteoroid striking Mars (the largest of such impact-driven quakes detected by InSight). This discovery was made by examining images from the Mars Reconnaissance Orbiter (MRO) HiRISE camera, which revealed a fresh crater almost 150 meters (500 feet) in diameter. It is thought that the meteoroid would have been about 5 to 12 meters (15 to 40 feet) in size — small enough that it would have burned up in Earth's thicker atmosphere. The contemporaneous operation of InSight and MRO provided the opportunity to make this discovery and this was an invaluable opportunity to examine the seismic effects of a relatively large impact. What's more, the HiRISE images also revealed boulder-sized chunks of ice that were excavated by the impact. This detection of ice is particularly exciting because it is the first time ice has been seen on Mars at such low latitudes, with important implications for future missions to the planet.

InSight has been a treasured part of PSD's fleet for many years and is a fantastic example of how the Discovery Program continues to change our understanding of the solar system. In fact, we will be celebrating Discovery's thirtieth anniversary this year, including a symposium in Washington, D.C., in the fall — stay tuned for more information. Among other PSD highlights for 2023 — including the launch of the European Space Agency's JUICE mission in April, the delivery of OSIRIS-REx's Bennu sample in September, and the launch of Psyche in October — we will also be seeing the first Commerical Lunar Payload Services (CLPS) deliveries to the Moon. Future CLPS deliveries will place seismic suites on the lunar surface, and will be the next step in planetary seismology — a legacy started with Apollo and continued superbly with InSight.

SOFIA OBSERVATIONS INDICATE NO PRESENCE OF PHOSPHINE ON VENUS



The spectral data from SOFIA overlain atop this image of Venus from NASA's Mariner 10 spacecraft are what the researchers observed in their study, showing the intensity of light from Venus at different wavelengths. If a significant amount of phosphine were present in Venus' atmosphere, there would be sharp dips in the graph at the four locations labeled "PH3," similar to but less pronounced than those seen on the two ends. Credit: Venus: NASA/JPL-Caltech; Spectra: Cordiner et al.

After the 2020 announcement of the discovery of phosphine above Venus' clouds, the Stratospheric Observatory for Infrared Astronomy (SOFIA) conducted follow-up observations to confirm or refute the finding. Its observations did not find phosphine in Venus' atmosphere, a potential biomarker and possible indicator of organic matter, or life.

Venus is considered Earth's twin in many ways, but thanks to SOFIA, one difference now seems clearer: Unlike Earth, Venus does not have any obvious phosphine.

Phosphine is a gas found in Earth's atmosphere, but the announcement of phosphine discovered above Venus' clouds made headlines in 2020 because of its potential as a biomarker. In other words, phosphine could be an indicator of life. Though common in the atmospheres of gas planets like Jupiter and Saturn, phosphine on Earth is associated with biology. On Earth, it is formed by decaying organic matter in bogs, swamps, and marshes.

"Phosphine is a relatively simple chemical compound — it's just a phosphorus atom with three hydrogens — so you would think that would be fairly easy to produce. But on Venus, it's not obvious how it could be made," said Martin Cordiner, a researcher in astrochemistry and planetary science at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

There may be other potential ways to form phosphine on a rocky planet, like through lightning or volcanic activity, but none of these apply if there simply isn't any phosphine on Venus. And according to SOFIA, there isn't.

Following the 2020 study, several different telescopes conducted follow-up observations to confirm or refute the finding. Cordiner and his team followed suit, using SOFIA in their search.

SOFIA, a far-infrared telescope mounted in a Boeing 747 aircraft, recently concluded its science operations in September 2022. Over the course of three flights in November 2021, it looked for hints of phosphine in Venus' sky. Thanks to its operation from Earth's sky, SOFIA could perform observations not accessible from ground-based observatories. Its high spectral resolution also enabled it to be sensitive to phosphine at high altitudes in Venus' atmosphere about 75 to 110 kilometers (45 to 70 miles) above the ground, the same region as the original finding, with spatial coverage across Venus' entire disk.

The researchers didn't see any sign of phosphine. According to their results, if there is any phosphine present in Venus' atmosphere at all, it is a maximum of about 0.8 parts phosphine per billion parts everything else, much smaller than the initial estimate.

Pointing SOFIA's telescope at Venus was a challenge in and of itself. The window during which Venus could be observed was short, about half an hour after sunset, and the aircraft needed to be in the right place at the right time. Venus also goes through phases like the Moon, making it difficult to center the telescope on the planet. Add in its proximity to the Sun in the sky, which the telescope must avoid, and the situation quickly became tense.

"You don't want sunlight accidentally coming in and shining on your sensitive telescope instruments," Cordiner said. "The Sun is the last thing you want in the sky when you're doing these kinds of sensitive observations."

Despite the fact the group did not find phosphine after the stressful observations, the study was a success. Along with complementary data from other observatories that vary in the depths they probe within Venus' atmosphere, the SOFIA results help build the body of evidence against phosphine anywhere in Venus' atmosphere, from its equator to its poles.

SOFIA was a joint project of NASA and the German Space Agency at DLR. SOFIA achieved full operational capability in 2014 and concluded its final science flight on September 29, 2022. For more information, visit www.sofia.usra.edu/.

SPLASHDOWN! NASA'S ORION RETURNS TO EARTH AFTER HISTORIC MOON MISSION

NASA's Orion spacecraft shown splashing down in the Pacific Ocean, west of Baja California, at 9:40 a.m. PST Sunday, December 11, 2022. Credit: NASA.

NASA's Orion spacecraft splashed down in the Pacific Ocean, west of Baja California, at 9:40 a.m. PST December 11, 2022, after a record-breaking mission, traveling more than 1.4 million miles on a path around the Moon and returning safely to Earth, completing the Artemis I flight test.

Splashdown is the final milestone of the Artemis I mission that began with a successful liftoff of NASA's Space Launch System (SLS) rocket November 16 from Launch Pad 39B at NASA's Kennedy Space Center in Florida. Over the course of 25.5 days, NASA tested Orion in the harsh environment of deep space before flying astronauts on Artemis II.

"The splashdown of the Orion spacecraft — which occurred 50 years to the day of the Apollo 17 Moon landing — is the crowning achievement of Artemis I. From the launch of the world's most powerful rocket to the exceptional journey around the Moon and back to Earth, this flight test is a major step forward in the Artemis Generation of lunar exploration," said NASA Administrator Bill Nelson. "It wouldn't be possible without the incredible NASA team. For years, thousands of individuals have poured themselves into this mission, which is inspiring the world to work together to reach untouched cosmic shores. Today is a huge win for NASA, the United States, our international partners, and all of humanity."

During the mission, Orion performed two lunar flybys, coming within 80 miles of the lunar surface. At its farthest distance during the mission, Orion traveled nearly 270,000 miles from our home planet, more than 1,000 times farther than where the International Space Station orbits Earth, to intentionally stress systems before flying crew.

"With Orion safely returned to Earth we can begin to see our next mission on the horizon which will fly crew to the Moon for the first time as a part of the next era of exploration," said Jim Free, NASA associate administrator for the Exploration Systems Development Mission Directorate. "This begins our path to a regular cadence of missions and a sustained human presence at the Moon for scientific discovery and to prepare for human missions to Mars."

Prior to entering the Earth's atmosphere, the crew module separated from its service module, which is the propulsive powerhouse provided by the European Space Agency. During re-entry, Orion endured temperatures about half as hot as the surface of the Sun at about 5,000°F. Within about 20 minutes, Orion slowed from nearly 25,000 mph to about 20 mph for its parachute-assisted splashdown.

During the flight test, Orion stayed in space longer than any spacecraft designed for astronauts has without docking to a space station. While in a distant lunar orbit, Orion surpassed the record for distance traveled by a spacecraft designed to carry humans, previously set during the Apollo 13 mission.

"Orion has returned from the Moon and is safely back on planet Earth," said Mike Sarafin, Artemis I mission manager. "With splashdown we have successfully operated Orion in the deep space environment, where it exceeded our expectations, and demonstrated that Orion can withstand the extreme conditions of returning through Earth's atmosphere from lunar velocities."

Artemis I was the first integrated test of NASA's deep space exploration systems – the Orion spacecraft, SLS rocket, and the supporting ground systems — and was supported by thousands of people around the world, from contractors who built the spacecraft and rocket, and the ground infrastructure needed to launch them, to international and university partners, to small businesses supplying subsystems and components.

Through Artemis missions, NASA will land the first woman and the first person of color on the surface of the Moon, paving the way for a long-term lunar presence and serving as a steppingstone for astronauts on the way to Mars.

Learn more about Artemis I at www.nasa.gov/artemis-1.

NASA'S INSIGHT LANDER DETECTS STUNNING METEOROID IMPACT ON MARS

Boulder-sized blocks of water ice can be seen around the rim of an impact crater on Mars, as viewed by the High-Resolution Imaging Science Experiment (HiRISE) camera onboard NASA's Mars Reconnaissance Orbiter. The crater was formed December 24, 2021, by a meteoroid strike in the Amazonis Planitia region. Credit: NASA/JPL-Caltech/University of Arizona.

NASA's InSight lander recorded a magnitude 4 marsquake December 24, 2021, but scientists learned later the cause of that quake: a meteoroid strike estimated to be one of the biggest seen on Mars since NASA began exploring the cosmos. What's more, the meteoroid excavated boulder-sized chunks of ice buried closer to the martian equator than ever found before, a discovery with implications for NASA's plans to send astronauts to the Red Planet.

Scientists determined the quake resulted from a meteoroid impact when they looked at before-and-after images from NASA's Mars Reconnaissance Orbiter (MRO) and spotted a new, yawning crater. Offering a rare opportunity to see how a large impact shook the ground on Mars, the event and its effects were detailed in two papers published October 27, 2022, in the journal *Science*.

The meteoroid is estimated to have spanned 5 to 12 meters (16 to 39 feet), small enough that it would have burned up in Earth's atmosphere, but not in Mars' thin atmosphere, which is just 1% as dense as our planet's. The impact, which occurred in a region called Amazonis Planitia, blasted a crater roughly 150 meters (492 feet) across and 21 meters (70 feet) deep. Some of the ejecta thrown by the impact flew as far as 37 kilometers (23 miles) away.

With images and seismic data documenting the event, this is believed to be one of the largest craters ever witnessed forming any place in the solar system. Many larger craters exist on the Red Planet, but they are significantly older and predate any Mars mission.

"It's unprecedented to find a fresh impact of this size," said Ingrid Daubar of Brown University, who leads InSight's Impact Science Working Group. "It's an exciting moment in geologic history, and we got to witness it."

InSight studied the planet's crust, mantle, and core. Seismic waves are key to the mission and have revealed the size, depth, and composition of Mars' inner layers. Since landing in November 2018, InSight detected 1,318 marsquakes, including several caused by smaller meteoroid impacts.

But the quake resulting from the December 2021 impact was the first observed to have surface waves, a kind of seismic wave that ripples along the top of a planet's crust. The second of the two Science papers related to the big impact describes how scientists use these waves to study the structure of Mars' crust.

In late 2021, InSight scientists reported to the rest of the team they had detected a major marsquake on December 24. The crater was first spotted February 11, 2022, by scientists working at Malin Space Science Systems (MSSS), which built and operates two cameras onboard MRO. The Context Camera (CTX) provides black-and-white, medium-resolution images, while the Mars Color

Imager (MARCI) produces daily maps of the entire planet, allowing scientists to track large-scale weather changes like the recent regional dust storm that further diminished InSight's solar power.

The impact's blast zone was visible in MARCI data that allowed the team to pin down a 24-hour period within which the impact occurred. These observations correlated with the seismic epicenter, conclusively demonstrating that a meteoroid impact caused the large December 24 marsquake.

"The image of the impact was unlike any I had seen before, with the massive crater, the exposed ice, and the dramatic blast zone preserved in the martian dust," said Liliya Posiolova, who leads the Orbital Science and Operations Group at MSSS. "I couldn't help but imagine what it must have been like to witness the impact, the atmospheric blast, and debris ejected miles downrange."

Establishing the rate at which craters appear on Mars is critical for refining the planet's geologic timeline. On older surfaces, such as those of Mars and our Moon, there are more craters than on Earth; on our planet, the processes of erosion and plate tectonics erase older features from the surface.

New craters also expose materials below the surface. In this case, large chunks of ice scattered by the impact were viewed by MRO's High-Resolution Imaging Science Experiment (HiRISE) color camera.

Subsurface ice will be a vital resource for astronauts, who could use it for a variety of needs, including drinking water, agriculture, and rocket propellant. Buried ice has never been spotted this close to the martian equator, which, as the warmest part of Mars, is an appealing location for astronauts.

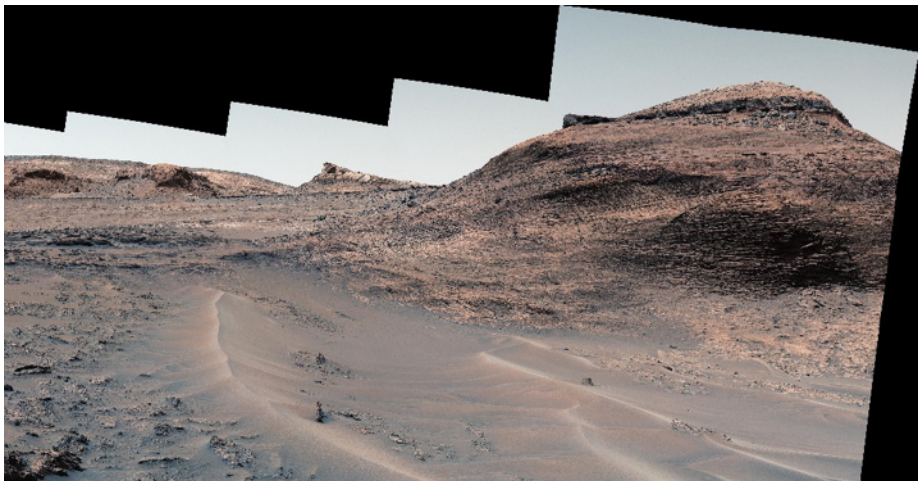
For more information, visit mars.nasa.gov/insight/.

NASA'S CURIOSITY MARS ROVER REACHES LONG-AWAITED SALTY REGION

The Curiosity Mars rover has arrived at a special region believed to have formed as Mars' climate was drying.

After journeying last summer through a narrow, sand-lined pass, NASA's Curiosity Mars rover recently arrived in the "sulfate-bearing unit," a long-sought region of Mount Sharp enriched with salty minerals.

Scientists hypothesize that billions of years ago, streams and ponds left behind the minerals as the water dried up. Assuming the hypothesis is correct, these minerals offer tantalizing clues as to how — and why — the Red Planet's climate changed from being more Earth-like to the frozen desert it is today.



NASA's Curiosity Mars rover used its Mast Camera, or Mastcam, to capture this panorama of a hill nicknamed Bolívar and adjacent sand ridges on August 23, the 3572nd martian day, or sol, of the mission. Credit: NASA/JPL-Caltech/MSSS.

The minerals were spotted by NASA's Mars Reconnaissance Orbiter years before Curiosity landed in 2012, so scientists have been waiting a long time to see this terrain up close. Soon after arriving, the rover discovered a diverse array of rock types and signs of past water, among them popcorn-textured nodules and salty minerals such as magnesium sulfate (Epsom salt is one kind), calcium sulfate (including gypsum), and sodium chloride (ordinary table salt).

They selected a rock nicknamed "Canaima" for the mission's 36th drill sample, and choosing the rock was no easy task. Along with scientific considerations, the team had to factor in the rover's hardware. Curiosity uses a percussive, or jackhammering, rotary drill at the end of its 2-meter (7-foot) arm to pulverize rock samples for analysis. Worn brakes on the arm recently led the team to conclude that some harder rocks may require too much hammering to drill safely.

"As we do before every drill, we brushed away the dust and then poked the top surface of Canaima with the drill. The lack of scratch marks or indentations was

"The sand ridges were gorgeous. You see perfect little rover tracks on them. And the cliffs were beautiful — we got really close to the walls."

an indication that it may prove difficult to drill," said Curiosity's new project manager, Kathya Zamora-Garcia of NASA's Jet Propulsion Laboratory (JPL) in Southern California. "We paused to consider whether that posed any risk to our arm. With the new drilling algorithm, created to minimize the use of percussion, we felt comfortable collecting a sample of Canaima. As it turned out, no percussion was needed."

The mission scientists look forward to analyzing portions of the sample with the Chemical and Mineralogy (CheMin) instrument and the Sample Analysis at Mars (SAM) instrument.

The journey to the sulfate-rich region took Curiosity through treacherous terrain, including the sandy "Paraitepuy Pass," an area that snakes between high hills, this past August. It took the rover more than a month to safely navigate to finally reach its destination.

While sharp rocks can damage Curiosity's wheels (which have plenty of life left in them), sand can be just as hazardous, potentially causing the rover to get stuck if the wheels lose traction. Rover drivers need to carefully navigate these areas.

The hills blocked Curiosity's view of the sky, requiring the rover to be carefully oriented based on where it could point its antennas toward Earth and how long it could communicate with orbiters passing overhead.

After braving those risks, the team was rewarded with some of the most inspiring scenery of the mission, which the rover captured with an August 14 panorama using its Mast Camera, or Mastcam.

"We would get new images every morning and just be in awe," said Elena Amador-French of JPL, Curiosity's science operations coordinator, who manages collaboration between the science and engineering teams. "The sand ridges were gorgeous. You see perfect little rover tracks on them. And the cliffs were beautiful — we got really close to the walls."

But this new region comes with its own challenges: While scientifically compelling, the rockier terrain makes it harder to find a place where all six of Curiosity's wheels are on stable ground. If the rover isn't stable, engineers won't risk unstowing the arm, in case it might bang into the jagged rocks.

"The more and more interesting the science results get, the more obstacles Mars seems to throw at us," Amador-French said.

But the rover, which recently marked its tenth year on Mars, and its team are ready for this next chapter of their adventure.

For more information about Curiosity, visit mars.nasa.gov/msl.

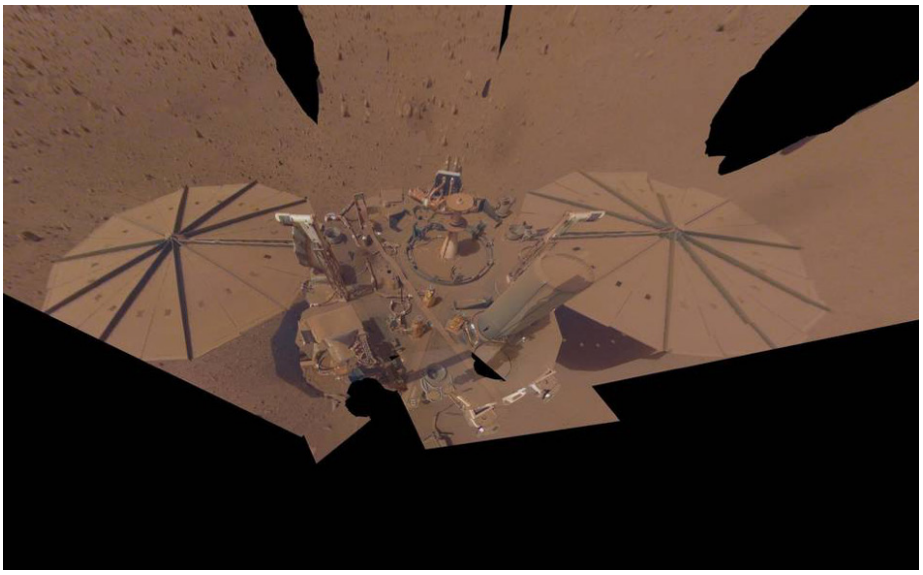
NASA RETIRES INSIGHT MARS LANDER MISSION AFTER YEARS OF SCIENCE

NASA's InSight mission has ended after more than four years of collecting unique science on Mars.

Mission controllers at the agency's Jet Propulsion Laboratory (JPL) in Southern California were unable to contact the lander after two consecutive attempts, leading them to conclude the spacecraft's solar-powered batteries have run out of energy, a state engineers refer to as "dead bus."

NASA had previously decided to declare the mission over if the lander missed two communication attempts. The agency will continue to listen for a signal from the lander, just in case, but hearing from it at this point is considered unlikely. The last time InSight communicated with Earth was December 15.

"I watched the launch and landing of this mission, and while saying goodbye to a spacecraft is always sad, the fascinating science InSight conducted is cause for celebration," said Thomas



An image of the final selfie taken by NASA's InSight Mars lander on April 24, 2022, the 1,211th martian day, or sol, of the mission. The lander is covered with far more dust than it was in its first selfie, taken in December 2018, not long after landing — or in its second selfie, composed of images taken in March and April 2019. Because InSight's dusty solar panels produced less power, the team put the lander's robotic arm in its resting position (called the "retirement pose") for the last time in May of 2022. Credit: NASA.

Zurbuchen, associate administrator of NASA's Science Mission Directorate in Washington. "The seismic data alone from this Discovery Program mission offers tremendous insights not just into Mars but other rocky bodies, including Earth."

Short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, InSight set out to study the deep interior of Mars. The lander data have yielded details about Mars' interior layers, the surprisingly strong remnants beneath the surface of its extinct magnetic dynamo, weather on this part of Mars, and lots of quake activity.

Its highly sensitive seismometer, along with daily monitoring performed by the French space agency Centre National d'Etudes Spatiales (CNES) and the Marsquake Service managed by ETH Zurich, detected 1,319 marsquakes, including quakes caused by meteoroid impacts, the largest of which unearthed boulder-size chunks of ice in late 2021.

Such impacts help scientists determine the age of the planet's surface, and data from the seismometer provides scientists a way to study the planet's crust, mantle, and core.

"With InSight, seismology was the focus of a mission beyond Earth for the first time since the Apollo missions, when astronauts brought seismometers to the Moon," said Philippe Lognonné of Institut de Physique du Globe de Paris (IPGP), principal investigator of InSight's seismometer. "We broke new ground, and our science team can be proud of all that we've learned along the way."

"Yes, it's sad to say goodbye, but InSight's legacy will live on, informing and inspiring."

The seismometer was the last science instrument that remained powered on as dust accumulating on the lander's solar panels gradually reduced its energy, a process that began before NASA extended the mission.

"InSight has more than lived up to its name. As a scientist who's spent a career studying Mars, it's been a thrill to see what the lander has achieved, thanks to an entire team of people across the globe who helped make this mission a success," said Laurie Leshin, director of JPL, which manages the mission. "Yes, it's sad to say goodbye, but InSight's legacy will live on, informing and inspiring."

All Mars missions face challenges, and InSight was no different. The lander featured a self-hammering spike, nicknamed "the mole," that was intended to dig 5 meters (16 feet) down, trailing a sensor-laden tether that would measure heat within the planet, enabling scientists to calculate how much energy was left over from Mars' formation.

Designed for the loose, sandy soil seen on other missions, the mole could not gain traction in the unexpectedly clumpy soil around InSight. The instrument, which was provided by the German Aerospace Center (DLR), eventually buried its 40-centimeter (16-inch) probe just slightly below the surface, collecting valuable data on the physical and thermal properties of the Martian soil along the way. This is useful for any future human or robotic missions that attempt to dig underground.

The mission buried the mole to the extent possible thanks to engineers at JPL and DLR using the lander's robotic arm in inventive ways. Primarily intended to set science instruments on the martian surface, the arm and its small scoop also helped remove dust from InSight's solar panels as power began to diminish. Counterintuitively, the mission determined they could sprinkle dirt from the scoop onto the panels during windy days, allowing the falling granules to gently sweep dust off the panels.

"We've thought of InSight as our friend and colleague on Mars for the past four years, so it's hard to say goodbye," said Bruce Banerdt of JPL, the mission's principal investigator. "But it has earned its richly deserved retirement."

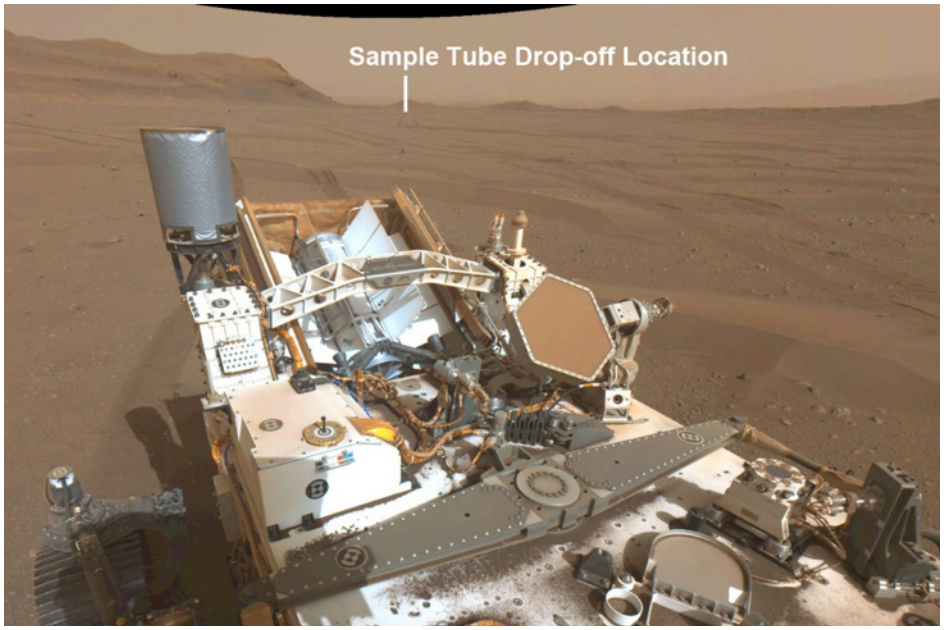
InSight is part of NASA's Discovery Program. Several European partners, including France's CNES and Germany's DLR, supported the InSight mission.

CNES provided the Seismic Experiment for Interior Structure (SEIS) instrument to NASA, with the principal investigator at IPGP. Significant contributions for SEIS came from IPGP; the Max Planck Institute for Solar System Research (MPS) in Germany; the Swiss Federal Institute of Technology (ETH Zurich) in Switzerland; Imperial College London and Oxford University in the United Kingdom; and JPL. DLR provided the Heat Flow and Physical Properties Package (HP3) instrument, with significant contributions from the Space Research Center (CBK) of the Polish Academy of Sciences and Astronika in Poland. Spain's Centro de Astrobiología (CAB) supplied the temperature and wind sensors.

For more information about the mission, visit www.nasa.gov/insight.

NASA AND ESA AGREE ON NEXT STEPS TO RETURN MARS SAMPLES TO EARTH

NASA's Perseverance rover will establish the first sample depot on Mars.



This annotated image from NASA's Perseverance shows the location of the first sample depot – where the Mars rover will deposit a group of sample tubes for possible future return to Earth – in an area of Jezero Crater called Three Forks. The image was taken August 29, 2022. Credit: NASA/JPL-Caltech.

The next step in the unprecedented campaign to return scientifically selected samples from Mars was made on October 19 with a formal agreement between NASA and its partner the European Space Agency (ESA). The two agencies will proceed with the creation of a sample tube depot on Mars. The sample depot, or cache, will be at "Three Forks," an area located near the base of an ancient river delta in Jezero Crater.

This cache will contain samples from carefully selected rocks on the surface of Mars, samples that can help tell the story of Jezero Crater's history and how Mars evolved and could perhaps even contain signs of ancient life. Scientists believe the cored samples from the delta's fine-grained sedimentary rocks, deposited in a lake billions of years ago, are the most likely to contain indicators of whether microbial life existed when Mars' climate was much different than what it is today.

"Never before has a scientifically curated collection of samples from another planet been collected and placed for return to Earth," said Thomas Zurbuchen, associate administrator for science at NASA Headquarters in Washington. "NASA and ESA have reviewed the proposed site and the Mars samples that will be deployed for this cache as soon as next month. When that first tube is positioned on the surface, it will be a historic moment in space exploration." The cache of samples, a duplicate set of the collection that Perseverance will retain on board, is one part of a robust plan to ensure mission success. The Perseverance rover will be the primary means to convey the collected samples to the Mars launch vehicle as part of the campaign. The Three Forks depot will serve as a backup, hosting the duplicate set.

"Choosing the first depot on Mars makes this exploration campaign very real and tangible. Now we have a place to revisit with samples waiting for us there," said David Parker, ESA director of Human and Robotic Exploration. "That we can implement this plan so early in the campaign is a testament to the skill of the international team of engineers and scientists working on Perseverance and Mars Sample Return. The first depot of Mars samples can be considered a major de-risking step for the Mars Sample Return Campaign."

The first step in the campaign is already in progress. Since Perseverance landed at Jezero Crater on February 18, 2021, the rover has explored 13.2 kilometers (8.2 miles) of martian surface and collected 14 rock-core samples during its first two science campaigns. During its first science campaign, the rover explored the crater's floor, a former lakebed, finding igneous rock, which forms deep underground from magma or during volcanic activity at the surface. The second science campaign has been highlighted by

the investigation of sedimentary rocks, formed when particles of various sizes settled in the once-watery environment.

The rover has also collected one atmospheric sample and three witness tubes. Witness tubes contain material that helps identify potential terrestrial contamination in the tubes that may have come from the rover during sampling operations.

"While a significant mission milestone will have taken place once those tubes are dropped, it doesn't mean Perseverance explorations or sample collection has concluded — not by a long shot," said Perseverance project scientist Ken Farley of Caltech in Pasadena, California. "Next, we'll be headed up to the top of the delta to an area that from satellite imagery appears geologically rich, performing science investigations and collecting more rock cores. Mars Sample Return is going to have a lot of great stuff to choose from."

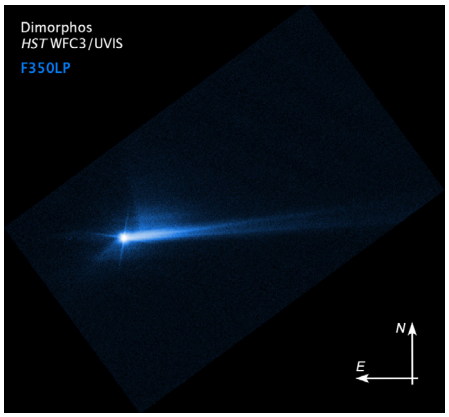
In another important milestone, the Mars Sample Return Program entered the Preliminary Design and Technology Completion Phase, known as Phase B, on October 1. During this phase, the campaign focuses on completing technology development, engineering prototyping, assessments of software and heritage hardware, and other risk-mitigation activities.

The NASA-ESA Mars Sample Return Campaign will revolutionize humanity's understanding of Mars by bringing scientifically selected samples to Earth for study using the most sophisticated instruments around the world. The campaign would fulfill a solar system exploration goal, a high priority since the 1970s and in the last three National Academy of Sciences Planetary Decadal Surveys.

This strategic NASA and ESA partnership would be the first mission to return samples from another planet and the first launch from the surface of another planet. The samples collected by Perseverance during its exploration of an ancient river delta are thought to present the best opportunity to reveal the early evolution of Mars, including the potential for life. By better understanding the history of Mars, we would improve our understanding of all rocky planets in the solar system, including Earth.

Learn more about the Mars Sample Return Program at mars.nasa.gov/msr/.

NASA CONFIRMS DART MISSION IMPACT CHANGED ASTEROID'S MOTION IN SPACE



This imagery from NASA's Hubble Space Telescope from October 8, 2022, shows the debris blasted from the surface of Dimorphos 285 hours after the asteroid was intentionally impacted by NASA's DART spacecraft on September 26. The shape of that tail has changed over time. Scientists are continuing to study this material and how it moves in space to better understand the asteroid. Credit: NASA/ESA/STScI/Hubble.

Analysis of data obtained over the past two weeks by NASA's Double Asteroid Redirection Test (DART) investigation team shows the spacecraft's kinetic impact with its target asteroid, Dimorphos, successfully altered the asteroid's orbit. This marks humanity's first time purposely changing the motion of a celestial object and the first full-scale demonstration of asteroid deflection technology.

"All of us have a responsibility to protect our home planet. After all, it's the only one we have," said NASA Administrator Bill Nelson. "This mission shows that NASA is trying to be ready for whatever the universe throws at us. NASA has proven we are serious as a defender of the planet. This is a watershed moment for planetary defense and all of humanity, demonstrating commitment from NASA's exceptional team and partners from around the world."

Prior to DART's impact, it took Dimorphos 11 hours and 55 minutes to orbit its larger parent asteroid, Didymos. Since DART's intentional collision with Dimorphos on September 26, astronomers have been using telescopes on Earth to measure how much that time has changed. Now, the investigation team has confirmed the spacecraft's impact altered Dimorphos' orbit around Didymos by 32 minutes, shortening the 11-hour and 55-minute orbit to 11 hours and 23 minutes. This measurement has a margin of uncertainty of approximately plus or minus 2 minutes.

Before its encounter, NASA had defined a minimum successful orbit period change of Dimorphos as 73 seconds or more. This early data show DART surpassed this minimum benchmark by more than 25 times.

"This result is one important step toward understanding the full effect of DART's impact with its target asteroid" said Lori Glaze, director of NASA's Planetary Science Division at NASA Headquarters in Washington. "As new data come in each day, astronomers will be able to better assess whether, and how, a mission like DART could be used in the future to help protect Earth from a collision with an asteroid if we ever discover one headed our way."

The investigation team is still acquiring data with ground-based observatories around the world, as well as with

radar facilities at NASA Jet Propulsion Laboratory's Goldstone planetary radar in California and the National Science Foundation's Green Bank Observatory in West Virginia. In addition, they are updating the period measurement with frequent observations to improve its precision.

Focus now is shifting toward measuring the efficiency of momentum transfer from DART's roughly 22,530-kilometer-per-hour (14,000-mile-per-hour) collision with its target. This includes further analysis of the "ejecta," the many tons of asteroidal rock displaced and launched into space by the impact. The recoil from this blast of debris substantially enhanced DART's push against Dimorphos, a little like a jet of air streaming out of a balloon sends the balloon in the opposite direction.

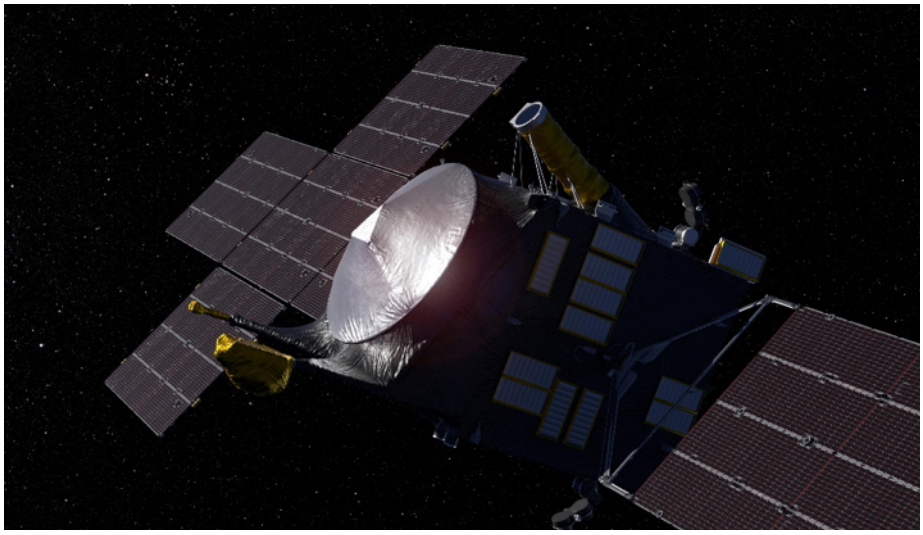
To successfully understand the effect of the recoil from the ejecta, more information on of the asteroid's physical properties, such as the characteristics of its surface, and how strong or weak it is, is needed. These issues are still being investigated.

"DART has given us some fascinating data about both asteroid properties and the effectiveness of a kinetic impactor as a planetary defense technology," said Nancy Chabot, the DART coordination lead from the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland. "The DART team is continuing to work on this rich dataset to fully understand this first planetary defense test of asteroid deflection."

Neither Dimorphos nor Didymos poses any hazard to Earth before or after DART's controlled collision with Dimorphos.

For more information about the DART mission, visit www.nasa.gov/dart.

NASA CONTINUES PSYCHE ASTEROID MISSION



This artist's concept depicts NASA's Psyche spacecraft. Originally scheduled for launch in August 2022, the Psyche mission will explore a metal-rich asteroid of the same name that lies in the main asteroid belt between Mars and Jupiter. Credit: NASA/JPL-Caltech/ASU.

NASA and the agency's Jet Propulsion Laboratory (JPL) in Southern California, which leads the Psyche mission, shared a response to the results of an independent review board convened to determine why the mission to study a metal-rich asteroid of the same name missed its planned 2022 launch opportunity.

The mission is moving forward as previously announced, and NASA will incorporate recommendations from the board to ensure its success.

The review board, convened at the request of NASA and JPL, found a significant factor in the delay was an imbalance between the workload and the available workforce at JPL. NASA will work closely with JPL management over the coming months to address the challenges raised in the report. The board will meet again in spring 2023 to assess progress.

For the Psyche mission, the board recommended increasing staffing, establishing open communications and an improved reporting system, as well as strengthening the review system to better highlight what issues might affect mission success.

In response, the Psyche project has added appropriately experienced leaders and project staff throughout the project, including filling the project chief engineer and guidance navigation and control cognizant engineer positions. JPL also formed a team to actively manage the staffing shortage across multiple projects including Psyche.

"We welcome this opportunity to hear the independent review board's findings and have a chance to address the concerns," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate in Washington. "It's our job to notice issues early – this report is essentially a canary in the coal mine — and address them. Information like this helps us for more than just Psyche, but also for

upcoming key missions such as Europa Clipper and Mars Sample Return."

The independent review board also looked at JPL as a whole. The report made recommendations to address what it called inadequate flight project staffing, in both the number of personnel and experience, as well as erosion of line organization technical acumen, and the post-pandemic work environment.

In response, changes to JPL's organizational reporting structure and reviews are in work, which along with other actions, are designed to increase institutional insight and oversight of missions including Psyche. JPL also is instituting new internal staffing approaches and working with industrial partners to support staffing needs and to redouble efforts to strengthen experienced leadership at all levels.

"I appreciate the thoughtful work of the Psyche independent review board," said Laurie Leshin, JPL director. "The board members worked diligently over the past several months to help JPL uncover and understand issues related to the delay of the Psyche launch. Their insights are helping JPL and NASA take the steps necessary to ensure success on Psyche and future missions."

To support JPL's staffing needs, NASA anticipates delaying the launch of the Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS) mission for at least three years. This choice would allow experienced staff at JPL to complete the development of strategic flagship missions further along in their development. A delay of VERITAS, a mission in early formulation, would also free up additional resources to enable the continuation of Psyche and positively affect other planetary funding needs.

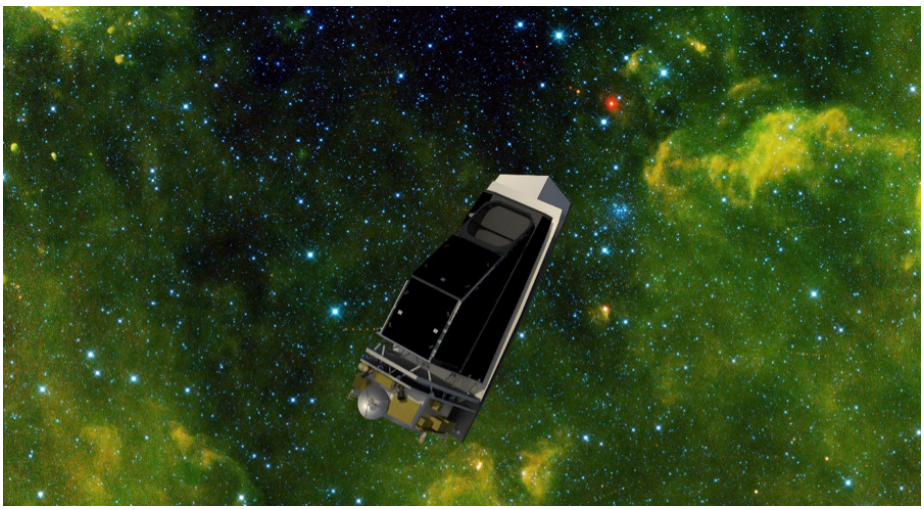
For a VERITAS delay, JPL will stand down their management and engineering teams for the mission and release the staff to other projects, while funding will be continued for science team support.

For more information about the Psyche mission, visit www.nasa.gov/psyche.

CONSTRUCTION BEGINS ON NASA'S NEXT-GENERATION ASTEROID HUNTER

NASA's Near-Earth Object (NEO) Surveyor is the first purpose-built space telescope that will advance NASA's planetary defense efforts by finding and tracking hazardous near-Earth objects.

A space telescope designed to search for the hardest-to-find asteroids and comets that stray into Earth's orbital neighborhood, NEO Surveyor recently passed a rigorous technical and programmatic review. Now the mission is transitioning into the final design-and-fabrication phase and establishing its technical, cost, and schedule baseline.



NASA's NEO Surveyor is seen in this illustration against an infrared observation of a starfield made by the agency's WISE mission. Credit: NASA/JPL-Caltech/University of Arizona.

The mission supports the objectives of NASA's Planetary Defense Coordination Office (PDCO) at NASA Headquarters in Washington. The NASA Authorization Act of 2005 directed NASA to discover and characterize at least 90% of the near-Earth objects more than 140 meters (460 feet) across that come within 48 million kilometers (30 million miles) of our planet's orbit. Objects of this size can cause significant regional damage, or worse, should they impact the Earth.

"NEO Surveyor represents the next generation for NASA's ability to quickly detect, track, and characterize potentially hazardous near-Earth objects," said Lindley Johnson, NASA's Planetary Defense Officer at PDCO. "Ground-based telescopes remain essential for us to continually watch the skies, but a space-based infrared observatory is the ultimate high ground that will enable NASA's planetary defense strategy."

Managed by NASA's Jet Propulsion Laboratory in Southern California, NEO Surveyor will journey a million miles to a region of gravitational stability called the L1 Lagrange point between Earth and the Sun, where the spacecraft will orbit during its five-year primary mission.

From this location, the NEO Surveyor will view the solar system in infrared wavelengths, light that is invisible to the human eye. Because those wavelengths are mostly blocked by Earth's atmosphere, larger ground-based observatories may

miss near-Earth objects that this space telescope will be able to spot by using its modest light-collecting aperture of nearly 50 centimeters (20 inches).

NEO Surveyor's cutting-edge detectors are designed to observe two heat-sensitive infrared bands that were chosen specifically so the spacecraft can track the most challenging-to-find near-Earth objects, such as dark asteroids and comets that don't reflect much visible light. In the infrared wavelengths to which NEO Surveyor is sensitive, these objects glow because they are heated by sunlight.

In addition, NEO Surveyor will be able to find asteroids that approach Earth from the direction of the Sun, as well as those that lead and trail our planet's orbit, where they are typically obscured by the glare of sunlight — objects known as Earth Trojans.

"For the first time in our planet's history, Earth's inhabitants are developing methods to protect Earth by deflecting hazardous asteroids," said Amy Mainzer, the mission's survey director at the University of Arizona in Tucson. "But before we can deflect them, we first need to find them. NEO Surveyor will be a game-changer in that effort."

The mission will also help to characterize the composition, shape, rotation, and orbit of near-Earth objects. While the mission's primary focus is on planetary defense, this information can be used to better understand the origins and evolution of asteroids and comets, which formed the ancient building blocks of our solar system.

When it launches, NEO Surveyor will build upon the successes of its predecessor, the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE). Repurposed from the WISE space telescope after that mission ended in 2011, NEOWISE proved highly effective at detecting and characterizing near-Earth objects, but NEO Surveyor is the first space mission built specifically to find large numbers of these hazardous asteroids and comets.

After the mission passed this milestone on November 29, key instrument development got underway. For instance, the large radiators that will allow the system to be passively cooled are being fabricated. To detect the faint infrared glow of asteroids and comets, the instrument's infrared detectors need to be much cooler than the spacecraft's electronics. The radiators will perform that important task, eliminating the need for complex active cooling systems.

"For the first time in our planet's history, Earth's inhabitants are developing methods to protect Earth by deflecting hazardous asteroids."

Additionally, construction of the composite struts that will separate the telescope's instrumentation from the spacecraft has begun. Designed to be poor heat conductors, the struts will isolate the cold instrument from the warm spacecraft and sunshield, the latter of which will block sunlight that might otherwise obscure the telescope's view of near-Earth objects and heat up the instrument.

Progress has also been made developing the instrument's infrared detectors, beam splitters, filters, electronics, and enclosure. And work has begun on the space telescope's mirror, which will be formed from a solid block of aluminum and shaped by a custom-built diamond-turning machine.

"The project team, including all of our institutional and industrial collaborators, is already very busy designing and fabricating components that will ultimately become flight hardware," said Tom Hoffman, NEO Surveyor project manager at JPL. "As the mission enters this new phase, we're excited to be working on this unique space telescope and are already looking forward to our launch and the start of our important mission."

The mission is tasked by NASA's Planetary Science Division within the Science Mission Directorate; program oversight is provided by the PDCO, which was established in 2016 to manage the agency's ongoing efforts in planetary defense. NASA's Planetary Missions Program Office at Marshall Space Flight Center provides program management for NEO Surveyor.

More information about NEO Surveyor is available at solarsystem.nasa.gov/missions/neo-surveyor.

NASA INCLUSION PLAN RESOURCES WEBSITE NOW AVAILABLE

Inclusion is a core NASA value, as described in the NASA policy statement on Diversity, Equity, Inclusion, and Accessibility (DEIA). Additionally, Strategy 4.1 of "Science 2020-2024: A Vision for Scientific Excellence" states that NASA should "increase the diversity of thought and backgrounds represented across the entire SMD portfolio through a more inclusive environment." In keeping with this core value, some NASA Research Opportunities in Space and Earth Sciences (ROSES) programs are piloting the addition of a required Inclusion Plan.

NASA'S Science Mission Directorate (SMD)'s Inclusion Plan Resources website is now live! This page contains a variety of resources and materials to help with the writing, revision, and implementation of Inclusion Plans. Links to the Inclusion Plan Best Practices Workshop recordings are also included. View the full Inclusion Plan Resources website at Inclusion Plan Resources.

The website provides resources to support writing, revision, and implementation of Inclusion Plans. This includes NASA's definitions of DEIA, materials supporting required elements of a plan, and other resources to facilitate the realization of a successful plan.

BETH BROWN MEMORIAL AWARD WINNERS FOR 2022

AAS Education & Mentoring Specialist Tom Rice and AAS DEI Committee Support Specialist Mildred Peyton with Beth Brown Memorial winners: Chris Carr, Caprice Phillips, Hodari-Sadiki Hubbard-James, and Myles Pope. Credit: AAS.

The American Astronomical Society (AAS) supports a prize program at the annual meeting of the National Society of Black Physicists (NSBP): The Beth Brown Memorial Awards.

The awards honor the memory of a vigorous and engaged young astronomer who passed away at age 39 from a pulmonary embolism. Beth Brown earned her bachelor's degree from Howard University and, in 1998, became the first African American woman to earn a Ph.D. from the University of Michigan's astronomy department. She died in 2008, just before beginning a new position as Assistant Director for Science Communication at NASA's Goddard Space Flight Center. Although her time working in the professional astronomical community was short, she had a significant impact on our discipline, not least by serving as a role model for many students from underrepresented groups.

Three awards are given: best poster presentations by an undergraduate and a graduate student, and best oral presentation by either an undergraduate or a graduate student. At the recent NSBP Annual Conference, recipients of the 2022 awards were announced:

Best Undergraduate Poster Presentation: Myles Pope (Howard University), "Accurate Masses of Extraordinary Red Giants"

Best Graduate Poster Presentation: Kiersten Boley (The Ohio State University), "Impacts on Planet Formation: Planet Occurrence Rates in the Metal-Poor Regime"

Memorial Oral Presentation: Caprice Phillips (The Ohio State University), "Is LTT 1445 Ab a Hycean World or a Cold Haber World? Exploring the Potential of Twinkle to Unveil Its Nature"

Read more at aas.org/posts/news/2022/12/beth-brown-memorial-award-winners-2022.

STEM STUDENTS RECOGNIZED FOR THEIR RESEARCH AND PRESENTATION SKILLS AT 2022 SACNAS

Credit: SACNAS.

The Society for the Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) awarded 110 graduate and undergraduate students from historically excluded communities for their research and presentation skills at 2022 SACNAS — The National Diversity in STEM Conference held in Puerto Rico on October 27–29, 2022. Student research presentations help equip young researchers with the skills and mentoring they need to be successful on their STEM journey. This experience helps them refine presentation skills, receive one-on-one mentoring and feedback on research, and connect with a supportive community of peers, mentors, and role models.

"As a young scientist, the National Diversity in STEM Conference is where I learned the skills needed to present my research. Watching the development of this program and seeing how many more students are participating now than have in the past shows the importance of a supportive community of peers and mentors. This work highlights the next generation of diverse scientists and STEM leaders while giving visibility to their research institutions, making science more accessible for everyone, bringing us closer to True Diversity in STEM," said SACNAS President Dr. Pam Padilla.

To view the full list of 2022 SACNAS — The National Diversity in STEM Conference Presentation Awardees, visit www.sacnas.org/diversity-news/stem-students-recognized-for-research-and-presentation-skills-at-2022-sacnas-the-national-diversity-in-stem-conference.

SCHOLARSHIPS AVAILABLE FOR WOMEN IN STEM

Credit: Getty Images.

If STEM careers offer premier growth and earnings, what are the barriers to working in STEM? For one, most STEM careers require a college degree. On top of that, women face unique obstacles when pursuing STEM careers.

Although women's representation in STEM has increased dramatically since 1970, those strides have leveled off in recent years. Despite computer science being the largest-growing STEM field, the number of women working in computing has dropped 7 percentage points from 2000 to 2016 and has remained stable since that year.

So what's the overall outlook for women interested in technical fields? BestColleges dives into the challenges and opportunities for women looking to establish a STEM career and also provides a list of great scholarships available to them. For more information, visit www.bestcolleges.com/blog/barriers-for-women-in-stem/#scholarships-for-women-in-stem.

2023 GEM ANNUAL BOARD MEETING AND CONFERENCE

The 2023 GEM Annual Board Meeting and Conference will be held September 14–16, 2023, in Philadelphia, Pennsylvania.

The GEM Annual Conference provides a wealth of resources for everyone: networking opportunities, career options and coaching, information on innovations and advancements in STEM, and the many benefits of being a part of the GEM family.

The annual conference embodies all aspects of scientific excellence! You'll find vetted and proven applied scientists and engineers, universities and faculty committed to cultural diversity in STEM, and employers who recognize the value of multiculturalism and excellence in the workplace.

Learn more about the conference at www.gemfellowship.org/about-the-annual-conference/.

Credit: The National GEM Consortium.

About GEM

Founded in 1976 at the University of Notre Dame, we have operated quietly and steadily to graduate over 4000 researchers, professors, entrepreneurs, inventors, and business leaders, including over 200 men and women with doctorates in the physical sciences, life sciences, and engineering. The mission of The National GEM Consortium is to enhance the value of the nation's human capital by increasing the participation of underrepresented groups (African Americans, American Indians, and Hispanic Americans) at the master's and doctoral levels in engineering and science.

LGBTQ+ IN ENGINEERING SUMMIT 2022

In October 2022, InterEngineering and the Royal Academy of Engineering hosted the second LGBTQ+ in Engineering Summit. The aim of the day was to analyze insights from the Royal Academy of Engineering's Inclusive Cultures survey, the largest collation of insights into culture, inclusion, and diversity for LGBTQ+ engineers to have ever existed.

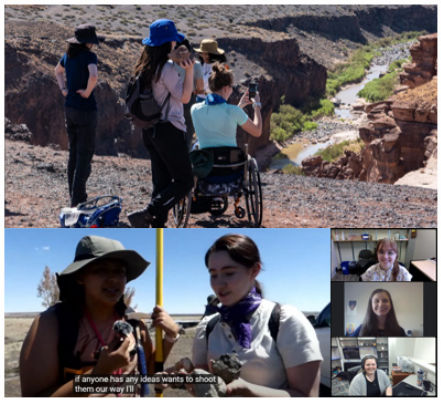
The day was attended by 30 leaders from industry, academia, and engineering professional bodies.

Read more about the summit at interengineeringlgbt.com/lgbtq-in-engineering-summit-2022/.

Credit: InterEngineering.

OPINION ARTICLES CELEBRATING INTERNATIONAL DAY OF PERSONS WITH DISABILITIES

To celebrate the International Day of Persons with Disabilities on December 3, 2022, *Nature Reviews Earth & Environment* published a series of opinion articles by geoscientists with disabilities, who outline their reflections on some of the challenges the community faces and offer solutions to make the Earth sciences a more inclusive space.



Credit: GeoSPACE, University of Florida Department of Geological Sciences.

Flexible fieldwork — Anita M. S. Marshall, Jennifer L. Piatek, David A. Williams, Elisabeth Gallant, Sean Thatcher, Stephen Elardo, Amy J. Williams, Trevor Collins, and Yesenia Arroyo

GeoSPACE is addressing the barrier of inaccessible field courses with a "planetary mission" approach, combining online and accessible in-person participation.

Looking out for visual impairments — Paul Upchurch

Paul Upchurch discusses how individuals, institutions, and funding bodies must take meaningful action to increase the representation of, and fight prejudice against, physically impaired colleagues.

Breaking barriers for those with hidden disabilities — Isabel Carrera Zamanillo

Isabel Carrera Zamanillo provides insight into the barriers and stresses that people with hidden disabilities can face in academia and invites you to reflect on your role in the creation of spaces where people with disabilities can thrive.

HOW THIS 37-YEAR-OLD AEROSPACE ENGINEER IS DESIGNING A SPACESUIT FOR WOMEN

Credit: CNBC.

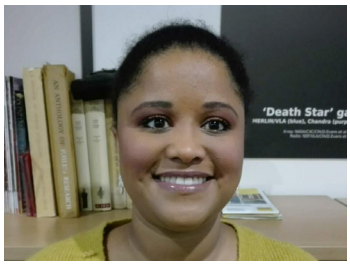
Although women ages 25 and older now represent a majority of the college-educated workforce in the U.S., they still trail men in many of the STEM fields, particularly in engineering and computing jobs. Sabrina Thompson is hoping to change that. The 37-year-old aerospace engineer is also the CEO and founder of Girl in Space Club. The direct-to-consumer fashion brand also has a mentorship arm aimed at getting more girls interested in STEM education through fashion. One of the group's largest projects is designing a women's in-vehicle spacesuit to be worn by astronauts during takeoff and re-entry. The project is still in its infancy.

View the full story on CNBC at www.cnbc.com/video/2022/11/01/37-year-old-aerospace-engineer-designing-a-spacesuit-for-women.html.

WHY WE NEED TO DECOLONIZE THE SKIES

South African astronomer Tana Joseph is passionate about making it possible for more people to look to the stars. In an article recently published with *The Wellcome Collection*, she explains the harms of colonial views of space and how indigenous perspectives are important not only for the well-being of scientists from diverse backgrounds but for our entire biosphere.

Read the full article at wellcomecollection.org/articles/Y2jPaxEAAKLNdrFU.



Credit: Astronomy in Colour.

"IDEA In Action" highlights organizations, individuals, and events within the planetary science community that highlight principles of inclusion, diversity, equity, and accessibility (IDEA). To submit content highlighting IDEA in the planetary community, contact the Lunar and Planetary Institute's Communications Department at LPI-Communications@usra.edu.

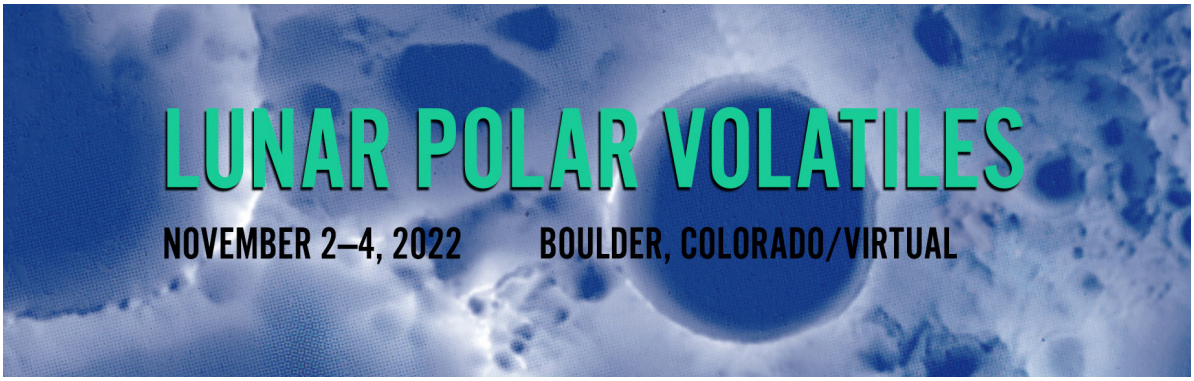
The Inclusion Plan Best Practices Workshop was held virtually on November 1–2, 2022. This workshop was motivated by the recent requirement for inclusion plans within several of NASA's Research Opportunities in Space and Earth Sciences (ROSES) programs.

For ROSES-2022, 12 programs [plus the Solar System Exploration Research Virtual Institute (SSERVI) Cooperative Agreement Notice] required proposals to contain an inclusion plan that outlines how the team will work against barriers to create and sustain inclusive work environments and how the team will equip members in such a way that they can go on to lead and contribute to other teams that are diverse and inclusive. One of the consistent requests from the planetary community has been for NASA to provide resources for proposers to help them write competent and responsive inclusion plans.

As a response to this request for more inclusion plan resources, NASA Science Mission Directorate (SMD) Program Officers, in coordination with social scientists from the Learning Management Institute, organized the two-day Inclusion Plan Best Practices Workshop. The goal of this workshop was to provide proposers with some background and tools needed to be active participants in creating and maintaining inclusive work environments. The workshop was open to any member of the science community, and had close to 900 registrants and around 500 participants on each day. The first hour of each day was dedicated to oral presentations given by NASA SMD personnel and inclusion, diversity, equity, and accessibility (IDEA) experts, followed by 45–60 minutes of questions and open discussion with the community. The first day of the workshop was focused on "Why Inclusion," with talks focusing on the importance of inclusion, inclusion killers, distinctions between inclusion and diversity, and more. The theme of the second day of the workshop was "How to Develop and Maintain an Inclusive Work Environment," and covered topics such as evaluation metrics, what an inclusion plan is **not**, lessons learned from development of research inclusion toolkits, and more. The second day also had lengthy discussions to clear up confusion regarding diversity vs. inclusion and what the requirements are for ROSES inclusion plans, as well as how teams can evaluate the success of their proposed plans.

One thing this workshop was not designed to do was to tell proposers exactly how to write an inclusion plan. Every team will face different barriers to inclusion, and there is no one right way to write an inclusion plan. The goal of this workshop was rather to introduce to proposers the importance of inclusion, and how to go about creating and maintaining inclusive work environments. In conjunction with this workshop, SMD has developed a website with more resources to guide proposers in learning more about IDEA and in crafting responsive inclusion plans (science.nasa.gov/researchers/inclusion). Additional iterations of this workshop will be held in the future, and recordings from this workshop can be found on the workshop meeting website at www.hou.usra.edu/meetings/inclusionplan2022/.

— *Text provided by Ryan Watkins*



The Lunar Polar Volatiles Conference was held from November 2–4, 2022 in Boulder, Colorado. It was organized by the Laboratory for Atmospheric and Space Physics (LASP) and the Lunar and Planetary Institute (LPI), and included in-person and remote participants from more than 10 countries. A total of 47 people attended in person and over 120 participated remotely, with a significant number of students and early-career scientists.

The meeting focused on understanding the abundance of lunar polar ice in preparation for future missions to the Moon. The first day provided background information and set the main goals for the meeting, and listed outstanding burning questions.

The second day featured presentations on models and observations of surface and subsurface ice, the potential types of cold-trapped volatiles, and the historic evolution of ice in polar cold traps. Notable contributions included discussions on the relationship between deeply buried ice and surface ice and the use of indirect observations, such as those of crater morphology, to understand this link. Other presentations highlighted the importance of combining thermal models with dynamic models of the Moon's orbital evolution in order to identify the first cold traps, which are the most likely to contain ice, and the importance of defining a "cold trapping criteria," based on estimates of the loss rate.

The third and final day of the conference focused on future missions and mission concepts to the lunar poles, including the Lunar Flashlight and VIPER missions, which are focused on surface and near-surface ice, as well as other proposals that aim to use interactions between matter and radiation to infer the abundance of deeply buried ice.

For more information about the conference, including links to the program and abstracts, visit www.hou.usra.edu/meetings/lunarpolar2022/.

— *Text provided by Lior Rubanenko*

The Exoplanets in Our Backyard 2 workshop was held in Albuquerque, New Mexico, on November 2–4, 2022. The workshop was an interdisciplinary and interdivisional education, networking, and collaboration event, motivated by a need to increase interaction between the exoplanet and planetary science communities.

There is a growing awareness of the power of systems- and process-based approaches to understanding planets, and it is increasingly clear that many of the most exciting and fruitful areas of research lie at the intersection of the traditionally separated domains of solar system and exoplanet research. Within our solar system, we find numerous examples of diverse worlds that can be studied close-up, showing us how planets operate on a level unthought of even a few decades ago. Comparative planetology between these worlds continues to empower a deeper understanding of the processes and phenomena that shape planets on wider scales than a single planet can tell us. Beyond our "cosmic backyard,"

more than 5000 exoplanets have been discovered as of November 2022. Despite the significant data limitations inherent to studying any individual exoplanet, these planets have the advantage of their vast numbers and can speak to planetary statistics and processes writ large. The same comparative planetology we apply within our solar system can be applied within and across these other planetary systems to reveal what is "rare" and what is "typical" on scales of individual worlds to the planetary system level — even showing us examples of worlds and processes unlike those seen in our solar system.

The Exoplanets in Our Backyard series of workshops was born out of a recognition of the value and potential of interdisciplinary, cross-divisional exoplanet and solar system research, and to encourage and grow the community of researchers working at this intersection. Exoplanets in Our Backyard 2 expanded the inter-assessment-group (AG) nature of the meeting compared with the first meeting by ensuring involvement from the following AGs: Exoplanet Exploration Program Analysis Group (ExoPAG), Mars Exploration Analysis Group (MEPAG), Mercury Exploration Assessment Group (MExAG), Outer Planets Assessment Group (OPAG), and Venus Exploration Analysis Group (VEXAG). The meeting successfully brought together solar system and exoplanetary scientists from different backgrounds and NASA divisions, fostered communication between researchers whose paths had never crossed at a meeting before, and spurred new collaborations.

The meeting was held at the New Mexico Museum of Natural History and Science immediately following the VEXAG meeting hosted at the same location. The meeting was attended by approximately 70 scientists on site and 40 online participants. Based on the success of the first two meetings, a third meeting is planned to be held in 2024.

— Text provided by Stephen Kane

The conference on Ancient Venus, the first of the series of meetings to be held as part of the Lunar and Planetary Institute's (LPI's) *Venus Science Initiative*, was held on July 25–27, 2022. Out of continuing caution about the COVID pandemic, the meeting was entirely virtual. The meeting was organized into sessions of related talks followed by question/answer periods for all the session's speakers — this format allowed for questions to multiple speakers and for speakers to question each other and explore topics in more detail.

The purpose of the Venus Science Initiative is to summarize and consolidate the community's understanding of Venus and to explore ways that the upcoming spacecraft missions can enhance and enlarge that understanding. Ancient Venus thus focused on the formation and environment of ancient Venus and the transition from that prior state. Sessions in the conference focused on the source(s) and evolution of Venus' atmosphere, the hypotheses that Venus might once have had an ocean of liquid water, Venus' tesserae as possible remnants of ancient primordial crust, and dynamics of Venus' interior and how its evolution affected the surface environment and atmosphere.

The atmosphere sessions focused on chemical clues, isotopic and elemental, about Venus' ancient past. There was a strong emphasis on noble gas elements, for which abundances are unaffected by chemical processes, and isotope ratios can be characteristic of their sources in the early solar system. Major unanswered questions center on xenon — whether its abundance has been strongly affected by atmospheric loss, and whether its isotope ratios are similar to those of Earth, Mars, or other reservoirs in the solar system.

The session about possible ancient oceans presented several climate models, in which oceans might or might not have been stable. A particular issue is coupling between the solid planet's rotation rate, the rotation of its atmosphere, and how clouds in these models affect solar insolation.

Sessions on tectonics focused on the nature of tesserae terrain, and the inferred transition(s) from some earlier to the present tectonic regime. Generally, it was inferred that Venus once supported mobile-lid tectonics (perhaps not like terrestrial plate tectonics), with most of the presentations centered on the

nature and timing of the transition to the current stagnant lid condition.

The Venus Science Initiative will include three more conferences in the coming years. Venus Surface and Atmosphere will be held January 30–February 1, 2023, at the LPI in Houston, Texas (www.hou.usra.edu/meetings/venussurface2023/). Venus as a System will be held in November 2023, likely in conjunction with the VEXAG 21 meeting. And Venus-Like Planets and Exoplanets will be held in May 2024, at a site to be determined.

For more information about the conference, including links to the program and abstracts, visit www.hou.usra.edu/meetings/ancientvenus2022/.

— Text provided by A. H. Treiman

The Ocean World Analog Field Site Assessment Workshop was held in Denver, Colorado, on October 13–15, 2022. This in-person workshop was sponsored by the Network for Ocean Worlds (NOW) and Network for Life Detection (NFoLD) Research Coordination Groups (RCNs). The motivation for the workshop was to address the need for a community-developed set of standards for evaluating ocean worlds analog sites.The goal of this workshop was to develop this set of standards into an assessment framework, validate these standards using worked examples, and develop tools for the community for use in planning efforts and proposals.

Field analog research at terrestrial analogs to study wide-scale planetary processes on ocean and icy worlds provides critical input to our fundamental knowledge of these planetary bodies. However, there are many obstacles to obtaining funding to perform analog field research, particularly for ocean and icy worlds, for which many analog field sites are remote and costly to access. The nature of these field sites often restricts their use as analogs to those researchers with the resources and/or professional networks to enable access. Furthermore, because there is no widely accepted set of standards for evaluating the fidelity of ocean worlds analog sites, more easily accessed sites are often overlooked as inappropriate analogs, even when they may claim a high level of fidelity to individual aspects of the target body. The intention of this workshop was to develop a set of criteria and a framework to assess the fidelity and operational parameters of ocean worlds analogs with respect to a science question (or engineering goal).

The workshop was limited to 60 participants, with 85% attending in person, and 15% participating virtually. Participants consisted of planetary and Earth scientists as well as engineers from a broad range of government, academic, and industry institutions including Primarily Undergraduate Institutions (PUI). A broad range of expertise within Earth, ocean, and planetary sciences were represented, including geologists, technology developers, oceanographers, biologists, astrobiologists, cryospheric scientists, geochemists, geophysicists, and geomorphologists. Participants were selected based on their prior field experience in terrestrial ocean worlds analogs, history of ocean-worlds-related research, and past participation in community-led efforts such as decadal white papers. Early career researchers made up ~40% of the participants and included graduate students, postdoctoral fellows, agency researchers, and pre-tenured faculty members, with the balance as mid-career (40%) and senior scientists and engineers (~20%).

The core agenda of the workshop consisted of four keynote talks and four breakouts. Keynotes were designed to provide the background and motivation for ocean worlds analog field work (Keynote 1: The Role of Analog Science in Ocean Worlds Exploration), provide specific examples or case studies of science-driven field work at ocean worlds analog sites (Keynote 2: Astrobiology: Studying Metabolism from Analog Perspectives and Keynote 3: Studying Geological Processes from Analog Perspectives), and an overview from Mary Voytek of NASA's programs that fund field studies (Keynote 4).

Prior to the workshop, participants were asked to submit a top-level science question relevant to their research, and three main criteria by which they evaluate the suitability of an analytical site to address their science question. Breakouts 1 and 2 focused on grouping the participant-submitted criteria and developing a framework for site evaluation. Breakouts 3 and 4 focused on using the framework to address specific participant-submitted science questions. An outline

for a manuscript detailing the output of the workshop was generated on the evening of the second day. The final day focused on writing in small groups.

Through the discussions, three methods to assess and present field site fidelity were developed: a narrative questionnaire, a comparative matrix table, and a graphic radar chart. Each of these tools have merits and caveats and can serve to both focus a scientific question and provide a cross-comparison of proposed field sites. While both methods require traceability from the specific science question to the field analog using various specific criteria, the narrative questionnaire approach represents a more open-ended approach, while the matrix represents a more constrained approach. The graphic radar chart can theoretically be used with either approach but is essentially a simplification and graphic form of the matrix approach.

With the variety of tools developed through this workshop, the most important outcome was the recognition that the fidelity of a field site must be considered within the context of the science question. With a broad range of scientific pursuits recognized by our participants — ranging from microbiology to ice rheology — no one field site is likely to accommodate all these parameter needs. The Field Site Assessment Framework Tools are designed to (1) help the researcher identify key features, (2) tabulate those needs, and (3) cross-compare potential sites. A detailed workshop report is forthcoming that will provide access and instructions for all framework tools developed during the workshop. In addition, a manuscript detailing the output of the workshop is in preparation for submission to a peer-reviewed journal, with the intent to provide a primer for those proposing field studies for ocean worlds analog research.

In addition, workshop findings included several programmatic recommendations for funding agencies. The need for improved access to field opportunities and training for early career researchers and other groups was recognized. The addition of an optional "Outreach or Community Development Addendum" to proposal solicitations was suggested to allow funding to be used to bring early career, interdisciplinary members, or teachers into the field, or to spend resources developing collaborations with local communities (e.g., native, rural). A requirement for a supplemental safety and logistics plan outside the proposal page limit was discussed to reduce competitive disadvantage of field proposers who need to allocate this text to a detailed field safety plan. Finally, reviewers should disclose if they have worked or published at the site where the scientific investigation is proposed when reviewing proposals in review panels.

— Text provided by Jennifer Stern

The NASA Outer Planets Assessment Group (OPAG) met in a hybrid format at the Lunar and Planetary Institute in Houston, Texas, on November 15–16, 2022.

OPAG typically holds this type of community meeting twice each year, to allow for discussion and feedback on current and upcoming outer-planets-related activities and to gather inputs as findings to NASA. The November 2022 meeting highlighted the science opportunities provided by the Uranus Orbiter and Probe mission concept prioritized by the recent Planetary and Astrobiology Decadal Survey.

Lightning talks and posters were presented by some attendees. The group discussed the unique challenges associated with accessing outer solar system targets in a timely manner. The group heard about recent outer-planets-related meetings, workforce-related efforts, and the current status of radioisotope power systems. Reports were given by representatives of current outer planet missions, including the James Webb Space Telescope. More information about the meeting is available at www.lpi.usra.edu/opag/meetings/nov2022/.

The next OPAG meeting will be held May 2–3, 2023, at the Johns Hopkins University's Applied Physics Laboratory in Laurel, Maryland.

— Text provided by Amanda Hendrix

OPPORTUNITIES FOR STUDENTS

INTERNSHIPS AND TRAINING PROGRAMS

SUMMER UNDERGRADUATE PROGRAM FOR PLANETARY RESEARCH (SUPPR)

The Summer Undergraduate Program for Planetary Research (SUPPR) invites undergraduate students who are interested in learning about research in planetary geoscience to apply for the 2023 program. Qualified applicants are paired with NASA-sponsored planetary geology and geophysics investigators at locations around the country for eight weeks during the summer. Students gain educational experience while contributing to NASA missions and science. Applications close on February 10, 2023. Visit SUPPR to learn more.

SOLAR REU INTERN PROGRAM

This summer, scientists from the Center for Astrophysics (CfA) Harvard & Smithsonian, will host undergraduate students from around the U.S. For 10 weeks, students will participate in research about the Sun and the heliosphere and learn the skills necessary for a successful scientific career. Projects range from data analysis to computer modeling to instrument building. Students will learn from experience about scientific research and how to apply their academic work to real-world problems. The deadline to apply is February 15, 2023. Visit SAO/NSF Solar REU Program to learn more.

SUMMER UNDERGRADUATE RESEARCH FELLOWSHIP (SURF)

The Summer Undergraduate Research Fellowships (SURF)@ JPL provides undergraduate students with the opportunity to conduct research under the guidance of experienced mentors at NASA's Jet Propulsion Laboratory. Applicants collaborate with a potential mentor to define and develop a project and write a research proposal. Students with selected proposals carry out the research project over a 10-week period during the summer. Applications for the 2023 term close on February 22, 2023. Visit JPL Summer Internship Program to learn more.

DRAGONFLY STUDENT AND EARLY CAREER INVESTIGATOR PROGRAM

Student Investigators will work with Dragonfly mission team members to conduct Titan research, help formulate Dragonfly mission science and operations plans, or assist in the development of instrumentation, hardware, or testing. A cohort of up to three qualified graduate students from U.S. colleges and universities will be selected annually for two-year terms to work with the Dragonfly team. The next application cycle will begin on/around January 2023. Program updates and available project descriptions will be posted then. Visit Student Opportunities to learn more.

NASA SUMMER INTERNSHIPS

The NASA Office of STEM Engagement (OSTEM) paid internships allow high school and college-level students to contribute to agency projects under the guidance of a NASA mentor. NASA is currently accepting applications for Summer 2023 internships. The summer session begins on June 5, and applications close on March 1, 2023. Visit NASA Internships to learn more.

CRESST II SUMMER INTERNSHIPS

The Center for Research and Exploration in Space Science and Technology II (CRESST II) works in conjunction with NASA/Goddard Space Flight Center (GSFC) to facilitate the CRESST II/NASA summer internship program. Summer internships are a 10-week paid internship where students can work alongside NASA scientists on research projects that support the science missions of NASA. The deadline to apply is March 1, 2023. Visit CRESST II Summer Internship Program to learn more.

NASA SCIENCE MISSION DESIGN SCHOOLS — PLANETARY SCIENCE SUMMER SCHOOL (PSSS)

NASA Science Mission Design Schools are 3-month-long career development experiences for doctoral students, recent Ph.D. recipients, postdocs, and junior faculty who have a strong interest in science-driven robotic space exploration missions. Participants learn the process of developing a hypothesis-driven robotic space mission in a concurrent engineering environment while getting an in-depth, first-hand look at mission design, life cycle, costs, schedule, and the trade-offs inherent in each. The Science Mission Design Schools are designed to prepare the next generation of scientists for participation and leadership in space science missions of the future. Applications are now open for the 2023 Planetary Science Summer School (PSSS) and are due March 27, 2023. Visit NASA Science Mission Design Schools to learn more.

Jet Propulsion Laboratory
California Institute of Technology

JPL SUMMER INTERNSHIP PROGRAM

The JPL Summer Internship Program, or SIP, offers 10-week, full-time, summer internship opportunities at JPL to undergraduate and graduate students pursuing degrees in STEM. Students are partnered with JPL scientists or engineers, who serve as mentors. Students complete designated projects, gaining educational experience in their fields of study while also contributing to NASA and JPL missions and science. Applications for Summer 2023 internship positions close on March 31, 2023. Visit JPL Summer Internship Program to learn more.

Ames Research Center

NASA SPACE LIFE SCIENCES TRAINING PROGRAM

The Space Life Sciences Training Program (SLSTP) provides undergraduate students with professional experience in space life science disciplines. The 10-week, paid summer program is hosted by NASA's Ames Research Center. Students work closely with renowned NASA scientists and engineers on cutting-edge research exploring the effects of spaceflight on living systems, developing advanced biotechnologies and facilities, and more. Applications for 2023 will open soon. Visit SLSTP to learn more.

SCHOLARSHIPS AND FELLOWSHIPS

GSA GRADUATE STUDENT RESEARCH GRANTS

The Geological Society of America (GSA) offers research grants to provide partial support of master's and doctoral thesis research in the geological sciences for graduate students enrolled in universities in the United States, Canada, Mexico, and Central America. Applications close on February 2, 2023. Visit Graduate Student Research Grants to learn more.

EXPANDING REPRESENTATION IN GEOSCIENCES SCHOLARSHIP

The goal of GSA's Expanding Representation in Geosciences (ERG) Scholarship is to foster the success of diverse students and to encourage their persistence in GSA as members, role models, and future leaders in geosciences. Applications open on March 1, 2023. Visit GSA to learn more.

HARRIET EVELYN WALLACE SCHOLARSHIP FOR WOMEN GEOSCIENCE GRADUATE STUDENTS

The Wallace Scholarship supports one Master's and one Doctoral female geoscience graduate student each year. This highly competitive award of $5000 is awarded based on academic merit and potential for a robust career in geosciences. All women pursuing a graduate degree during the 2023-2024 academic year at accredited U.S. institutions in a recognized geoscience program are encouraged to apply. Applications are due on February 5, 2023. Visit Wallace Scholarship to learn more.

AGI SCHOLARSHIP FOR ADVANCING DIVERSITY IN THE GEOSCIENCE PROFESSION

This scholarship helps geoscience students from underrepresented communities bridge the challenging step of moving from an undergraduate degree in geosciences into a full-time graduate program. This scholarship provides a $5000 award to support a student of high potential through this critical point of their geoscience career. The deadline to apply is February 13, 2023. Visit Diversity Scholarship to learn more.

ASSOCIATION FOR WOMEN IN SCIENCE (AWIS) SCHOLARSHIPS

The 2023 application window for Association for Women in Science (AWIS) scholarships is now open. Thirteen scholarships are available across four different categories, supporting women pursuing STEM degrees and careers at undergraduate, postdoctoral, and professional levels. All scholarship applications close on February 28, 2023. Visit AWIS Scholarships to learn more.

AGU RESEARCH GRANTS

The American Geophysical Union (AGU) offers yearly travel and research grants to students and early career researchers to support travel to AGU meetings and research in specific areas of Earth and space science. Currently, applications are being accepted for six different research grants. Topics include atmosheric and space science, geophysics, petrology and geochemistry, and more. Applications close on April 12, 2023. Visit AGU Travel Grants to learn more.

POSTDOCTORAL POSITIONS

Opportunities for recent Ph.D. graduates can be found in industry, national labs, nonprofit institutions, and government. Below is a selection of postdoctoral fellowship opportunities for a range of disciplines and backgrounds.

NASA Postdoctoral Program

LPI Postdoctoral Positions

JPL Postdoctoral Positions

STScI Postdoctoral Fellowships

JHU APL Doctoral Level Opportunities

Center for Astrophysics Fellowships and Visiting Scientist Positions

SwRI Postdoctoral Positions

U.S. National Labs Postdoctoral Positions

AGU Job Board Postdoctoral Positions

LIGO Postdoctoral Positions

PROFESSIONAL DEVELOPMENT AND PUBLIC ENGAGEMENT EVENTS

The 54th Lunar and Planetary Science Conference (LPSC) will be held as a hybrid conference on March 13–17, 2023. With in-person and virtual participation, attendees will have the opportunity to share their research and network with colleagues. Engagement opportunities for scientists, students, and the public will take place during the 2023 conference. For more information, visit 54th LPSC or contact LPI Science Engagement.

SEMINAR: OPTIMIZING YOUR LPSC EXPERIENCE

Tuesday, February 28, 3:00 p.m. CST

Planning to attend LPSC and looking for information on how to prepare? Join the LPI for a virtual, 90-minute program that will explore topics like networking, time management, in-person and online presenting, and more. You'll hear from planetary science experts and LPSC veterans about how to get the most out of the conference experience. To register, visit LPI Webinar Registration. The recording, slides, and resource document from the 2022 seminar are available.

LPSC EARLY-CAREER PRESENTERS VIRTUAL HELP DESK

Session 1: Wednesday, March 1, 1:00 p.m.–3:00 p.m. CST

Session 2: Thursday, March 2, 1:00 p.m.–3:00 p.m. CST

Session 3: Friday, March 3, 1:00 p.m.–3:00 p.m. CST

Students, post-doctoral researchers, and early-career scientists preparing to attend LPSC are invited to stop by a virtual Help Desk for assistance in enhancing their oral or poster presentations. Participants will have the opportunity to receive feedback from experienced scientists prior to submitting their files for the conference. To register, visit LPSC Early Career Presenters Help Desk. To volunteer as a reviewer or to request more information, email Andy Shaner.

LPSC INSIGHTS: GET CONNECTED, STAY CONNECTED

March 13, 2023 — In person

Are you a student attending LPSC for the first time? Are you unsure how to navigate the conference? Are you nervous about networking? This mentoring program is for you! First-time student attendees who register for this program will be introduced to an experienced LPSC attendee, and the pair will spend time attending sessions and networking together. Spaces are limited. To register, visit 2023 LPSC Insights. To volunteer as a mentor or for more information, email Andy Shaner.

PUBLIC EVENT: LIVE FROM LPSC

Thursday, March 16, 6:00 p.m. CDT

The public is invited to tune in for a virtual conversation with planetary scientists who will share some of the latest news, exciting discoveries, and cutting-edge research being presented at LPI's annual science conference. We hope you'll join us! Visit LPI Webinar Registration to register.

OPPORTUNITIES AND RESOURCES FOR STEM OUTREACH AND PROFESSIONAL DEVELOPMENT

PROFESSIONAL ADVANCEMENT WORKSHOP SERIES (PAWS)

PAWS is sponsored by NASA's Astrobiology Program and is intended to serve the current astrobiology community and those that might join it in the future. This program is designed to teach insights, tools, and actions that support career advancement for early-career professionals in academia, industry, or anywhere. The 90-minute interactive webinars are held every month and led by experts. To learn more, visit PAWS.

LPI PROFESSIONAL DEVELOPMENT FOR PLANETARY SCIENTISTS

The Lunar and Planetary Institute has launched a new series of professional development webinars and resources intended to support postdoctoral and early-career researchers. To receive notifications about upcoming programs in this series, sign up for the News for Students and Early-Career Scientists newsletter. To learn more, visit Professional Development Webinar for Scientists.

LPI PROFESSIONAL DEVELOPMENT FOR PLANETARY SCIENTISTS

March 15, 2023

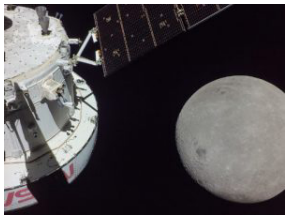
The Association for Women in Science (AWIS) Virtual Career Fair is a free opportunity that aims to connect AWIS members and all women in science with employers seeking top talent. Whether you're looking for a new career challenge, your first or next step into a leadership position, a transition from academia to industry, or want to keep your options open and see what opportunities may be available for you, the AWIS Virtual Career Fair will have something for everyone. To learn more, visit AWIS Virtual Career Fair.

NEW NASA CITIZEN SCIENCE PROJECT: EXOPLANET WATCH

Exoplanet Watch is a NASA citizen science project sponsored by NASA's Universe of Learning that lets anyone and everyone learn about planets that orbit stars beyond our solar system and get involved in observing them. Check out the program and learn how to bring exoplanet science to your audiences. To learn more, visit Exoplanet Watch.

TOPICS FOR PUBLIC ENGAGEMENT

Are you interested in sharing your science and expertise with the public? Education and public engagement opportunities may be available online or in your community. Explore ways to get involved by contacting your local museums and planetariums, libraries, Solar System Ambassadors, or amateur astronomy clubs.



Fight Day 6: A Selfie with the Moon. Credit: NASA.

ARTEMIS I LAUNCH AND SPLASHDOWN

November 16–December 11

Following the successful launch of NASA's highly anticipated new spacecraft and rocket system on November 16, the uncrewed Artemis I mission flew to lunar orbit and back, spending 25 days in space. Visit Artemis I to learn more.

A Wreath of Star Formation in NGC 7469. Credit: NASA.

CELEBRATING ONE YEAR AROUND L2

On January 24, 2022, the James Webb Space Telescope (JWST) reached its final home, orbiting around the second Sun-Earth Lagrange point, or L2, nearly one million miles from Earth. Approximately six months later, commissioning activities were completed, and its scientific mission began. Find the latest news and images from the JWST website.

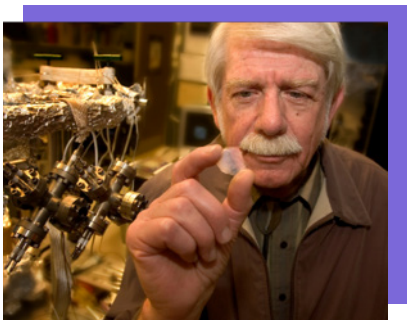
Final image of martian surroundings from InSight. Credit: NASA/JPL-Caltech.

AFTER YEARS OF PEERING DEEP INTO THE RED PLANET, INSIGHT RELAYS FINAL MESSAGE

During its time on Mars, NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander used seismometers and heat sensors to study the Martian interior, helping scientists understand the planet's formation and evolution. With dust accumulating on its solar panels, the lander had been operating on reduced power for several months. In early December 2022, it shared a goodbye message and final image. After multiple unsuccessful attempts to contact the InSight Mars Lander, the mission ended on December 15, 2022. Visit NASA Retires InSight Mars Lander Mission After Years of Science to learn more.

"Spotlight on Education" highlights events and programs that provide opportunities for planetary scientists to become involved in education and public engagement. If you know of space science educational programs or events that should be included, please contact the Lunar and Planetary Institute's Education Department at education@lpi.usra.edu.

IN MEMORIAM



Credit: University of Minnesota.

ROBERT O. PEPIN

1933–2023

Professor Emeritus Robert Pepin of the School of Physics and Astronomy at the University of Minnesota passed away on January 6 at the age of 89.

Pepin joined the school as a Research Associate in 1965 and joined the faculty as an assistant professor in 1966. He was a Professor of Physics from 1975 until his retirement in 2008. Pepin's research focused on mass spectrometry. He was a leader in using the isotopes of rare gases to probe the geology of our solar system, including meteorites, lunar rocks returned during the Apollo missions (in which he played a leading role), and interplanetary dust returned from missions in the early 2000s.

Pepin was the director of the Lunar Science Institute (now the Lunar and Planetary Institute) from 1974 to 1975. He was recognized with a host of awards, most recently the Fred Whipple Award from the American Geophysical Union in 2020. After retirement he continued to work as a consultant to NASA on the Mars rover missions as well as other projects.

Pepin's career included service to the university as director of the Institute of Technology (now the College of Science and Engineering) Honors Program from 1989 to 2007. In addition to his research accolades, he received several teaching awards, including the Morse-Alumni Award for Contributions to Undergraduate Education.

Professor Paul Crowell, Head of the School of Physics and Astronomy, said of Pepin, "Bob loved his work and particularly the University of Minnesota and its students. Many of us worked with Bob while teaching the first-year honors course. His rapport with students was extraordinary. He was a gentle and kind human being and an eternal optimist, which was evident in my most recent conversation with him last week. We will miss him greatly."

— Text courtesy of the University of Minnesota

Credit: NASA.

WALTER CUNNINGHAM

1932–2023

Former astronaut Walter Cunningham, who flew into space on Apollo 7, the first crewed flight in NASA's Apollo program, died on January 3. He was 90 years old.

"Walt Cunningham was a fighter pilot, physicist, and an entrepreneur — but, above all, he was an explorer. On Apollo 7, the first launch of a crewed Apollo mission, Walt and his crewmates made history, paving the way for the Artemis Generation we see today," said NASA Administrator Bill Nelson. "NASA will always remember his contributions to our nation's space program and sends our condolences to the Cunningham family."

Cunningham was born March 16, 1932, in Creston, Iowa. He graduated from Venice High School in Venice, California, before going on to receive a Bachelor of Arts with honors in physics in 1960 and a Master of Arts with distinction in physics in 1961 from the University of California at Los Angeles. He then completed a doctorate in physics with exception of thesis at the Advanced Management Program in the Harvard Graduate School of Business in 1974.

The Cunningham family offered the following statement: "We would like to express our immense pride in the life that he lived, and our deep gratitude for the man that he was — a patriot, an explorer, pilot, astronaut, husband, brother, and

father. The world has lost another true hero, and we will miss him dearly."

He joined the Navy in 1951 and served on active duty with the U.S. Marine Corps, retiring with the rank of colonel. He flew 54 missions as a night fighter pilot in Korea. He worked as a scientist for the Rand Corporation for three years. While with Rand, he worked on classified defense studies and problems related to Earth's magnetosphere. Cunningham accumulated more than 4500 hours of flying time in 40 different aircraft, including more than 3400 hours in jet aircraft.

Cunningham was selected as an astronaut in 1963 as part of NASA's third astronaut class.

"On behalf of NASA's Johnson Space Center, we are beholden to Walt's service to our nation and dedication to the advancement of human space exploration," said Vanessa Wyche, center director. "Walt's accomplished legacy will continue to serve as an inspiration to us all."

Prior to his assignment to the Apollo 7 crew, Cunningham was on the prime crew for Apollo 2 until it was canceled and the backup lunar module pilot for Apollo 1.

On October 11, 1968, Cunningham piloted the 11-day flight of Apollo 7, the first human flight test of the Apollo spacecraft. With Walter M. Schirra Jr. and Donn F. Eisele, he tested maneuvers necessary for docking and lunar orbit rendezvous using the third stage of their Saturn IB launch vehicle. The crew successfully completed eight tests, igniting the service module engine, measuring the accuracy of performance of all spacecraft systems, and providing the first live television transmission of onboard crew activities. The 263-hour, 4.5-million-mile flight splashed down October 22, 1968, in the Atlantic Ocean.

Cunningham's last assignment at NASA Johnson Space Center was as chief of the Skylab branch of the Flight Crew Directorate. In this capacity, he was responsible for the operational inputs for five major pieces of manned space hardware, 2 different launch vehicles, and 56 major experiments that comprised the Skylab Program.

Cunningham retired from NASA in 1971 and would go on to lead multiple technical and financial organizations. He served in senior leadership roles with Century Development Corp., Hydrotech Development Company, and 3D International. Cunningham was also a long-time investor and entrepreneur, organizing small businesses and private investment firms. He also was a frequent keynote speaker and radio talk show host.

His numerous awards include the NASA Exceptional Service Medal and NASA Distinguished Service Medal. For his service he was inducted into the Astronaut Hall of Fame, International Space Hall of Fame, Iowa Aviation Hall of Fame, San Diego Air and Space Museum Hall of Fame, and Houston Hall of Fame. Cunningham and the Apollo 7 crew also earned an Emmy in the form of the National Academy of Television Arts and Sciences Special Trustee Award.

— *Text courtesy of NASA*

Credit: Division of Planetary Sciences.

ROBERT W. CARLSON

1941–2022

Robert "Bob" Carlson died peacefully in his sleep in Reno, Nevada, surrounded by family, after a months-long battle with cancer.

Carlson was born in Waseca, Minnesota, graduated from Cal Poly San Luis Obispo in 1963, and received his Ph.D. in physics from the University of Southern California in 1970. He spent most of his career (1978–2016) at the Jet Propulsion Laboratory in Pasadena, California.

As Principal Investigator of the Galileo Near Infrared Mapping Spectrometer (NIMS), Carlson was also the greatest skeptic of the results. Among many firsts by Carlson and the NIMS team, the discovery of hydrogen peroxide and a radiolytic sulfur cycle on Europa have transformed our understanding of the potential habitability of that world, and have helped set the stage for future exploration.

As an AGU Fellow and Editor-in-Chief for the *Journal of Geophysical Research–Planets*, Carlson worked hard to see the best in every manuscript. In the lab, he was meticulous and diligent, enjoying every opportunity to solve a new planetary puzzle. He was a brilliant scientist, as well as an amazing mentor, friend, husband, father, and grandfather. Those who knew him will recall fond memories of his soft, but detailed approach to any problem — always gracious and insightful.

— *Text courtesy of the Division for Planetary Sciences of the American Astronomical Society*

JAMES A. MCDIVITT

1929–2022

Credit: NASA.

Former NASA astronaut James A. McDivitt, who commanded the Gemini IV and Apollo 9 missions, died peacefully in his sleep in Tucson, Arizona, on October 13. He was 93 years old.

McDivitt was born June 10, 1929, in Chicago, Illinois. He graduated from Kalamazoo Central High School in Kalamazoo, Michigan, before going on to receive a Bachelor of Science degree in Aeronautical Engineering from the University of Michigan, graduating first in his class in 1959.

He joined the Air Force in 1951 and retired with the rank of Brigadier General. He flew 145 combat missions during the Korean War in F-80 and F-86 aircraft. He was a graduate of the U.S. Air Force Experimental Test Pilot School and the U.S. Air Force Aerospace Research Pilot course and served as an experimental test pilot at Edwards Air Force Base, California. He logged more than 5000 flying hours during his piloting career.

McDivitt was selected as an astronaut by NASA in September 1962 as part of NASA's second astronaut class.

He first flew in space as commander of the Gemini IV mission in June 1965. McDivitt was joined by fellow Air Force pilot Ed White on the program's most ambitious flight to date. During Gemini IV, White would become the first American to venture outside his spacecraft for what officially is known as an extravehicular activity (EVA). In the following years, it was a skill that allowed Apollo explorers to walk on the Moon and American astronauts and their partners from around the world to build the International Space Station. Gemini IV's four-day duration nearly doubled NASA astronauts' previous time in space to that point, with the longest American spaceflight previously being Gordon Cooper's 34-hour Mercury 9 mission.

McDivitt's second spaceflight as the commander of Apollo 9 played a critical role in landing the first humans on the Moon. This was the first flight of the complete set of Apollo hardware and was the first flight of the Lunar Module. The mission launched from NASA's Kennedy Space Center on March 3, 1969, with Commander McDivitt, Command Module Pilot David Scott, and Lunar Module Pilot Russell Schweickart. After launch, Apollo 9 entered Earth orbit, and the crew performed an engineering test of the first crewed lunar module, nicknamed "Spider," from beginning to end. They simulated the maneuvers that would be performed during actual lunar missions. During the mission, the astronauts performed a series of flight tasks with the command and service module and the lunar module. The top priority was rendezvous and docking of the lunar module with the command and service module. The crew also configured the lunar module to support a spacewalk by McDivitt and Schweickart. On Flight Day 10, March 13, 1969, the Apollo 9 capsule re-entered Earth's atmosphere and splashed down in the Atlantic Ocean within three miles and in full view of the recovery ship, the USS Guadalcanal, about 341 miles north of Puerto Rico.

McDivitt logged more than 14 days in space.

After Apollo 9, he became manager of lunar landing operations, and led a team that planned the lunar exploration program and redesigned the spacecraft to accomplish this task. In August 1969, he became manager of the Apollo program, guiding the program through Apollos 12, 13, 14, 15, and 16.

McDivitt retired from the U.S. Air Force and left NASA in June 1972 to take the position of executive vice-president of corporate affairs for Consumers Power Company. In March 1975, he joined Pullman, Inc. as executive vice-president and a director. In October 1975, he became president of the Pullman Standard Division, The Railcar Division, and later had additional responsibility for the leasing and engineering and construction areas of the company. In January 1981, he joined Rockwell International as senior vice president of government operations and Rockwell International Corporation in Washington, DC.

His numerous awards included two NASA Distinguished Service Medals and the NASA Exceptional Service Medal. For his service in the U.S. Air Force, he also was awarded two Air Force Distinguished Service Medals, four Distinguished Flying Crosses, five Air Medals, and U.S. Air Force Astronaut Wings. McDivitt also received the Chong Moo Medal from South Korea, the U.S. Air Force Systems Command Aerospace Primus Award, the Arnold Air Society JFK Trophy, the Sword of Loyola, and the Michigan Wolverine Frontiersman Award.

— *Text courtesy of NASA*

NASA ADMINISTRATOR NAMES GLENN RESEARCH CENTER DIRECTOR

Credit: NASA.

NASA Administrator Bill Nelson has named Dr. Jimmy Kenyon director of the agency's Glenn Research Center in Cleveland, effective immediately. Kenyon has served as the acting director of Glenn since June.

"I'm honored to be chosen to lead the more than 3,200 employees and contractors at Glenn Research Center who work each day to design, develop, and test the innovative technologies that make NASA's space exploration, science, and aeronautics missions possible," Kenyon said. "Glenn's research and development efforts are crucial to the Ohio and national space economy, fueling new industries and technologies, supporting job growth, and increasing the demand for a highly skilled STEM workforce."

Before being named Glenn's acting director, Kenyon served as director of the Advanced Air Vehicles Program in the Aeronautics Research Mission Directorate at NASA Headquarters in Washington. He supported the mission directorate and its leadership in a broad range of activities, including strategic and program planning, budget development, program review and evaluation, and external coordination and outreach.

Prior to joining NASA in 2019, Kenyon worked with Pratt & Whitney, where he held leadership roles in business development, program management, and engineering. Kenyon also served as a civilian with the Department of Defense, including 11 years at Wright-Patterson Air Force Base in Dayton, Ohio, and six years in the Office of the Secretary of Defense.

At Glenn, Kenyon will oversee a center responsible for leading the Gateway Power and Propulsion Element, supporting the Orion spacecraft and Space Launch System rocket, and conducting revolutionary aeronautics research to make sustainable commercial aviation a reality.

For more information on NASA and agency activities, visit www.nasa.gov.

EDWARD STONE RETIRES AFTER 50 YEARS AS NASA VOYAGER'S PROJECT SCIENTIST

Ed Stone in 2019, in front of a scale-model of the Voyager spacecraft at NASA's Jet Propulsion Laboratory. Credit: NASA/JPL-Caltech.

Edward Stone has retired as the project scientist for NASA's Voyager mission a half-century after taking on the role. Stone accepted scientific leadership of the historic mission in 1972, five years before the launch of its two spacecraft, Voyager 1 and Voyager 2. Under his guidance, the Voyagers explored the four giant planets and became the first human-made objects to reach interstellar space, the region between the stars containing material generated by the death of nearby stars.

Until now, Stone was the only person to have served as project scientist for Voyager, maintaining his position even while serving as director of NASA's Jet Propulsion Laboratory (JPL) in Southern California from 1991 to 2001. JPL manages the Voyager mission for NASA. Stone retired from JPL in 2001 but continued to serve as the mission's project scientist.

Linda Spilker will succeed Stone as Voyager's project scientist as the twin probes continue to explore interstellar space. Spilker was a member of the Voyager science team during the mission's flybys of Jupiter, Saturn, Uranus, and Neptune. She later became project scientist

for NASA's now-retired Cassini mission to Saturn and rejoined Voyager as deputy project scientist in 2021.

Jamie Rankin, a research scientist at Princeton University and a member of the Voyager science steering group, has been appointed deputy project scientist for the mission. Rankin received her Ph.D. in 2018 from Caltech, where Stone served as her advisor. Her research combines data from Voyager and other missions in NASA's heliophysics fleet.

Among the many honors bestowed on him, Stone has been a member of the National Academy of Sciences since 1984. He was awarded the National Medal of Science from President George H.W. Bush in 1991. When Stone was interviewed on the late-night TV show "The Colbert Report" in 2013, NASA arranged for host Stephen Colbert to present him with the NASA Distinguished Public Service Medal, the agency's highest honor for a nongovernment individual. In 2019, he received the Shaw Prize in Astronomy from the Shaw Foundation in Hong Kong for his work on the Voyager mission.

For more information about the Voyager spacecraft, visit www.nasa.gov/voyager.

UNIVERSITIES SPACE RESEARCH ASSOCIATION ANNOUNCES THE 2022 DISTINGUISHED UNDERGRADUATE AWARD WINNERS

Universities Space Research Association (USRA) proudly announced the winners of the prestigious 2022 USRA Distinguished Undergraduate Awards on December 8.

USRA bestows these awards to honor outstanding undergraduate students in various majors through a competitive process. These awards are granted to students who tackle challenging problems in aerospace engineering, space science research and exploration, demonstrate leadership, promote diversity in science and engineering, and are poised to make significant contributions to their fields.

The following students are the winners of the USRA 2022 Distinguished Undergraduate Awards:

Claire Blaske, Astrophysics, Astrophysics, Arizona State University
—Thomas R. McGetchin Memorial Scholarship

Brooke Carruthers, Molecular and Cellular Biology, University of Arizona
—James B. Willett Education Memorial Scholarship

Jennifer Berry, Mechanical Engineering, University of Canterbury
—Frederick A. Tarantino Memorial Scholarship

Theo O'Neill, Astronomy-Physics and Applied Statistics, University of Virginia
—Judith L. Pipher Memorial Scholarship

Sabrina NoorAhmad-Yarzada, Electrical and Computer Engineering, University of California, Davis
—John. R. Sevier Memorial Scholarship

"We are proud to honor these 2022 Distinguished Undergraduate Award winners," said Dr. Jeffrey A. Isaacson, USRA President and CEO, "and we are especially pleased to award our inaugural Judith L. Pipher Memorial Scholarship. All of these students set themselves apart with their scholastic achievements, leadership potential, and passion for excellence. We wish them continued success in their promising careers."

Five other students received an Honorable Mention:

- Kevin Boes, Mechanical Engineering, Purdue University

- Amelia Korveziroska, Physics Engineering, Illinois State University
- Isabella Macias, Astrophysics, University of Florida
- Shane Riley, Mechanical Engineering & Computer Science, University of Pittsburgh
- Madison VanWyngarden, Astronomy & Physics, Boston University

Established to honor the service and memory of individuals who made significant contributions to their fields and to USRA, these awards are made possible by financial contributions, including those made by USRA employees. This year, USRA added the Judith L. Pipher Memorial Award in memory of a former member of the USRA Board of Trustees who made seminal contributions to the field of infrared astronomy.

Faculty from USRA Member Universities review the applications for the awards. Through a rigorous process, they evaluate the students based on stated career goals and accomplishments, leadership qualities, outreach to their communities, and strengths such as initiative, creativity and perseverance. Recommendation letters from their professors and intern advisors also play an important role in the review.

In 2022, USRA received 85 eligible applications from 57 different universities (including member universities from New Zealand and Israel). From this pool of applicants, the four review committees — two for science applicants and two for engineering applicants — reviewed the students' dossiers and recommended the finalists. The USRA President and CEO selected the winners from among the finalists.

NASA SOLAR SYSTEM AMBASSADORS:

Sharing the Science for 25 Years

Dr. Sian Proctor is a Solar System Ambassador, a geoscientist, and an astronaut. Proctor took her Solar System Ambassador patch with her when she piloted the first all-civilian mission to orbit Earth in September 2021. Credit: Image courtesy of Dr. Sian Proctor.

NASA's Solar System Ambassadors Program celebrated its 25th anniversary in fall 2022. The program is funded by NASA's Science Mission Directorate and is managed by NASA's Jet Propulsion Laboratory (JPL) in Southern California.

The Solar Systems Ambassadors Program works with motivated volunteers across the nation to communicate the science and excitement of NASA's space exploration missions and discoveries with their communities.

In the spirit of a genuine grassroots endeavor, the Solar System Ambassadors Program was originally called the Galileo Ambassador Program. In 1996, Tom Estill, a New Hampshire teacher, attended a Galileo mission educator workshop. Tom suggested to Leslie Lowes (then the lead outreach coordinator for NASA JPL's Galileo mission) that NASA create a coordinated program for volunteers across the country.

The Galileo Ambassador Program was born in 1997 with Tom as one of the first 16 volunteers. The program quickly gained support from other JPL missions, and in 1999, the Solar System Ambassadors Program was officially formed with 145 volunteers.

Today, the Solar System Ambassadors Program has more than 1,100 dedicated volunteers reaching over 11 million audience members through both in-person and online events in their communities.

The program's wide-reaching local approach to sharing NASA's dedicated efforts in space and science with the public has led to a deep impact among individuals and communities — particularly those not traditionally served by NASA.

From a local library in a small town in Iowa to a military base in Guam, volunteers share professionally designed presentations based on the latest updates from scientists and engineers working at the leading edge of NASA's solar system exploration.

To learn more about the Solar System Ambassadors program, visit solarsystem.nasa.gov/solar-system-ambassadors/events/.

NASA AWARDS SPACEX SECOND CONTRACT OPTION FOR ARTEMIS MOON LANDING

NASA has awarded a contract modification to SpaceX to further develop its Starship human landing system to meet agency requirements for long-term human exploration of the Moon under Artemis.

With this addition, SpaceX will provide a second crewed landing demonstration mission in 2027 as part of NASA's Artemis IV mission.

Known as Option B, the modification follows an award to SpaceX in July 2021 under the Next Space Technologies for Exploration Partnerships-2 (NextSTEP-2) Appendix H Option A contract. NASA previously announced plans to pursue this Option B with SpaceX. The contract modification has a value of about $1.15 billion.

"Continuing our collaborative efforts with SpaceX through Option B furthers our resilient plans for regular crewed transportation to the lunar surface and establishing a long-term human presence under Artemis," said Lisa Watson-Morgan, manager for the Human Landing System program at NASA's Marshall Space Flight Center in Huntsville, Alabama. "This critical work will help us focus on the development of sustainable, service-based lunar landers anchored to NASA's requirements for regularly recurring missions to the lunar surface."

The aim of this new work under Option B is to develop and demonstrate a Starship lunar lander that meets NASA's sustaining requirements for missions beyond Artemis III, including docking with Gateway, accommodating four crew members, and delivering more mass to the surface.

NASA initially selected SpaceX to develop a human landing system variant of Starship to land the next American astronauts on the Moon under Artemis III, which will mark humanity's first return to the lunar surface in more than 50 years. As part of that contract, SpaceX will also conduct an uncrewed demonstration mission to the Moon prior to Artemis III.

Artist's rendering of SpaceX Starship human lander design. Credit: SpaceX.

The agency is pursuing two parallel paths for human lunar landers developed according to NASA's sustained requirements to increase the competitive pool of capable industry providers — the existing contract with SpaceX and another solicitation released earlier this year. The other solicitation, NextSTEP-2 Appendix P, is open to all other U.S. companies to develop additional human landing system capabilities and includes uncrewed and crewed demonstration missions from lunar orbit to the surface of the Moon.

Astronaut Moon landers are a vital part of NASA's deep space exploration plans, along with the Space Launch System rocket, Orion spacecraft, ground systems, spacesuits and rovers, and Gateway.

For more information about Artemis, visit www.nasa.gov/artemis.

CAPSTONE FORGES NEW PATH FOR NASA'S FUTURE ARTEMIS MOON MISSIONS

NASA's CAPSTONE spacecraft has completed final maneuvers to place it in its target orbit around the Moon.

The spacecraft is now in the operational phase of its pathfinding mission, during which it will test an orbit key to future Artemis missions and demonstrate new technologies for spacecraft operating near the Moon.

CAPSTONE — short for Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment — is a technology demonstration designed to prove the reliability of new capabilities so that they can be used in future missions. CAPSTONE is the first spacecraft to fly in a near-rectilinear halo orbit (NRHO) and the first CubeSat to operate at the Moon. This orbit is the same planned for Gateway, an upcoming

Moon-orbiting space station that will support NASA's Artemis missions. CAPSTONE will gather data on this orbit for at least six months to support Gateway's operational planning.

CAPSTONE took a four-month journey from launch to orbit — overcoming challenges related to communications and propulsion along the way — and performed an initial orbit insertion maneuver on November 13. In the following days, the CAPSTONE mission operations team, led by Advanced Space of Westminster, Colorado, analyzed data from the spacecraft to confirm it was in the expected orbit and carried out two clean-up maneuvers to refine its track.

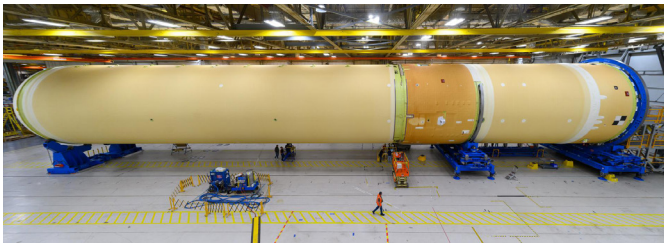
In addition to studying this unique orbit, CAPSTONE's mission also includes two technology demonstrations that could be used by future spacecraft. The Cislunar Autonomous Positioning System, or CAPS, is a navigational software developed by Advanced Space that would allow spacecraft operating near the Moon to determine their position in space without relying exclusively on tracking from Earth. CAPSTONE will demonstrate this technology by communicating directly with NASA's Lunar Reconnaissance Orbiter, which has been in orbit around the Moon since 2009. CAPSTONE will also demonstrate one-way ranging using a chip-scale atomic clock, which could allow spacecraft to determine their position in space without the need for a dedicated downlink to ground stations.

An illustration of NASA's Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment, or CAPSTONE. Credit: NASA/Daniel Rutte.

CAPSTONE is commercially owned and operated by Advanced Space. It represents an innovative collaboration between NASA and private industry to provide rapid results and feedback to inform future exploration and science missions. The spacecraft was designed and built by Terran Orbital. Operations are performed jointly by teams at Advanced Space and Terran Orbital. The mission is also supported by Stellar Exploration, Space Dynamics Laboratory, Orion Space Solutions, Tethers Unlimited, Inc., and Morehead State University.

Learn more about CAPSTONE at www.nasa.gov/capstone.

NASA COMMITS TO FUTURE ARTEMIS MOON ROCKET PRODUCTION



NASA joined the Space Launch System rocket's core stage forward assembly, seen here, with the 130-foot liquid hydrogen tank in March 2022. Credit: NASA/Eric Bordelon.

NASA has finalized its contract with Boeing of Huntsville, Alabama, for approximately $3.2 billion to continue manufacturing core and upper stages for future Space Launch System (SLS) rockets for Artemis missions to the Moon and beyond.

Under the SLS Stages Production and Evolution Contract action, Boeing will produce SLS core stages for Artemis III and IV, procure critical and long-lead material for the core stages for Artemis V and VI, and provide the exploration upper stages (EUS) for Artemis V and VI, as well as tooling and related support and engineering services.

In October 2019, NASA provided initial funding and authorization for Artemis III core stage work and targeted long-lead materials and cost-efficient bulk purchases. The finalization of this contract extends production activities and preparations for future work through July 2028. As part of the contract, NASA may order up to ten core stages and eight exploration upper stages total to support future deep space exploration missions.

The SLS rocket delivers propulsion in stages and is designed to evolve to more advanced configurations to power NASA's deep space missions. Each SLS rocket configuration uses the same 212-foot-tall core stage to produce more than 2 million pounds of thrust to help propel the mega rocket off the launch pad.

The contract comes as NASA optimizes manufacturing capabilities as Boeing will use Kennedy Space Center in Florida

to perform some core stage assembly and outfitting activities beginning with the Artemis III rocket. In tandem, teams will continue all core stage manufacturing activities at Michoud.

Teams continue to make progress assembling and manufacturing core stages for Artemis II, III, and IV. The Artemis II stage is scheduled to be completed and delivered to Kennedy in 2023. The engine section for Artemis III was recently loaded onto NASA's Pegasus barge for delivery to Kennedy, where it will be outfitted and later integrated with the rest of the rocket.

For more information about the Space Launch System, visit www.nasa.gov/sls.

NASA RECEIVES 12TH SUCCESSIVE "CLEAN" FINANCIAL AUDIT RATING

For the 12th consecutive year, NASA has received an unmodified or "clean" opinion from an external auditor on its fiscal year 2022 financial statements.

The rating is the best possible audit opinion, certifying that NASA's financial statements conform with accepted accounting principles for federal agencies and accurately present the agency's financial position.

NASA's FY22 Agency Financial Report (AFR) provides transparency into NASA's strategic and operational posture and results by presenting a complete presentation of financials in accordance with Generally Accepted Accounting Principles.

The AFR presents the agency's progress over the past year, including the launch into orbit of the James Webb Space Telescope as the most advanced deep space observation telescope ever assembled. It also includes NASA's Moon to Mars objectives, which will help the agency and its partners chart our future together in deep space. The steady progress of the Artemis program, which includes sending astronauts to the Moon, also is outlined in the report.

The agency produces its AFR as well as its Annual Performance Report (APR). NASA provides its APR as part of its annual Volume of Integrated Performance (VIPer). The VIPer reports prior-year performance with an updated performance plan for the current fiscal year, and a proposed performance plan for the upcoming fiscal year. The VIPer is published in conjunction with the President's Budget Request.

For more information on NASA's budget, visit www.nasa.gov/budget.

NASA'S ECONOMIC BENEFIT REACHES ALL 50 STATES

Credit: NASA.

NASA released the results of its second agency-wide economic impact report in October, demonstrating how its Moon to Mars activities, investments in climate change research and technology, as well as other work, generated more than $71.2 billion in total economic output during fiscal year 2021.

Combined, NASA's impact supported more than 339,600 jobs nationwide and generated nearly $7.7 billion in federal, state, and local taxes throughout the United States.

The study found NASA's Moon to Mars exploration approach generated more than $20.1 billion in total economic output and supported more than 93,700 jobs nationwide. For investments in climate research and technology, the agency's activities generated more than $7.4 billion in total economic output and supported more than 37,000 jobs nationwide.

Additional key findings of the study include:

- Every state in the country benefits economically through NASA activities. Forty-six states have an economic impact of more than $10 million. Of those 46 states, nine have an economic impact of $1 billion or more.

- NASA's agency-wide fiscal year 2021 economic output increased by 10.7% from fiscal year 2019, the year the agency conducted its first report.

- The agency's Moon to Mars campaign, which includes the Artemis program, generated nearly $2.2 billion in tax revenue and saw an economic output increase of 42.6% from fiscal year 2019. These activities provided about 28% of NASA's economic impact.

- The agency's investments in climate change research and technology generated nearly $810 million in tax revenue and provided 11% of NASA's economic impact.

- NASA had more than 2,655 active domestic and international agreements for various scientific research and technology development activities in fiscal year 2021. The International Space Station is a significant representative of international partnerships — representing 15 nations and five space agencies and has been operating for more than 20 years.

- NASA has 700 different active partnerships with non-federal U.S. partners and partnerships in 44 of 50 states. For example, flight technology like NASA's all-electric X-57 Maxwell.

- NASA spinoffs, which are public products and processes that are developed with NASA technology, funding, or expertise, provide a benefit to American lives beyond dollars and jobs. The agency has recorded more than 2,000 spinoff technologies since 1976. For example, NASA's indoor agricultural techniques in vertical farm structures are being adopted by private companies to build indoor farms.

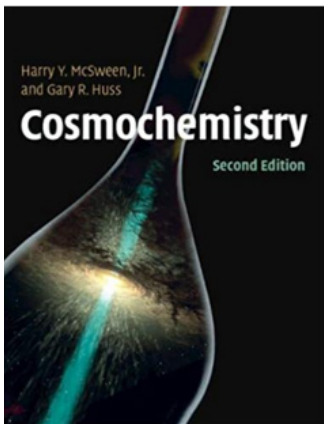
- Scientific research and development, which fuels advancements in science and technology that can help improve daily life on Earth and for humanity, enjoy the largest single-sector impact, accounting for 20% of NASA's overall economic output.

The study was conducted by the Nathalie P. Voorhees Center for Neighborhood and Community Improvement at the University of Illinois at Chicago.

To see a summary of the report, visit go.nasa.gov/3gQlFuJ.

To review the full study, visit go.nasa.gov/3Fj4MnC.

NEW AND NOTEWORTHY

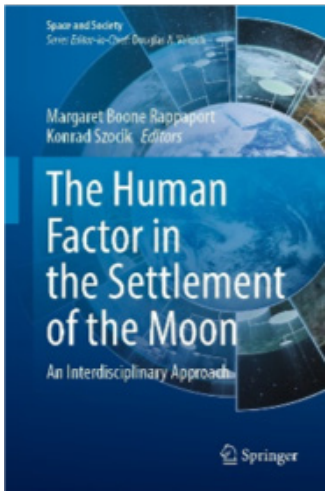


COSMOCHEMISTRY, SECOND EDITION

By Harry Y. McSween, Jr. and Gary R. Huss

Cambridge University Press, 2022, 452 pp., Hardcover. $79.99. www.cambridge.org

Cosmochemistry is a rapidly evolving field of planetary science, and the second edition of this classic text reflects the exciting discoveries made over the past decade from new spacecraft missions. Topics covered include the synthesis of elements in stars, behavior of elements and isotopes in the early solar nebula and planetary bodies, and compositions of extraterrestrial materials. Radioisotope chronology of the early solar system is also discussed, as well as geochemical exploration of planets by spacecraft and cosmochemical constraints on the formation of solar systems. Thoroughly updated throughout, this new edition features significantly expanded coverage of chemical fractionation and isotopic analyses; focus boxes covering basic definitions and essential background material on mineralogy, organic chemistry, and quantitative topics; and a comprehensive glossary. An appendix of analytical techniques and end-of-chapter review questions with solutions available online also contribute to making this the ideal teaching resource for courses on the solar system's composition as well as a valuable reference for early career researchers.



THE HUMAN FACTOR IN THE SETTLEMENT OF THE MOON: An Interdisciplinary Approach

Edited by Margaret Boone Rappaport and Konrad Szocik

Springer, 2021, 317 pp., Hardcover. $139.99. www.springer.com

Approaching the settlement of our Moon from a practical perspective, this book is well suited for space program planners. It addresses a variety of human factor topics involved in colonizing Earth's Moon, including history, philosophy, science, engineering, agriculture, medicine, politics and policy, sociology, and anthropology. Each chapter identifies the complex interdisciplinary issues of human factors that will arise in the early phases of settlement on the Moon. Besides practical issues, there is emphasis placed on preserving, protecting, and experiencing the lunar environment across a broad range of occupations, from scientists to soldiers and engineers to construction workers. This book identifies utilitarian and visionary factors that will shape human lives on the Moon. It offers recommendations for program planners in the government and commercial sectors and serves as a helpful resource for academic researchers. Together, the coauthors ask and attempt to answer: "How will lunar society be different?"

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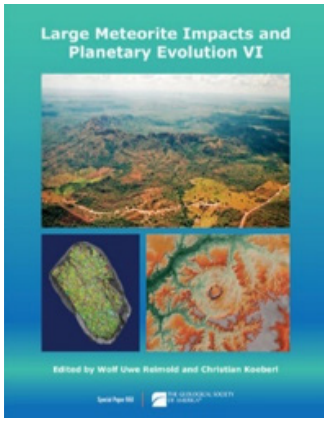
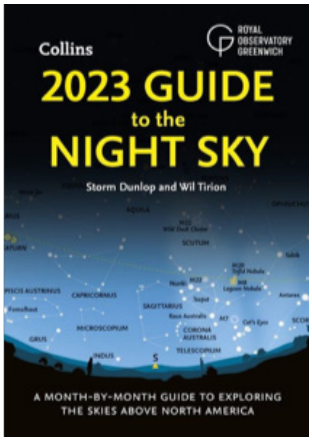


LARGE METEORITE IMPACTS AND PLANETARY EVOLUTION VI

Edited by Wolf Uwe Reimold and Christian Koeberl

Geological Society of America, 2021, 642 pp., Paperback. $99.00. rock.geosociety.org/store

This volume, Geological Society of America Special Paper 550, represents the proceedings of the homonymous international conference on all aspects of impact cratering and planetary science, which was held in October 2019 in Brasília, Brazil. The volume contains a sizable suite of contributions dealing with regional impact records (Australia, Sweden), impact craters and impactites, early Archean impacts and geophysical characteristics of impact structures, shock metamorphic investigations, post-impact hydrothermalism, and structural geology and morphometry of impact structures — on Earth and Mars. Many contributions report results from state-of-the-art investigations, for example, several that are based on electron backscatter diffraction studies, and deal with new potential chronometers and shock barometers (e.g., apatite). Established impact cratering workers and newcomers to the field will appreciate this multifaceted, multidisciplinary collection of impact cratering studies.



2023 GUIDE TO THE NIGHT SKY: A Month-by-Month Guide to Exploring the Skies Above North America

By Storm Dunlop and Wil Tirion

Collins Astronomy, 2022, 112 pp., Paperback. $11.95. www.harpercollins.com

This practical guide is the ideal resource for beginners and experienced stargazers in the United States and Canada and has been updated to include new and practical information covering events occurring in North America's night sky throughout 2023. This guide is both an easy introduction to astronomy and a useful reference for seasoned stargazers, and this edition now includes a section on comets and a map of the Moon. Written and illustrated by astronomical experts, Storm Dunlop and Wil Tirion, and approved by the astronomers of the Royal Observatory Greenwich, this guide includes advice on where to start looking, easy-to-use star maps for each month with descriptions of what to see, positions of the Moon and visible planets, and details of objects and events in 2023.

APOLLO REMASTERED: The Ultimate Photographic Record

By Andy Saunders

Black Dog & Leventhal Publishers, 2022, 432 pp., Hardcover. $75.00. www.blackdogandleventhal.com

This unique, definitive book about the Apollo missions reveals hundreds of extraordinary, newly restored, and all-new images from the NASA archives that provide a never-before-seen perspective on the Apollo endeavors. In Houston, Texas, there is a frozen vault that preserves the original NASA photographic film of the Apollo missions. For half a century, almost every image of the Moon landings publicly available was produced from a lower-quality copy of these frozen originals. Over the last few years, NASA image restorer Andy Saunders has been working hard. Taking newly available digital scans and applying painstaking care and cutting-edge enhancement techniques, he has created the highest-quality Apollo photographs ever produced. Never-before-seen spacewalks and crystal-clear portraits of astronauts in their spacecraft, along with startling new visions of Earth and the Moon, offer astounding new insight into one of our greatest endeavors.

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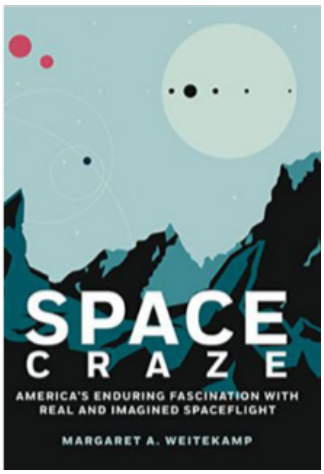
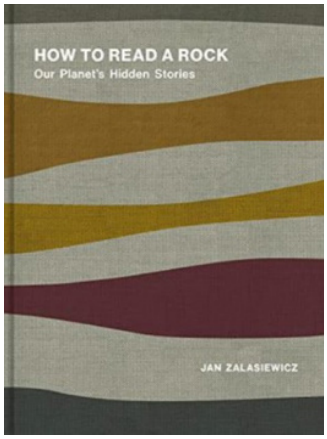


SPACE CRAZE: America's Enduring Fascination with Real and Imagined Spaceflight

By Margaret A. Weitekamp

Smithsonian Books, 2022, 304 pp., Hardcover. $29.95. www.smithsonianbooks.com

Spanning from the 1929 debut of the futuristic Buck Rogers to present-day privatization of spaceflight, Space Craze celebrates America's endless enthusiasm for space exploration. Author Margaret Weitekamp, curator at the Smithsonian's National Air and Space Museum, writes with warmth and personal experience to guide readers through extraordinary spaceflight history while highlighting objects from the Smithsonian's spaceflight collection. Featuring historical milestones in space exploration, films and TV shows, literature and comic strips, toys and games, and internet communities, Space Craze is a sci-fi lover's dream. The book investigates how spaceflight, both real and imagined, has served as the nexus where contemporary American concerns, such as race, gender, sexuality, freedom, and national identity, have been explored and redefined. From the almost 650 million viewers who tuned in to watch the first steps on the Moon, to the ardent Star Trek fandom that burgeoned into a cultural force, Space Craze taps into the country's enduring love affair with space.



HOW TO READ A ROCK: Our Planet's Hidden Stories

By Jan Zalasiewicz

Smithsonian Books, 2022, 224 pp., Hardcover. $34.95. www.smithsonianbooks.com

Rocks are time machines and the keepers of our history. This guide is a geological field trip through Earth's incredible rock formations and the stories they hold. Like rings on a tree stump hold the history of the tree, the history of Earth is written in its rocks. This book teaches readers to decipher the rocks all around us, from backyard stones to mountain ranges, and trace Earth's history layer by layer. Spanning from prehistoric Earth's shifting continents, to contemporary human impact, to the future surfaces of space exploration, the book reviews a remarkable array of topics, including diamond volcanoes; ancient coastlines, rivers, deserts, and coral reefs; how animals have changed rocks; the making of mud; urban rock strata; humanmade rocks and minerals; the current limestone rock crisis; and technofossils (the footprints humans will leave behind through their material goods). The book's imagery captures the power, majesty, and history of the planet. Rocks carry the memories of dinosaur landscapes and vanished oceans, show evidence of the greening of the planet and the effect of natural forces, and convey clues on climate and energy consumption. *How to Read a Rock* unearths the most fascinating stories rocks can tell us, not only about our past, but how the past can help imagine the future.

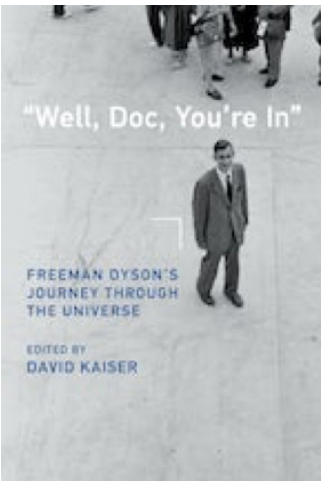
NOTE: PRODUCT DESCRIPTIONS ARE TAKEN FROM PUBLISHERS' WEBSITES. LPI IS NOT RESPONSIBLE FOR FACTUAL CONTENT.

SPACE RACE 2.0: SpaceX, Blue Origin, Virgin Galactic, NASA, and the Privatization of the Final Frontier

By Brad Bergan

Motorbooks, 2022, 176 pp., Hardcover. $40.00. www.quarto.com

In the 1950s and 1960s, the first Space Race pitted two political ideologies against one another: either communism or capitalism would prove superior. Ultimately, the U.S. landed on the Moon, the race's crowning achievement. Now, more than a half-century later, the Space Race has pivoted from a contest between ideological rivals to private aerospace firms competing for contracts. Today, the defining success of a launch system extends beyond engineering and science to image and return on investment (ROI). Founded in 2002, SpaceX's trajectory was determined by Elon Musk's realization that he could achieve higher profits by vertically integrating — manufacturing his own rockets and spacecraft — rather than relying on third parties. The decision was prescient, resulting in a state-of-the-art headquarters in Hawthorne, California, and a series of stunning achievements. Space Race 2.0 follows the development of commercial space exploration to the present. While tentative first steps in private ventures are covered, such as those by Space Services Inc. and Orbital Science in the 1980s and 1990s, the focus is on today's major players: SpaceX, Blue Origin, and Virgin Galactic. While examining the hardware, author Brad Bergan also explores such considerations as the importance of design-forward equipment and the endgame: What ultimately is "in it" for firms at the forefront? Natural resources? NASA and ESA contracts? Commercial travel? Communications? And what legal boundaries, if any, restrain corporate interests in space? *Space Race 2.0* is the ultimate visual look at this relatively young industry, looking back at recent remarkable decades — and looking ahead to what the future might bring.



"WELL, DOC, YOU'RE IN": Freeman Dyson's Journey Through the Universe

Edited by David Kaiser

MIT Press, 2022, 304 pp., Hardcover. $29.95. www.mitpress.mit.edu

Freeman Dyson (1923–2020) — renowned scientist, visionary, and iconoclast — helped invent modern physics. Not bound by disciplinary divisions, he went on to explore foundational topics in mathematics, astrophysics, and the origin of life. General readers were introduced to Dyson's roving mind and heterodox approach in his 1979 book Disturbing the Universe, an autobiographical reflection on life and science. "*Well, Doc, You're In*" (the title quotes Richard Feynman's remark to Dyson at a physics conference) offers a fresh examination of Dyson's life and work, exploring his particular way of thinking about deep questions that range from the nature of matter to the ultimate fate of the universe. The chapters — written by leading scientists, historians, and science journalists, including some of Dyson's colleagues — trace Dyson's formative years, his budding interests and curiosities, and his wide-ranging work across the natural sciences, technology, and public policy. They describe Dyson's innovations at the intersection of quantum theory and relativity, his novel nuclear reactor design (and his never-realized idea of a spacecraft powered by nuclear weapons), his years at the Institute for Advanced Study, and his foray into cosmology. In the coda, Dyson's daughter Esther reflects on growing up in the Dyson household. This book assesses Dyson's successes, blind spots, and influence, assembling a portrait of a scientist's outsized legacy.

NASA SPACE LAUNCH SYSTEM (SLS) MODEL

Produced by Estes Industries

$76.99. www.estesrockets.com

Standing taller than the Statue of Liberty and with more thrust than the mighty Saturn V, the NASA Space Launch System (SLS) is ready to return humanity to the Moon... and beyond! The NASA SLS Block1 will generate 8.8 million pounds of thrust at liftoff, enough raw power to carry the Orion crew vehicle, an upper stage booster, and four astronauts all the way to lunar orbit and back. This 19.4-inch-tall 1:200 scale replica portrays the Project Artemis Block 1 configuration, the first in the proposed series of heavy lift launch vehicles. Pre-assembled, pre-finished, and ready to launch, this highly detailed model realistically reproduces the features and markings of America's next generation rocket for deep space missions. Launching the Estes NASA SLS model rocket couldn't be easier. Prepare your rocket for flight by attaching the included transparent fins and then loading with an Estes C6-3 engine. Launch up to 350 feet in the air and then return to Earth under a colorful 15-inch parachute. Between launches, the Estes NASA SLS model can be displayed with its own custom clear fins that double as a display stand. Additional equipment required for launch, including launch pad, launch controller, engines, starters, and parachutes, sold separately. For ages 10 and up, with adult supervision suggested for those under 12.

A CHILD'S INTRODUCTION TO SPACE EXPLORATION: An Explorer's Guide to Rockets, Astronauts, and Life in Zero Gravity

By Michael E. Bakich and David J. Eicher

Black Dog & Leventhal Publishers, 2022, 96 pp., Hardcover. $19.99. www.blackdogandleventhal.com

Get ready to blast off into the space! This interactive, fact-filled book by two space experts takes kids on a journey through the universe with answers to their questions about space exploration, from what the first rockets looked like and the first animal in space to what space food tastes like and what it's like to live in zero gravity. The authors, revered science writers, explore the history of space exploration from the very first rocket in China, to the Moon landing, to the latest missions to Mars and beyond. They also include profiles of noteworthy scientists, engineers, and astronauts including Isaac Newton, Neil Armstrong, and Mae Jemison; fun sections on space food, UFOs, and a timeline of space suits; information about how to go to the bathroom in space; and STEM experiments like how to build your own rocket and how to tell time using the Sun. Packed with dozens of NASA photos, original illustrations, and a pull-out poster, this fascinating book reveals the wonders of space exploration — past, present, and future! For ages 8 to 12.

NOTE: PRODUCT DESCRIPTIONS ARE TAKEN FROM PUBLISHERS' WEBSITES. LPI IS NOT RESPONSIBLE FOR FACTUAL CONTENT.

THE FIRE OF STARS: The Life and Brilliance of the Woman Who Discovered What Stars Are Made Of

By Kirsten W. Larsen

Chronicle Books, 2023, 48 pp., Hardcover. $18.99. www.chronicklebooks.com

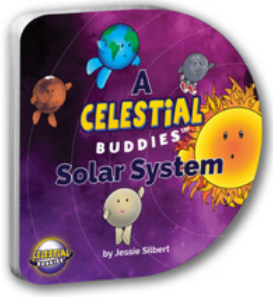
The Fire of Stars is a poetic picture book celebrating the life and scientific discoveries of the groundbreaking astronomer Cecilia Payne, an astronomer and astrophysicist who was the first person to discover what burns at the heart of stars. But she didn't start out as the groundbreaking scientist she would eventually become. She started out as a girl full of curiosity, hoping one day to unlock the mysteries of the universe. With lyrical, evocative text by Kirsten Larson and extraordinary illustrations by award-winning illustrator Katherine Roy, this moving biography powerfully parallels the kindling of Payne's own curiosity and her scientific career with the process of a star's birth, from mere possibility in an expanse of space to an eventual, breathtaking explosion of light. For ages 5–8.

PLANET DOKU: Sudoku in Spaaace! Game

Produced by Hungry Robot

$24.00. www.hungryrobot.com

Calling all Sudoku lovers! Test your Sudoku skills by playing the popular number game in space. Planet Doku has three levels of challenging puzzles. Use planet and Sun tokens instead of numbers on the cosmic game board to solve the various challenges from around the solar system. This visually stunning version of Sudoku adds an exciting twist to a classic game. For ages 9 and up.

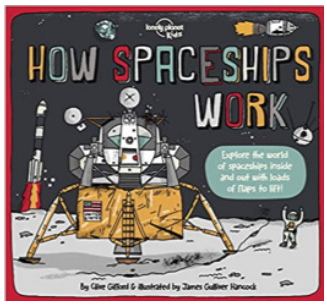


A CELESTIAL BUDDIES SOLAR SYSTEM BOARD BOOK

By Jessie Silbert

Celestial Buddies, 2021, Hardcover, $12.99. www.celestialbuddies.com

This whimsical book from Celestial Buddies teaches kids about our solar system. With informative illustrations and photos of real planets, this board book is the perfect way to introduce your kids to astronomy and give them a love for space. The thick board book pages are easy for babies and toddlers to hold. Other board books in this series are *A Poem by Little Earth and A Poem by Little Moon*. For ages 0 and up.



HOW SPACESHIPS WORK

By Clive Gifford

Lonely Planet Kids, 2021, 24 pp., Hardcover. $18.99. www.shoplonelyplanet.com

Featuring fantastic illustrations by James Gulliver Hancock, this book explores the ultimate vehicles: spaceships — how they do what they do, what they're used for, and their development through history. Spreads look at how rockets blast off into space, how people were sent to the Moon and back, and how space centers prepare spaceships and astronauts for amazing adventures across the cosmos. The book also looks at different types of spacecraft, including space stations and satellites orbiting Earth, rovers trundling over the surface of Mars, and probes traveling at thousands of miles per second through the outer reaches of the solar system on incredible journeys of discovery. Full-page gatefolds and flaps explore spaceships both big and small, inside and out. For ages 6–8.

CALENDAR

For the most up-to-date information about planetary science meetings, we invite you to visit the LPI website at www.hou.usra.edu/meetings/calendar/.

The Lunar and Planetary Information Bulletin collects, synthesizes, and disseminates current research and findings in the planetary sciences to the research community, science libraries, educators, students, and the public. The Bulletin is dedicated to engaging, exciting, and educating those with a passion for the space sciences while developing future generations of explorers.

The Bulletin welcomes articles dealing with issues related to planetary science and exploration. Of special interest are articles describing web-based research and educational tools, meeting highlights and summaries, and descriptions of space missions. Peer-reviewed research articles, however, are not appropriate for publication in the Bulletin. Suggested topics can be emailed to the editors, who will provide guidelines for formatting and content.

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