

CITIZEN SCIENCE IN PLANETARY EXPLORATION: PART 1

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CITIZEN SCIENCE IN PLANETARY EXPLORATION: Part 1

Note from the Editors: In this two-part series we explore the role that citizen scientists (or amateur astronomers) play in supporting planetary exploration in the U.S. and internationally. In Part 1, Drs. Nick Lang and Michael Kelley explore the active programs that NASA uses to engage directly with citizen scientists, and Dr. Ted Stryk explores ongoing activities in monitoring astronomical events in the solar system. Part 2, which will appear in the July issue, will continue the story as Stryk looks at how citizen scientists engage with ongoing and past planetary missions to facilitate data processing. — Paul Schenk and Renée Dotson

Citizen Science Within NASA's Planetary Science Division

**Nicholas Lang and
Michael Kelley, NASA**

Citizen science is an excellent way to engage the public in active science projects. And with April being Citizen Science Month, it seems only fitting to talk about citizen science here.

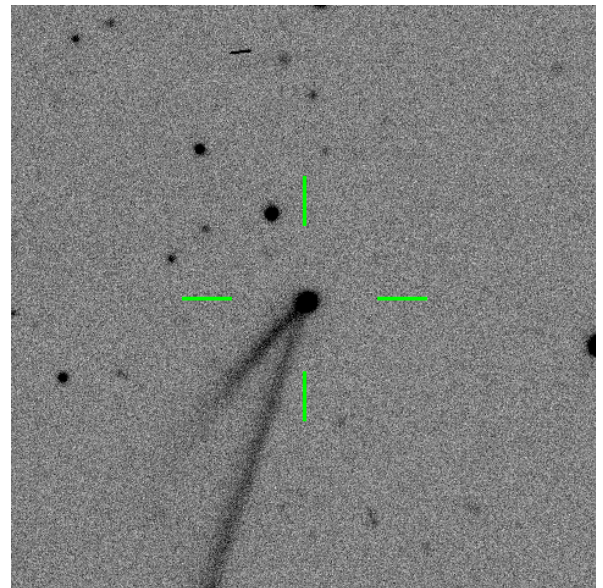
[NASA's Citizen Science programs](#) give people with varying levels of scientific knowledge and training (none to a lot!) the opportunity to contribute to ongoing research projects, while also providing researchers with [volunteers](#) to broaden their data collection or image analyses. In this contribution, we discuss the efforts we are making within the Planetary Science Division (PSD) at NASA Headquarters to promote citizen science and to suggest ways people can get involved. For more about how NASA's Science Mission Directorate (SMD) defines citizen science, please see the SMD Policy Document covering this topic ([SPD-33](#)).

Within PSD, we are actively looking to expand the visibility of the Citizen Science program to increase (1) the number and diversity of one-year seed funding proposals that are submitted and (2) the number of citizen scientists involved in the projects associated with PSD.

Our first approach to increase visibility has been to start creating a webpage

hosted by PSD that will not only link to active projects for individuals looking to participate in an established project, but will also provide guidance to scientists who would like to submit a citizen science proposal. We are currently in the building stages of this webpage and plan to have it active in calendar year 2023.

Another approach has been to advocate for sessions at annual Geological Society of America (GSA) conferences. For example, we have worked with staff from the SMD Citizen Science Office to submit a session proposal titled, "[Engaging the Public in Science: Promoting a Deeper Understanding of Our World and Beyond](#)" for the upcoming GSA Annual Meeting in Pittsburgh, Pennsylvania, in October. The proposed session aims to highlight citizen science done on planetary-science-related projects and those from other SMD divisions. Citizen science sessions have been quite successful at other meetings such as the American Geophysical Union (AGU). However, GSA has been underutilized for highlighting and recruiting NASA-sponsored citizen science projects and we hope that



With the Active Asteroids program, participants search images captured by the 4-meter Blanco telescope in Chile to find candidate active asteroids. Image from the NASA Active Asteroids site.

increasing our presence there will increase participation in our programs.

If you are a researcher who could use volunteers to help you collect and/or analyze images or data for your work, you may be interested in the following citizen science resources:

[NASA resources supporting citizen science](#)

[Government-wide citizen science resources](#)



Participants in the Cloudspotting on Mars project contribute to the fundamental understanding of martian clouds. Credit: NASA/JPL-Caltech/MSSS.

Furthermore, if you are planning to start a new citizen science project, we encourage you to submit a one-year [seed funding](#) proposal, to help develop citizen science projects. The Citizen Science Seed Funding Program (CSSFP) is a ROSES Appendix F program (F9) and the 2023 solicitation for this program will be released soon. If you have an existing citizen science project, the CSSFP also supports critical transitions intended to broaden the scope of a project. Please also check out opportunities with NASA's [Established Program to Stimulate Competitive Research \(EPSCoR\)](#) for broadening participation with existing citizen science projects.

For volunteers looking to jump in on an established PSD-related citizen

science project, you may want to check out the following opportunities:

- [Active Asteroids](#): Citizen scientists help this project find new asteroids with comet tails in the search for water and ice in space
- [Catalina Sky Survey](#): For more than 20 years, citizen scientists helped the Catalina Outer Solar System Survey confirm whether animated images of transneptunian objects (TNOs) were real or false detections made by computers
- [Cloudspotting on Mars](#): Citizen scientists helped researchers comb through 15 years of cloud observations on Mars to confirm and classify images

- [Jovian Vortex Hunter](#): Uses JunoCam images that have been processed by the mission science team for spotting vortices on Jupiter
- [Stardust@Home](#): Citizen scientists comb through digital images of samples of interstellar dust collected by NASA's Stardust mission to find grains of cometary dust in the aerogel collectors

For all citizen science opportunities across SMD, please see the [SMD citizen science website](#).

We also encourage individuals to attend the second ever in-person gathering of NASA citizen science leaders at the [C*Sci2023 conference](#) in Tempe, Arizona, on May 22, 2023! If you are a researcher involved in a citizen science project, please do strongly consider attending.

For more information about NASA's Planetary Citizen Science programs, please contact the PSD Citizen Science Program officers [Nick Lang](#) or [Michael Kelley](#).

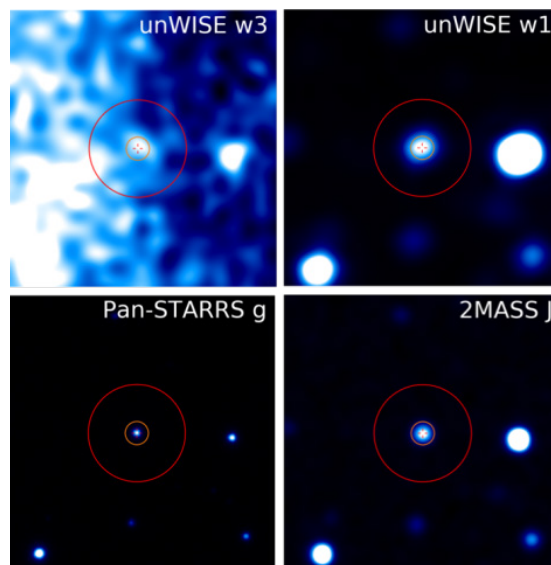
Note from the Editors: Citizen scientists also make critical contributions outside of the NASA programs outlined above. Amateur astronomers have been central in the observation of clouds on Mars and Jupiter, the discovery and monitoring of comets, and other features for centuries. Because large telescope time is very competitive, professional astronomers cannot monitor the solar system continuously; and the terabytes of spacecraft data are simply too vast for scientists to evaluate fully. This is where citizen scientists step in. Ted Stryk, professor at Roane State Community College in Harriman, Tennessee, describes several major efforts where these observers are key. Stryk is also a citizen scientist in his own right, regularly reprocessing archived planetary imaging using modern image processing tools.

—Paul Schenk and Renée Dotson

Planetary Citizen Scientists in Action

Ted Stryk, Roane State Community College

One of the more recent developments in amateur astronomy has been the monitoring of flashes of light on Jupiter caused by meteor impacts. These flashes are thought to be the result of small asteroids or comets colliding with the planet's atmosphere, causing a bright explosion that can be seen from Earth.



In the Disk Detective project, citizen scientists view images of stars taken by multiple different telescopes and compare images to determine if a particular star has a disk. Image from the NASA Disk Detective site.

- [International Astronomical Search Collaboration \(IASC\)](#): This program, which also includes educational resources for integration in K–16 formal curricula, provides astronomical data enabling citizen scientists to make discoveries, including the search for asteroids
- [JunoCam](#): Amateur astronomers are invited to participate by uploading telescopic images and data of Jupiter, which, in turn, help inform NASA's Juno mission

Comet Shoemaker-Levy 9 (SL-9) was discovered by astronomers Carolyn and Eugene Shoemaker and David Levy in March 1993, and was subsequently observed as it approached Jupiter over the course of the next year. What made SL-9 so remarkable was that it had broken apart into several large pieces, which were predicted to collide with Jupiter in July 1994. These collisions were expected to produce a series of explosions on the planet's surface, creating massive fireballs that would be visible from Earth.

As predicted, SL-9 collided with Jupiter in July 1994, producing a series of 21 impacts over the course of several days. The impacts were captured by numerous telescopes and spacecraft, including the Hubble Space Telescope and the Galileo spacecraft, which was en route to orbit Jupiter at the time.

Big dark spots were seen at the site of major impacts. Astronomers started poring through past observations, looking for similar impacts from undiscovered objects colliding with the planet. Several suspicious flashes followed by surface splotches were identified.

The study of these flashes is important for a number of reasons. First, they help scientists better understand the makeup of Jupiter's atmosphere. By analyzing the light emitted by these flashes, astronomers can determine the chemical composition of the planet's atmosphere and gain insights into its structure and behavior. Additionally, these flashes are of interest because they provide valuable data about the frequency and size of meteor impacts on Jupiter. By monitoring the frequency and intensity of these flashes over time, astronomers can gain a better understanding of the risks that such impacts pose to the planet and its surrounding moons.

In 1993, aside from sheer luck, monitoring the planet with equipment sensitive enough continually watch for impacts was prohibitive, even for professionals. Modern webcam and software technology have upended this. Today, the monitoring of these flashes is primarily done by amateur astronomers using

backyard telescopes and cameras. These individuals are often highly skilled and dedicated, spending countless hours observing and recording data in order to contribute to the scientific understanding of Jupiter and its atmosphere.

In addition to telescopes, astronomers also use specialized cameras that are capable of capturing video footage at extremely high frame rates. These cameras are often capable of capturing footage at up to 1000 frames per second, allowing them to capture even the briefest of flashes in stunning detail. They are also designed to be highly sensitive to light, ensuring that they are able to capture even the faintest of events.

To capture video footage of Jupiter, astronomers often use a technique called "lucky imaging." This involves taking multiple frames of video and selecting only the sharpest and clearest frames for analysis. By combining these frames into a single image, astronomers are able to create a final product that is incredibly sharp and detailed, providing a wealth of information about the event in question.

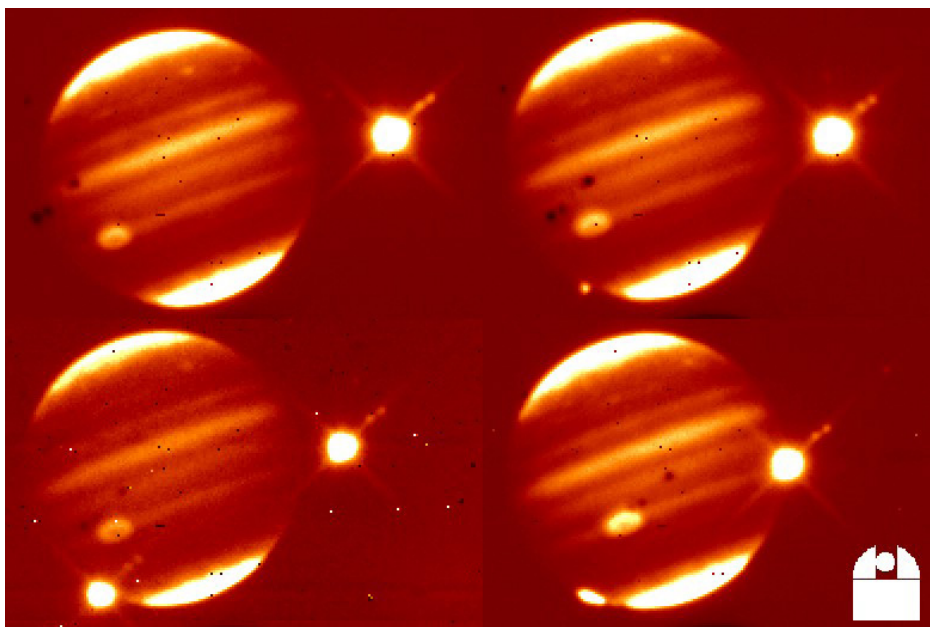
Once the video footage has been captured, astronomers use specialized software to analyze the data and

extract relevant information about the flash. This software is designed to automatically identify and track the flash, measuring its size, brightness, and other characteristics. This data can then be used to build a more complete picture of the impact event and the behavior of Jupiter's atmosphere.

In recent years, technological advances have made it easier than ever for amateur astronomers to participate in this type of study. High-speed cameras and telescopes have become more affordable and easier to use, allowing even more people to contribute to the study of Jupiter and its atmosphere. Moreover, the rise of online communities and forums dedicated to amateur astronomy has made it possible for enthusiasts to collaborate and share data, creating a truly global network of researchers.

Once a flash has been observed and recorded, astronomers can analyze the data to determine its size, brightness, and other characteristics. This data can then be used to build a more complete picture of the impact event and the behavior of Jupiter's atmosphere.

Amateur astronomers have reported observing brief flashes of light on the



A time sequence of four frames showing the impact of the first of the 20 odd fragments of Comet Shoemaker-Levy 9 into Jupiter. The images were taken at the German-Spanish 3.5-meter telescope on Calar Alto in southern Spain, using the near-infrared camera of the Max Planck Institut fuer Astronomie in Heidelberg, Germany. Credit: Calar Alto Astronomical Observatory.



The location of around 2000 TLP reports from 554 AD to the present time. The spot area indicates the frequency of reports for the feature concerned. Credit: Society for Popular Astronomy.

surface of the Moon for many years. These flashes, known as lunar flashes or transient lunar phenomena (TLP), are typically brief and unpredictable, lasting only a few seconds. Although the cause of TLP is not yet fully understood, several hypotheses have been proposed. One theory suggests that the flashes are caused by meteoroid impacts on the Moon's surface, while another proposes

that they are caused by the release of gas from the Moon's interior. Other theories include electrostatic discharges, moonquakes, and reflected sunlight.

Despite the uncertainty surrounding the cause of TLP, amateur astronomers have been instrumental in studying and documenting these phenomena. This utilizes the same type of equipment used

to look for flashes on Jupiter, so there is a lot of overlap between these activities.

One of the largest and most organized efforts to study TLP by amateurs is the Association of Lunar and Planetary Observers (ALPO) Lunar Flashes Program. This program encourages amateur astronomers to report their observations of lunar flashes to a central database, which is used to study the frequency and characteristics of these events. The program has collected thousands of reports of lunar flashes over the past several decades, providing valuable data for researchers studying TLP.

In Part 2 of this article, to be featured in Issue 173 (July 2023), we will further explore the role of citizen scientists in evaluating and reprocessing data from ongoing and past planetary missions.

FROM THE DESK OF LORI GLAZE



LONG JOURNEYS, WORTHWHILE DESTINATIONS

Lori S. Glaze

Director, NASA's Planetary Science Division, April 2023

As I write, I am about to travel to Kourou, French Guiana, for the launch of the European Space Agency's (ESA's) Jupiter Icy Moons Explorer (JUICE) mission. I'm excited to have the chance to congratulate our ESA colleagues and JUICE team members in person and to wish JUICE a hearty bon voyage! But embarking on my somewhat convoluted trip to Kourou (via Paris!) has led me to thinking about how journeys, as well as destinations, are important in our business of planetary exploration.

All being well, JUICE will launch on its Ariane 5 from the Guiana Space Centre on April 13 and begin its eight-year journey to the Jupiter system [Update: After a one-day, weather-related delay, JUICE launched successfully on April 14.]. Eight years may sound long, but this journey will not be boring. JUICE will conduct several flybys, including those of Venus, Earth, and the

first-ever Lunar-Earth gravity assist (LEGA) to help it on its way. The LEGA (a flyby of the Moon followed by one of Earth only a day and a half later) will save a substantial amount of propellant on the spacecraft.

JUICE will finally arrive at Jupiter in July 2031, where it will have a nominal science mission of four years. But even after it arrives at Jupiter, JUICE's journeying will not be over. JUICE will first spend many months orbiting Jupiter itself, conducting several flybys of Europa, Ganymede, and Callisto. Then, in its final phase, JUICE will be the first spacecraft to orbit a moon in the outer solar system when it begins its orbital tour of Ganymede. Once all JUICE's propellant has been consumed, the plan is for the spacecraft to be deorbited and to impact Ganymede at the end of 2035.

The significance of the JUICE mission, however, is obviously not just its journey.

By observing Jupiter, Ganymede, Callisto, and Europa, in unprecedented detail, we hope to learn much more about the nature of the Jovian system — by characterizing Jupiter's atmosphere, magnetic environment, ring system, and interactions with its satellites. Moreover, it is thought that Ganymede, Callisto, and Europa all bear oceans beneath their icy shells, so JUICE's investigations will help investigate their potential habitability (both past and present).

To do this, JUICE is carrying a payload of 10 scientific instruments on its journey, built by teams at institutes from Europe, Japan, Israel, and the U.S. The payload includes Janus (an optical camera system), the Moons and Jupiter Imaging Spectrometer (MAJIS), the Sub-millimeter Wave Instrument (SWI), the Ganymede Laser Altimeter (GALA), the Gravity and Geophysics of Jupiter and Galilean Moons

experiment (3GM), a magnetometer (J-MAG), and the Radio and Plasma Wave Investigation (RPWI). In particular, I'm extremely proud that NASA has contributed the UV imaging Spectrograph (UVS), led by Principal Investigator (PI) Randy Gladstone (SwRI), as well as enabling components for the Participle Environment Package (PEP). Development of the NASA-provided hardware for PEP, known as the Jovian Energetic Neutrals and Ions Sensor (JENI) and the Jovian Energetic Electron Sensor (JOEE), was led by PI Pontus Brandt (JHUAPL). Lastly, Co-PI Jeffrey Plaut (JPL) helped lead NASA/JPL's contributions for the Radar for Ice Moon Exploration (RIME) instrument.

Of course, JUICE will not be exploring the Jovian system alone in the early 2030s. NASA's own Europa Clipper mission is following hot on the heels of JUICE and is on track to launch in the fall of 2024. The Assembly, Test, Launch, and Operations (ATLO) phase of the mission is continuing a pace and eight of the nine scientific instruments have now been delivered to JPL for integration on the spacecraft. We expect the final instrument to be delivered this summer. You can follow along with Clipper's progress in JPL's High Bay 24/7 with the "[Clipper Cam](#)."

The intricacies of launch vehicles and planetary dynamics mean that Europa Clipper will live up to its name and arrive at Jupiter in April 2030 — before JUICE, even though it will launch more than a year later. Clipper's journey will include gravity assist flybys from Mars and then

Earth. The spacecraft — equipped with its huge 30-meter-wide (100-foot-wide) solar panels — will orbit Jupiter and spend about three years conducting more than 40 close flybys of Europa.

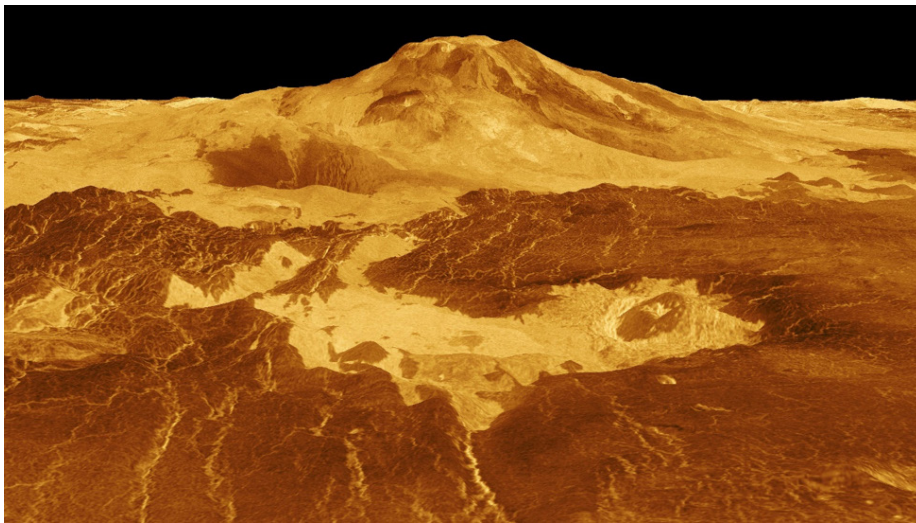
Like JUICE, Europa Clipper will have a sophisticated science payload of 10 instruments. The Clipper instruments, however, are designed specifically to characterize Jupiter's premier ocean world and investigate its habitability. The spacecraft's cameras and spectrometers will provide high-resolution images and compositional maps of Europa's surface and thin atmosphere. Data from the ice-penetrating radar, magnetometer, plasma sensors, and gravity investigation will give new insights into Europa's ocean and deep interior. The thermal camera will help to pinpoint areas of warmer ice, shallow water bodies, and recent eruptions of water. Lastly, the dust analyzer and mass spectrometer will be used to study the chemistry of particles and gases in Europa's immediate environment. In addition, because JUICE and Clipper will be in orbit around Jupiter contemporaneously, there will be some great opportunities for synergistic (two-point) measurements from many of the payloads.

Although missions to the outer reaches of our solar system come with long journeys and long waits for the science, they provide a great opportunity to train the next generation of leaders in planetary science missions. I'm happy to say that we are already working on plans for the future of the Europa

Clipper Science team. Our goal is to create a Clipper extended mission science team that will be representative of our nation's diversity. This effort will have several parts, including outreach, training, and opportunities for a broader set of institutions that have traditionally dominated planetary science. Our Here to Observe (H2O) undergraduate program is part of this broader plan. Europa Clipper played an important role in the success of H2O's pilot, and I'm excited that we are now working to expand this program. The new [Here to Observe](#) (C.24) solicitation in ROSES-2023 is now open for proposals from non-R1 institutions for undergraduate students to observe PSD mission meetings/activities alongside mentors and peers — proposals can be submitted at any time! I can't wait to see the journeys of students and early-career researchers as they grow with our long-lived missions.

For those with long memories, you might recall that the JUICE mission was selected in May 2012 after starting life as a reformulation of ESA's component of the canceled joint NASA/ESA Europa Jupiter System Mission–Laplace, and that Europa Clipper was approved as our next flagship mission in 2015. Like many planetary missions, there have been long journeys for both JUICE and Clipper to get to the launch pad, but I know the collaborations and hard work from both teams will be worthwhile when they arrive at their destinations and undoubtedly transform our understanding of Jupiter and its icy worlds.

MAGELLAN DATA REVEALS VOLCANIC ACTIVITY ON VENUS



This computer-generated 3D model of Venus' surface shows the summit of Maat Mons, the volcano that is exhibiting signs of activity. A new study found one of Maat Mons' vents became enlarged and changed shape over an eight-month period in 1991, indicating an eruptive event occurred. Credit: NASA/JPL-Caltech.

Direct geological evidence of recent volcanic activity has been observed on the surface of Venus for the first time. Scientists made the discovery after poring over archival radar images of Venus taken more than 30 years ago, in the 1990s, by NASA's Magellan mission. The images revealed a volcanic vent changing shape and increasing significantly in size in less than a year.

Scientists study active volcanoes to understand how a planet's interior can shape its crust, drive its evolution, and affect its habitability. One of NASA's new missions to Venus will do just that. Led by the agency's Jet Propulsion

Laboratory in Southern California, VERITAS – short for Venus Emissivity, Radio science, InSAR, Topography, And Spectroscopy – will launch within a decade. The orbiter will study Venus from surface to core to understand how a rocky planet about the same size as Earth took a very different path, developing into a world covered in volcanic plains and deformed terrain hidden beneath a thick, hot, toxic atmosphere.

"NASA's selection of the VERITAS mission inspired me to look for recent volcanic activity in Magellan data," said Robert Herrick, a research professor at the University of Alaska Fairbanks and

member of the VERITAS science team, who led the search of the archival data. "I didn't really expect to be successful, but after about 200 hours of manually comparing the images of different Magellan orbits, I saw two images of the same region taken eight months apart exhibiting telltale geological changes caused by an eruption."

The search and its conclusions are described in a new study published in the journal *Science*. Herrick also presented the findings at the 54th Lunar and Planetary Science Conference in the Woodlands, Texas, on March 15.

The geological changes Herrick found occurred in Atla Regio, a vast highland region near Venus' equator that hosts two of the planet's largest volcanoes, Ozza Mons and Maat Mons. The region has long been thought to be volcanically active, but there was no direct evidence of recent activity. While scrutinizing Magellan radar images, Herrick identified a volcanic vent associated with Maat Mons that changed significantly between February and October 1991.

In the February image, the vent appeared nearly circular, covering an area of less than 2.2 square kilometers (1 square mile). It had steep interior sides and showed signs of drained lava down its exterior slopes, factors that hinted at activity. In radar images captured eight months later, the same vent had doubled in size and become misshapen. It also appeared to be filled to the rim with a lava lake.

But because the two observations were from opposite viewing angles, they had different perspectives, which made them difficult to compare. The low resolution of the three-decade-old data only made the work more complicated.

"I saw two images of the same region taken eight months apart exhibiting telltale geological changes caused by an eruption."

Herrick teamed up with JPL's Scott Hensley, the project scientist for VERITAS and a specialist in analyzing radar data like Magellan's. The two researchers created computer models of the vent in various configurations to test different geological-event scenarios, such as landslides. From those models, they concluded that only an eruption could have caused the change.

"Only a couple of the simulations matched the imagery, and the most likely scenario is that volcanic activity occurred on Venus' surface during Magellan's mission," said Hensley. "While this is just one data point for an entire planet, it confirms there is modern geological activity."

The scientists liken the size of the lava flow generated by the Maat Mons activity to the 2018 Kilauea eruption on the Big Island of Hawaii.

Herrick, Hensley, and the rest of the VERITAS team are eager to see how the mission's suite of advanced science instruments and high-resolution data will

complement Magellan's remarkable trove of radar imagery, which transformed humanity's knowledge of Venus.

"Venus is an enigmatic world, and Magellan teased so many possibilities," said Jennifer Whitten, associate deputy principal investigator of VERITAS at Tulane University in New Orleans. "Now that we're very sure the planet experienced a volcanic eruption only 30 years ago, this is a small preview for the incredible discoveries VERITAS will make."

VERITAS will use state-of-the-art synthetic aperture radar to create 3D global maps and a near-infrared spectrometer to figure out what the surface is made of. The spacecraft will also measure the planet's gravitational field to determine the structure of Venus' interior. Together, the instruments will offer clues about the planet's past and present geologic processes.

And whereas Magellan's data was originally cumbersome to study – Herrick

said that in the 1990s they relied on boxes of CDs of Venus data that were compiled by NASA and delivered in the mail – VERITAS' data will be available online to the science community. That will enable researchers to apply cutting-edge techniques, such as machine learning, to analyze the planet and help reveal its innermost secrets.

Those studies will be complemented by EnVision, an ESA (European Space Agency) mission to Venus slated for launch in the early 2030s. The spacecraft will carry its own synthetic aperture radar (called VenSAR), which is being developed at JPL, as well as a spectrometer similar to the one VERITAS will carry. Both Hensley and Herrick are key members of the VenSAR science team.

STUDY FINDS VENUS' "SQUISHY" OUTER SHELL MAY BE RESURFACING THE PLANET

Earth and Venus are rocky planets of about the same size and rock chemistry, so they should be losing their internal heat to space at about the same rate. How Earth loses its heat is well known, but Venus' heat flow mechanism has been a mystery. A study that uses three-decade-old data from [NASA's Magellan mission](#) has taken a new look at how Venus cools and found that thin regions of the planet's uppermost layer may provide an answer.

Our planet has a hot core that heats the surrounding mantle, which carries that heat up to Earth's rigid outer rocky layer, or lithosphere. The heat is then lost to space, cooling the uppermost region of the mantle. This mantle convection drives [tectonic processes](#)



This illustration of the large Quetzalpetlatl Corona located in Venus' southern hemisphere depicts active volcanism and a subduction zone, where the foreground crust plunges into the planet's interior. A new study suggests coronae reveal locations where active geology is shaping Venus' surface. Credit: NASA/JPL-Caltech/Peter Rubin.

“While Venus doesn’t have Earth-style tectonics, these regions of thin lithosphere appear to be allowing significant amounts of heat to escape, similar to areas where new tectonic plates form on Earth’s seafloor.”

on the surface, keeping a patchwork of mobile plates in motion. Venus doesn’t have tectonic plates, so how the planet loses its heat and what processes shape its surface have been long-running questions in planetary science.

The study looks at the mystery using observations the Magellan spacecraft made in the early 1990s of quasi-circular geological features on Venus called coronae. Making new measurements of coronae visible in the Magellan images, the researchers concluded that coronae tend to be located where the planet’s lithosphere is at its thinnest and most active.

“For so long we’ve been locked into this idea that Venus’ lithosphere is stagnant and thick, but our view is now evolving,” said Suzanne Smrekar, senior research scientist at NASA’s Jet Propulsion Laboratory in Southern California, who led the study published in [Nature Geoscience](#).

Just as a thin bedsheet releases more body heat than a thick comforter, a thin lithosphere allows more heat to escape from the planet’s interior via buoyant plumes of molten rock rising to the outer layer. Typically, where there is enhanced heat flow, there is increased volcanic activity below the surface. So coronae

likely reveal locations where active geology is shaping Venus’ surface today.

The researchers focused on 65 previously unstudied coronae that are up to a few hundred miles across. To calculate the thickness of the lithosphere surrounding them, they measured the depth of the trenches and ridges around each corona. What they found is that ridges are spaced more closely together in areas where the lithosphere is more flexible, or elastic. By applying a computer model of how an elastic lithosphere bends, they determined that, on average, the lithosphere around each corona is about 11 kilometers (7 miles) thick, much thinner than previous studies suggest. These regions have an estimated heat flow that is greater than Earth’s average, suggesting that coronae are geologically active.

“While Venus doesn’t have Earth-style tectonics, these regions of thin lithosphere appear to be allowing significant amounts of heat to escape, similar to areas where new tectonic plates form on Earth’s seafloor,” said Smrekar.

To calculate how old a celestial body’s surface material is, planetary scientists count the number of visible impact craters. For a tectonically active planet

like Earth, impact craters are erased by the subduction of continental plates and covered by molten rock from volcanoes. If Venus lacks tectonic activity and the regular churn of Earth-like geology, it should be covered in old craters. But by counting the number of venusian craters, scientists estimate that the surface is relatively young.

Recent studies suggest the youthful appearance of Venus’ surface is likely due to volcanic activity, which drives regional resurfacing today. This finding is supported by the new research indicating higher heat flow in coronae regions, a state that Earth’s lithosphere may have resembled in the past.

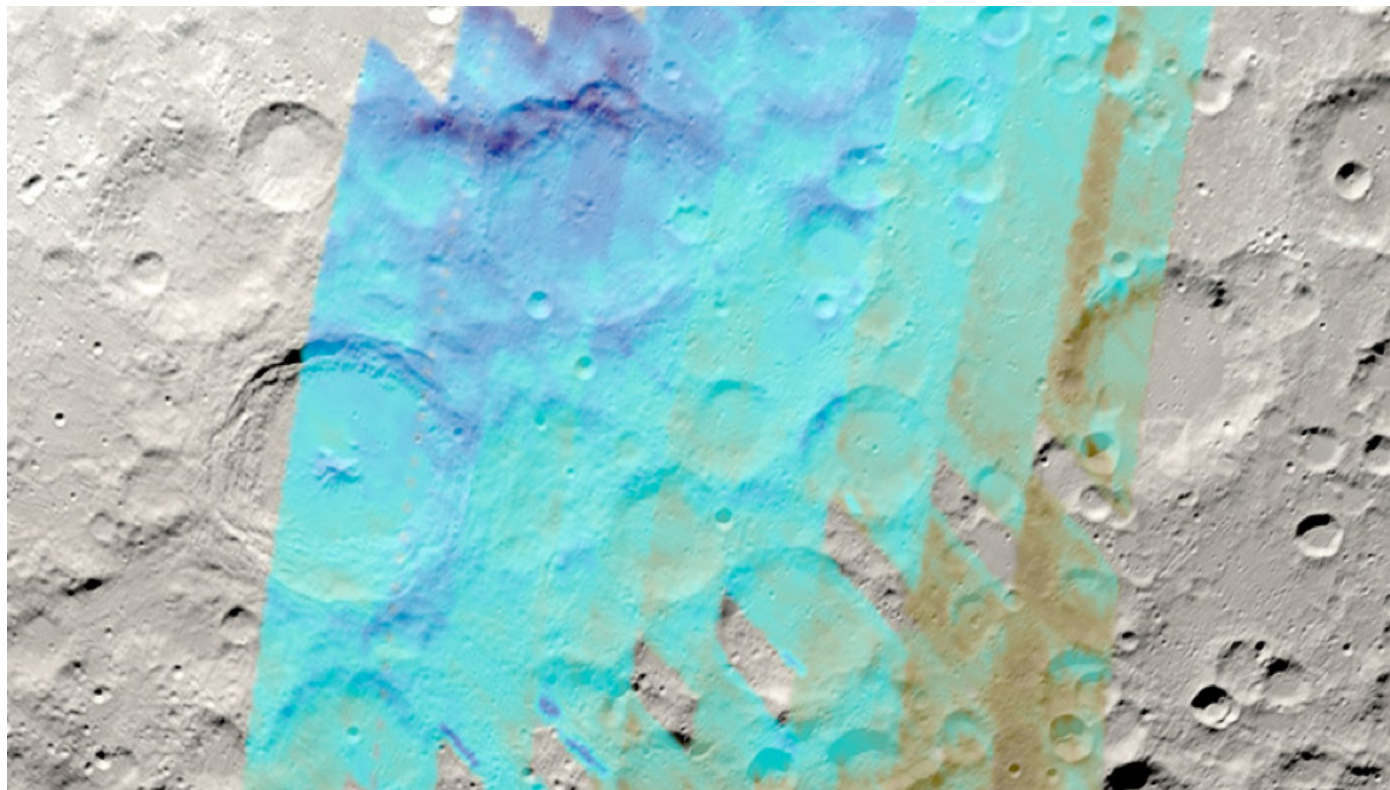
“What’s interesting is that Venus provides a window into the past to help us better understand how Earth may have looked over 2.5 billion years ago. It’s in a state that is predicted to occur before a planet forms tectonic plates,” said Smrekar, who is also the principal investigator of NASA’s forthcoming Venus Emissivity, Radio science, InSAR, Topography, And Spectroscopy ([VERITAS](#)) mission.

VERITAS will pick up where Magellan left off, improving upon that mission’s data, which are low resolution and come with large margins of error. Targeting launch within a decade, the mission will use a state-of-the-art synthetic aperture radar to create 3D global maps and a near-infrared spectrometer to figure out what the surface is made of. VERITAS will also measure the planet’s gravitational field to determine the structure of Venus’ interior. The instruments will together fill in the story of the planet’s past and present geologic processes.

“VERITAS will be an orbiting geologist, able to pinpoint where these active areas are, and better resolve local variations in lithospheric thickness. We’ll even be able to catch the lithosphere in the act of deforming,” said Smrekar. “We’ll determine if volcanism really is making the lithosphere ‘squishy’ enough to lose as much heat as Earth, or if Venus has more mysteries in store.”

SOFIA REVEALS MAP OF MOON'S WATER NEAR ITS SOUTH POLE

ARTEMIS LANDING SITES



A visualization of the data from SOFIA's observations of a "light signature" of water overlaid on a visualization of the Moon as it appeared at the time of the observations in February 2022. Darker blue indicates a higher concentration of water. Near the top left of the studied region, a "wet ridge" is visible in dark blue, where the water is particularly concentrated on the shady side of a steep lunar feature. Halfway down the left side of the region is Moretus Crater. The inner wall on the crater's upper half is clearly delineated in dark blue, indicating a greater presence of water on this shady surface. Although the right side of the region is drier overall, water can still be seen tracing the insides of craters in light blue. Credit: NASA's Goddard Space Flight Center Scientific Visualization Studio/Ernie Wright.

A new study using NASA's and German aerospace center DLR's now-retired Stratospheric Observatory for Infrared Astronomy (SOFIA) has pieced together the first detailed, wide-area map of water distribution on the Moon. With clear, identifiable lunar features marked out by the water data, the study provides hints about how water may be moving across the Moon's surface, particularly near the South Pole, an important area for space exploration. The results were presented at a press conference at the 2023 Lunar and Planetary Science Conference held in March.

The new map covers about one-quarter of the Earth-facing side of the lunar surface below 60° latitude and is the first to extend to the Moon's South Pole.

Given the large region covered, the researchers could easily identify how water relates to surface features on the Moon, shifting away from the Sun's illumination and favoring cold areas.

"When looking at the water data, we can actually see crater rims, we see the individual mountains, and we can even see differences between the sunny and shady sides of the mountains, thanks to the higher concentration of water in shady places," said Bill Reach, lead author of the paper and director of the SOFIA Science Center at NASA's Ames Research Center in California.

This finding, along with two previous SOFIA results about the amount and distribution of water on the Moon's sunlit

surface, tracks a unique light signature of water. Other missions observing wide areas of the lunar surface have studied different wavelengths of light, which can't distinguish water from similar molecules, such as hydroxyl. The Moon's water is present in the soil and might be found as ice crystals, or as water molecules chemically bound to other materials.

Instead of determining the absolute quantity of water in the region, the researchers compared the data obtained around the Moon's South Pole to a relatively dry reference region near the Moon's equator to see how its abundance changes. The water was found in greater concentrations on the shadowed sides of craters and mountains, similar to the way skiers on Earth know

the slopes receiving less direct sun retain snow longer. This suggests the Moon's local geography plays an important role in the amount of water present.

In late 2024, NASA's Volatiles Investigating Polar Exploration Rover (VIPER) will land in the region studied by SOFIA, atop Mons Mouton, to conduct the first resource mapping mission beyond Earth. The flat-topped lunar mountain will be a region of emphasis in the next paper from the team that led the current study of SOFIA data.

As NASA prepares to send astronauts back to the Moon under Artemis, the agency has identified 13 candidate landing regions near the lunar South Pole. Through Artemis, NASA will land the first woman and the first person of color on the Moon, and lunar water will be a critical resource for establishing a long-term human presence.

"With this map of SOFIA data, and others to come, we are looking at how

water is concentrated under different lunar environmental conditions," said Casey Honniball, a visiting assistant research scientist and VIPER science team member at NASA's Goddard Space Flight Center in Greenbelt, Maryland, who was involved in the work. "This map will provide valuable information for the Artemis program on potential prospecting areas but also provides regional context for future missions, like VIPER."

In addition to the southern region for which the new map results were created, SOFIA observations of sites relevant to other missions are in the archive and are now being analyzed. NASA Artemis-related missions including Lunar Trailblazer, a small spacecraft which will orbit the Moon to map its hydroxyl and water, will target both polar and non-polar regions.

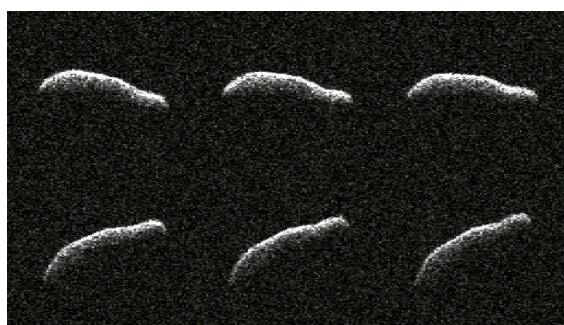
Where the Moon's water may be coming from — whether it exists inherently in the Moon's minerals or is exclusively delivered by comets and solar wind, and whether it is migrating along the Moon's surface — is

another important question left open by the SOFIA observations. VIPER will aim to better understand this distinction, which is important in determining if the water is widespread and deep within the surface, or only scattered at or near the surface.

It is clear, however, that even at its lowest limit, the Moon contains much more water than we once believed.

"Our common knowledge from the Apollo era that the Moon is bone dry was wrong," said Paul Lucey, a professor at the University of Hawaii at Mānoa and co-author of the paper. "We already know it's wrong, but the question is by how much."

PLANETARY RADAR CAPTURES DETAILED VIEW OF OBLONG ASTEROID



This collage shows six planetary radar observations of 2011 AG5 a day after the asteroid made its close approach to Earth on February 3, 2023. With dimensions comparable to the Empire State Building, 2011 AG5 is one of the most elongated asteroids to be observed by planetary radar to date. Credit: NASA/JPL-Caltech.

On February 3, 2023, an asteroid more than three times as long as it is wide safely flew past Earth at a distance of about 1.8 million kilometers (1.1 million miles, or a little under five times the distance between the Moon and

Earth). While there was no risk of the asteroid — called 2011 AG5 — impacting our planet, scientists at NASA's Jet Propulsion Laboratory (JPL) in Southern California closely tracked the object, making invaluable observations to help determine its size, rotation, surface details, and most notably, shape.

This close approach provided the first opportunity to take a detailed look at the asteroid since it was

discovered in 2011, revealing an object about 500 meters (1,600 feet) long and about 150 meters (500 feet) wide, dimensions comparable to the Empire State Building. The powerful 70-meter (230-foot) Goldstone Solar

System Radar antenna dish at the Deep Space Network's facility near Barstow, California, revealed the dimensions of this extremely elongated asteroid.

"Of the 1,040 near-Earth objects observed by planetary radar to date, this is one of the most elongated we've seen," said Lance Benner, principal scientist at JPL who helped lead the observations.

The Goldstone radar observations took place between January 29 and February 4 and captured several other details: Along with a large, broad concavity in one of the asteroid's two hemispheres, 2011 AG5 has subtle dark and lighter regions that may indicate small-scale surface features a few dozen meters across. And if the asteroid were viewed by the human eye, it would appear as dark as charcoal. The observations also

confirmed 2011 AG5 has a slow rotation rate, taking nine hours to fully rotate.

Beyond contributing to a better understanding of what this object looks like up close, the Goldstone radar observations provide a key measurement of the asteroid's orbit around the Sun. Radar provides precise distance measurements that can help scientists at NASA's Center for Near Earth Object Studies (CNEOS) refine the asteroid's orbital path. Asteroid 2011 AG5 orbits the Sun once every

621 days and won't have a very close encounter with Earth until 2040, when it will safely pass our planet at a distance of about 1.1 million kilometers (670,000 miles, or nearly three times the distance between the Moon and Earth).

"Interestingly, shortly after its discovery, 2011 AG5 became a poster-child asteroid when our analysis showed it had a small chance of a future impact," said Paul Chodas, the director of CNEOS at JPL. "Continued observations of this object ruled out

any chance of impact, and these new ranging measurements by the planetary radar team will further refine exactly where it will be far into the future."

CNEOS calculates every known near-Earth asteroid orbit to provide assessments of potential impact hazards. More information about planetary radar, CNEOS, and near-Earth objects can be found at www.jpl.nasa.gov/asteroid-watch.

ENGINEERS KEEP AN EYE ON FUEL SUPPLY OF NASA'S OLDEST MARS ORBITER

Since NASA launched the 2001 Mars Odyssey Orbiter to the Red Planet almost 22 years ago, the spacecraft has looped around Mars more than 94,000 times. That's about the equivalent of 2.21 billion kilometers (1.37 billion miles), a distance that has required extremely careful management of the spacecraft's fuel supply. This feat is even more impressive given that Odyssey has no fuel gauge; engineers have had to rely on math instead.

Their work has helped Odyssey build a scientific legacy: The spacecraft has mapped minerals across the martian surface, allowing scientists to better understand the planet's history. Odyssey has found ice deposits that could be used by future astronauts. It has studied radiation that could harm those same astronauts. And it has scouted potential landing sites for missions to come. Odyssey is also among a small constellation of orbiters that relays data back to Earth from NASA's rovers and landers (almost 150 gigabytes to date and counting).

But last year, Odyssey looked as if it might be running out of gas: Calculations indicated its hydrazine fuel was much lower than expected.

Odyssey launched in 2001 with almost 225.3 kilograms (500 pounds) of



NASA's 2001 Mars Odyssey orbiter is depicted in this illustration. The mission team spent most of 2021 assessing how much propellant is left on the orbiter, concluding it has enough to stay active through at least 2025. Credit: NASA/JPL-Caltech.

hydrazine propellant. Because there is no fuel gauge, engineers have used a variety of ways to infer how much hydrazine the spacecraft has consumed over time. One way to measure Odyssey's fuel is to apply heat to the spacecraft's two propellant tanks and watch how long they take to reach a certain temperature. As with a teapot, a nearly empty fuel tank would heat up faster than a full one.

That is, in fact, what appeared to occur with a fuel estimate performed on Odyssey in the summer of 2021. The math seemed to

show that about 5 kilograms (11 pounds) of propellant remained available, less than the mission's modeling had predicted. Another estimate in January 2022 indicated only 2.8 kilograms (6 pounds) of hydrazine remained.

If the figures were accurate, Odyssey would be running on empty in less than a year. Either the spacecraft had experienced some kind of failure, like a leak, or something was off in the team's measurements.

Months of testing and intense investigation ensued. After studying the mystery of

the “missing” fuel, mission engineers learned new things about how the aging spacecraft’s complex fuel system behaves in flight. Their conclusion: The orbiter should have enough fuel to last at least through the end of 2025.

Odyssey doesn’t need a lot of hydrazine to get by on any given day. Solar panels power its systems, while three strategically placed reaction wheels help the orbiter point its science instruments at the martian surface. As the reaction wheels spin inside the spacecraft bus, or body, they create torque that causes Odyssey to move in the opposite direction.

“These reaction wheels have to work together to maintain the spacecraft’s pointing,” said Odyssey’s mission manager, Jared Call of NASA’s Jet Propulsion Laboratory (JPL) in Southern California. “But with Odyssey completing a full loop every orbit, you need a way to unload the increasing momentum.”

That is where Odyssey’s hydrazine comes in. The spacecraft’s thrusters release this propellant in small, calculated bursts to counter the reaction wheels’ building momentum.

So when the team’s calculations showed that their propellant supply was lower than expected, engineers at JPL got to work with those at Lockheed Martin Space, which built

Odyssey, maintains mission operations, and provides spacecraft engineering support.

“First, we had to verify the spacecraft was OK,” said Joseph Hunt, Odyssey’s project manager at JPL. “After ruling out the possibility of a leak or that we were burning more fuel than estimated, we started looking at our measuring process.”

The team agreed that they needed some fresh eyes to assess the situation. They brought in Boris Yendler, an outside consultant who also specializes in spacecraft propellant estimation.

Like all spacecraft, Odyssey relies on heaters to keep various parts, including the fuel tanks, working in the cold of space. Yendler wondered whether heat was being added to the propellant from some other source on the spacecraft, complicating the fuel measurement. After lots of experimentation, the team confirmed that was the case. Heaters along a fuel

line connecting the tanks were warming them faster than expected, making it seem as if the tanks were nearly empty.

“Our method of measurement was fine. The problem was that the fluid dynamics occurring on board Odyssey are more complicated than we thought,” Call said.

After figuring out how much heat wasn’t being accounted for in their calculations, the team concluded that Odyssey has about 4 kilograms (9 pounds) of hydrazine left. That is enough to continue the mission for a few more years. Although the number could change as the team works to refine the measurements and improve their accuracy, they are resting easier now that they better understand their spacecraft.

“It’s a little like our process for scientific discovery,” Call said. “You explore an engineering system not knowing what you’ll find. And the longer you look, the more you find that you didn’t expect.”

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CURIOSITY ROVER FINDS SURPRISE CLUES TO MARS’ WATERY PAST

When NASA’s Curiosity rover arrived at the “sulfate-bearing unit” last fall, scientists thought they’d seen the last evidence that lakes once covered this region of Mars. That’s because the rock layers here formed in drier settings than regions explored earlier in the mission. The area’s sulfates — salty minerals — are thought to have been left behind when water was drying to a trickle.

So Curiosity’s team was surprised to discover the mission’s clearest evidence

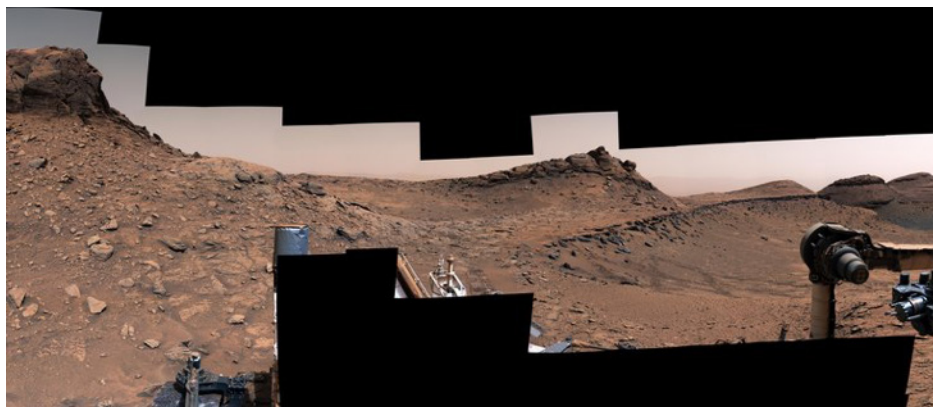
yet of ancient water ripples that formed within lakes. Billions of years ago, waves on the surface of a shallow lake stirred up sediment at the lake bottom, creating rippled textures left in rock over time.

“This is the best evidence of water and waves that we’ve seen in the entire mission,” said Ashwin Vasavada, Curiosity’s project scientist at NASA’s Jet Propulsion Laboratory in Southern California. “We climbed through thousands of feet of lake deposits and never saw evidence like

this — and now we found it in a place we expected to be dry.”

Since 2014, the rover has been ascending the foothills of Mount Sharp, a 5-kilometer-tall (3-mile-tall) mountain that was once laced with lakes and streams that would have provided a rich environment for microbial life, if any ever formed on the Red Planet.

Mount Sharp is made up of layers, with the oldest at the bottom of the mountain



NASA's Curiosity used its Mastcam to capture this 360° panorama of Marker Band Valley on December 16, 2022. Rippled rock textures found in this area are the clearest evidence the rover has seen of water and waves from Mars' ancient past. Credit: NASA/JPL-Caltech/MSSS.

and the youngest at the top. As the rover ascends, it progresses along a martian timeline, allowing scientists to study how Mars evolved from a planet that was more Earth-like in its ancient past, with a warmer climate and plentiful water, to the freezing desert it is today.

Having climbed nearly a half-mile above the mountain's base, Curiosity has found these rippled rock textures preserved in what has been nicknamed the "Marker Band," a thin layer of dark rock that stands out from the rest of Mount Sharp. This rock layer is so hard that Curiosity hasn't been able to drill a sample from it despite several attempts. It's not the first time Mars has been unwilling to share a sample: Lower down the mountain, on "Vera Rubin Ridge," Curiosity had to try three times before finding a spot soft enough to drill.

Scientists will be looking for softer rock in the weeks ahead. But even if they never get a sample from this unusual strip of rock, there are other sites they're eager to explore.

Far ahead of the Marker Band, scientists can see another clue to the history of Mars' ancient water in a valley named Gediz Vallis. Wind carved the valley, but a channel running through it that starts higher up on Mount Sharp is thought to have been eroded by a small river. Scientists suspect wet landslides also occurred here, sending car-size boulders and debris to the bottom of the valley.

Because the resulting debris pile sits on top of all the other layers in the valley, it's clearly one of the youngest features on Mount Sharp. Curiosity got a glimpse of

this debris at Gediz Vallis Ridge twice last year but could only survey it from a distance. The rover team hopes to have another chance to view it later this year.

One more clue within the Marker Band that has fascinated the team is an unusual rock texture likely caused by some sort of regular cycle in the weather or climate, such as dust storms. Not far from the rippled textures are rocks made of layers that are regular in their spacing and thickness. This kind of rhythmic pattern in rock layers on Earth often stems from atmospheric events happening at periodic intervals. It is possible the rhythmic patterns in these martian rocks resulted from similar events, hinting at changes in the Red Planet's ancient climate.

"The wave ripples, debris flows, and rhythmic layers all tell us that the story of wet-to-dry on Mars wasn't simple," Vasavada said. "Mars' ancient climate had a wonderful complexity to it, much like Earth's."

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

PERSEVERANCE ROVER SET TO BEGIN THIRD YEAR AT JEZERO CRATER

NASA's Perseverance celebrated its second anniversary on the surface of Mars on February 18. Since arriving at Jezero Crater in 2021, the six-wheeled, nuclear-powered rover has been examining geologic features and collecting samples of the Red Planet that are central to the first step of the NASA-ESA (European Space Agency) Mars Sample Return campaign. Scientists want to study martian samples with

powerful lab equipment on Earth to search for signs of ancient microbial life and to better understand the processes that have shaped the surface of Mars.

"Anniversaries are a time of reflection and celebration, and the Perseverance team is doing a lot of both," said Perseverance project scientist Ken Farley of Caltech in Pasadena. "Perseverance has inspected and performed data

collection on hundreds of intriguing geologic features, collected 15 rock cores, and created the first sample depot on another world. With the start of the next science campaign, known as 'Upper Fan,' on February 15, we expect to be adding to that tally very soon."

In addition to the rock cores, Perseverance has collected two regolith samples and one atmospheric sample, and it has

sealed three “witness” tubes. [Click here](#) to learn more about the samples taken so far.

Numbers play a big role in the life of a Mars rover mission, not just because the team includes an impressive quantity of scientists (who don’t usually mind numbers) and engineers (who love them), but because statistics provide the best and most efficient glimpse of vehicle trends and performance.

For instance, the mission can tell you not only that the rover has driven 14.97 kilometers (9.3 miles), but also that as of February 14, its left front wheel has performed 9,423 revolutions. They can tell you not only that the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) technology demonstration has produced 92.11 grams (3.25 ounces) of oxygen, but also that the Gas Dust Removal Tool (gDRT) — the little gas-puffing device on the robotic arm — has puffed 62 times to clear residual dust and particles from rock-abrading activities.

“We deal with a lot of numbers,” said Perseverance deputy project manager Steve Lee from NASA’s Jet Propulsion Laboratory (JPL) in Southern California. “We collect them, evaluate them, compare them, and more times than we want to admit, bore our loved ones with them during a family dinner.”

With that, here are some of the most up-to-date statistics regarding Perseverance’s first two Earth years of Jezero surface operations. Some will seem obscure, while others are more immediate, but they all underscore how productive the mission has been.

The rover carries seven science instruments, and they’ve been busy.

- Laser shots fired by the SuperCam science instrument: 230,554
- Soundings performed by the Radar Imager for Mars’ Subsurface Experiment (RIMFAX) ground-penetrating radar to study underground rock layers: 676,828
- Mars audio recordings taken by SuperCam’s microphone: 662

- Hours of Mars weather data recorded by the Mars Environmental Dynamics Analyzer (MEDA): 15,769.1

- Hours the X-ray filament on the Planetary Instrument for X-ray Lithochemistry (PIXL) instrument has operated: 298.2

- Laser shots by the Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument: 4,337,010

- SHERLOC spectroscopy observations: 33

Along with the massive drill-toting robotic arm, the rover has a small sample handling arm inside its belly.

- Times the rover’s main robotic arm has been unstowed and stowed: 64
- Times the drill on that arm has touched Mars: 39
- Times drill bits have been exchanged: 48
- Abrasions performed by the drill: 17
- Distance the rover’s sample handling arm’s z-stage has traveled up and down: 206.1 meters (676.1 feet)

Perseverance packs seven science cameras along with nine engineering cameras. Together, those cameras have taken more than 166,000 images. Here are the image tallies for several of them.

- Mastcam-Z: 86,660
- Navigation Cameras: 21,571
- Front Hazard-Avoidance Cameras: 3,909
- Rear Hazard-Avoidance Cameras: 474
- Sampling and Caching System Camera: 1,321
- SuperCam Remote Micro-Imager: 2,825



This image of the floor of Jezero Crater was taken by one of the Navcam imagers onboard NASA’s Perseverance Mars rover on February 5, 2023, the 698th martian day, or sol, of the mission. Credit: NASA/JPL-Caltech.

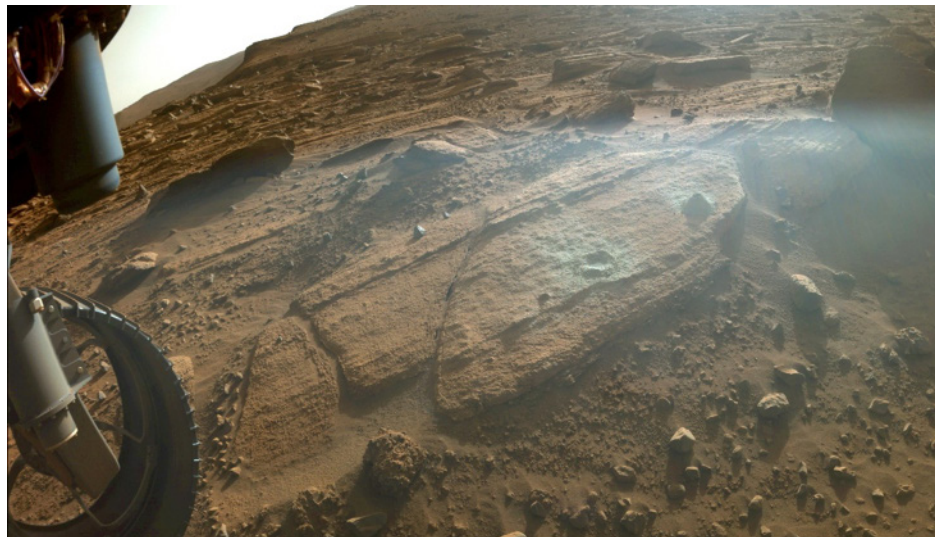
- MEDA SkyCam: 1,831
- PIXL Micro-Context Camera: 1,012
- SHERLOC WATSON: 5,754
- SHERLOC Context Imager: 2,260
- Entry, Descent, and Landing Cameras: 33,279

“Behind each number is a lot of thought and effort from a very talented group of women and men on the Perseverance team,” said Art Thompson, Perseverance project manager at JPL. “We have come a long way together, and I can’t think of a better group to work with as we go even farther.”

In fact, when Perseverance marked its second landing anniversary, Mars was 156 kilometers (97 million miles) from Earth. The weather at Jezero Crater was expected to be sunny with a high of about minus 14°C (7°F). The rover has instructions to perform remote science and take images of a place in Jezero Crater called “Jenkins Gap.” People on the mission team were able to take a moment to recall where they were and how they felt two years ago when Perseverance landed on Mars.

For more highlights of Perseverance’s first two years on Mars, visit mars.nasa.gov/mars2020/mission/highlights/.

PERSEVERANCE COLLECTS FIRST MARS SAMPLE OF NEW SCIENCE CAMPAIGN



This image shows the rocky outcrop the Perseverance science team calls “Berea” after the NASA Mars rover extracted a rock core (right) and abraded a circular patch (left). The image was taken by one of the rover’s front hazard cameras on March 30, 2023, the 749th martian day, or sol, of the mission. Credit: NASA/JPL-Caltech.

NASA’s Perseverance rover cored and stored the first sample of the mission’s newest science campaign on Thursday, March 30, 2023. With each campaign, the team explores and studies a new area. On this campaign, the rover is exploring the top of Jezero Crater’s delta. Perseverance has collected a total of 19 samples and three witness tubes, and it recently deposited 10 tubes as a backup cache on the martian surface as part of the NASA-European Space Agency (ESA) Mars Sample Return campaign.

Scientists want to study martian samples with powerful lab equipment on Earth to search for signs of ancient microbial life and to better understand the water cycle that has shaped the surface and interior of Mars.

Cored from a rock the science team calls “Berea,” this latest sample is the 16th cored rock sample of the mission. (There are also samples of regolith — or broken rock and dust — as well as Mars atmosphere.) The science team believes Berea formed from rock deposits that were carried downstream by an ancient river to this location. That would mean

were present in this part of Jezero Crater, it could be a rock like this one that could very well hold their secrets.”

One big puzzle is how Mars’ climate worked back when this area was covered with liquid water. Because carbonates form due to chemical interactions in liquid water, they can provide scientists with a long-term record of changes in the planet’s climate. By studying the carbonate in the Berea sample, the science team could help fill in the gaps.

“The Berea core highlights the beauty of rover missions,” said Perseverance’s project scientist, Ken Farley of Caltech in Pasadena. “Perseverance’s mobility has allowed us to collect igneous samples from the relatively flat crater floor during the first campaign, and then travel to the base of the crater’s delta, where we found fine-grained sedimentary rocks deposited in a dried lakebed. Now we are sampling from a geologic location where we find coarse-grained sedimentary rocks deposited in a river. With this diversity of environments to observe and collect from, we are confident that these samples will allow us to better understand what occurred here at Jezero Crater billions of years ago.”

the material could have come from an area well beyond the confines of Jezero Crater, and it is one reason why the team finds the rock so promising.

“The second reason is that the rock is rich in carbonate,” said Katie Stack Morgan, deputy project scientist for Perseverance at NASA’s Jet Propulsion Laboratory in Southern California. “Carbonate rocks on Earth can be good at preserving fossilized lifeforms. If biosignatures

“A key objective for Perseverance’s mission on Mars is astrobiology, including caching samples that may contain signs of ancient microbial life.”

With this latest sample stored safely in a sample tube in the rover's belly, the six-wheeler will continue to climb Jezero's sedimentary fan toward the next bend in the dry riverbed, a location the science team calls "Castell Henllys."

A key objective for Perseverance's mission on Mars is astrobiology, including caching samples that may

contain signs of ancient microbial life. The rover will characterize the planet's geology and past climate, pave the way for human exploration of the Red Planet, and be the first mission to collect and cache martian rock and regolith.

Subsequent NASA missions, in cooperation with ESA, would send spacecraft to Mars to collect these sealed

samples from the surface and return them to Earth for in-depth analysis.

The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

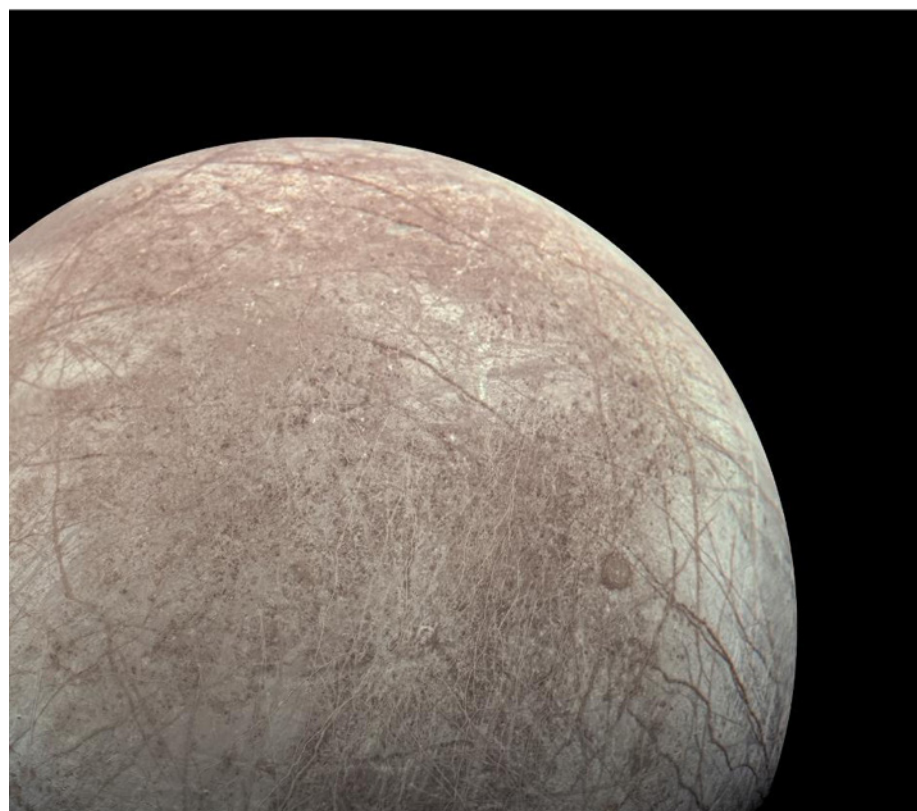
STUDY FINDS OCEAN CURRENTS MAY AFFECT ROTATION OF EUROPA'S ICY CRUST

NASA scientists have strong evidence that Jupiter's moon Europa has an internal ocean under its icy outer shell — an enormous body of salty water swirling around the moon's rocky interior. New computer modeling suggests the water may actually be pushing the ice shell along, possibly speeding up and slowing down the rotation of the moon's icy shell over time.

Scientists have known that Europa's shell is probably free-floating, rotating at a different rate than the ocean below and the rocky interior. The new modeling is the first to show that Europa's ocean currents could be contributing to the rotation of its icy shell.

A key element of the study involved calculating drag, the horizontal force that the moon's ocean exerts on the ice above it. The research hints at how the power of the ocean flow and its drag against the ice layer could even account for some of the geology seen on Europa's surface. Cracks and ridges could result from the icy shell slowly stretching and collapsing over time as it is pushed and tugged by the ocean currents.

"Before this, it was known through laboratory experiments and modeling that heating and cooling of Europa's ocean may drive currents," said Hamish Hay, a researcher at the University of Oxford and lead author of the study published in the *Journal of Geophysical*



This view of Jupiter's icy moon Europa was captured by the JunoCam imager onboard NASA's Juno spacecraft during the mission's close flyby on September 29, 2022. The agency's Europa Clipper spacecraft will explore the moon when it reaches orbit around Jupiter in 2030. Credit: Image data: NASA/JPL-Caltech/SwRI/MSSS; Image processing: Kevin M. Gill CC BY 3.0.

Research: Planets. Hay performed the research while he was a postdoctoral research associate at NASA's Jet Propulsion Laboratory (JPL) in Southern California. "Now our results highlight a coupling between the ocean and the rotation of the icy shell that was never previously considered."

It might even be possible, using measurements gathered by NASA's upcoming *Europa Clipper mission*, to determine with precision how fast the icy shell rotates. When scientists compare images gathered by Europa Clipper with those captured in the past by NASA's *Galileo* and *Voyager* missions, they

will be able to examine locations of ice surface features and potentially determine if the position of the moon's icy shell has changed over time.

For decades, planetary scientists have debated whether Europa's icy shell might be rotating faster than the deep interior. But rather than tying it to the ocean's movement, scientists focused on an outside force: Jupiter. They theorized that as the gas giant's gravity pulls on Europa, it also tugs on the moon's shell and causes it to spin slightly faster.

"To me, it was completely unexpected that what happens in the ocean's circulation could be enough to affect the icy shell. That was a huge surprise," said co-author and Europa Clipper project scientist Robert Pappalardo of JPL. "And the idea that the cracks and ridges we see on Europa's surface could be tied to the circulation of the ocean below — geologists don't usually think, 'Maybe it's the ocean doing that.'"

Europa Clipper, now in its assembly, test, and launch operations phase at JPL, is

set to launch in 2024. The spacecraft will begin orbiting Jupiter in 2030 and will use its [suite of sophisticated instruments](#) to gather science data as it flies by Europa about 50 times. The mission aims to determine if Europa, with its deep internal ocean, has conditions that could be suitable for life.

Like a Pot of Water

Using techniques developed to study Earth's oceans, the paper's authors relied on [NASA supercomputers](#) to make large-scale models of Europa's ocean. They explored the complexities of how the water circulates and how heating and cooling affects that movement.

Scientists believe that Europa's internal ocean is heated from below due to radioactive decay and tidal heating within the moon's rocky core. Like water heating in a pot on a stove, Europa's warm water rises to the top of the ocean.

In the simulations, the circulation initially moved vertically, but the rotation of the moon as a whole caused the flowing

water to veer in a more horizontal direction — in east-west and west-east currents. By including drag in their simulations, the researchers were able to determine that if the currents are fast enough, there could be adequate drag on the ice above to speed up or slow down the shell's rotation speed. The amount of interior heating — and thus, circulation patterns in the ocean — may change over time, potentially speeding up or slowing rotation of the icy shell above.

"The work could be important in understanding how other ocean worlds' rotation speeds may have changed over time," Hay said. "And now that we know about the potential coupling of interior oceans with the surfaces of these bodies, we may learn more about their geological histories as well as Europa's."

More information about Europa can be found at europa.nasa.gov.

WEBB DETECTS EXTREMELY SMALL MAIN BELT ASTEROID



This illustration depicts an asteroid that has been detected by a team of European astronomers using NASA's James Webb Space Telescope. At 100 to 200 meters (300 to 650 feet) in length, it is roughly the size of Rome's Colosseum. Credits: N. Bartmann (ESA/Webb), ESO/M. Kornmesser and S. Brunier, N. Risinger (skysurvey.org).

An asteroid roughly the size of Rome's Colosseum — between 100 to 200

meters (300 to 650 feet) in length — has been detected by an international team of European astronomers using NASA's James Webb Space Telescope. Their project used data from the calibration of the [Mid-InfraRed Instrument](#) (MIRI), in which the team serendipitously detected an interloping asteroid. The object is likely the smallest observed to date by Webb and may be an example of an object measuring under one kilometer (0.6 miles) in length within the main asteroid belt located between Mars and Jupiter. More observations are needed to better characterize this object's nature and properties.

"We — completely unexpectedly — detected a small asteroid in publicly available MIRI calibration observations," explained Thomas Müller, an astronomer at the Max Planck Institute for Extraterrestrial Physics in Germany. "The measurements are some of the first MIRI measurements targeting the ecliptic plane, and our work suggests that many new objects will be detected with this instrument."

These Webb observations, published in the journal [Astronomy and Astrophysics](#), were not designed to hunt for new asteroids. In fact, they were calibration images of the main-belt asteroid (10920) 1998 BC1, which astronomers discovered in 1998. The observations were conducted to test the performance of some of MIRI's filters,

but the calibration team considered them to have failed for technical reasons due to the brightness of the target and an offset telescope pointing. Despite this, the data on asteroid 10920 were used by the team to establish and test a new technique to constrain an object's orbit and to estimate its size. The validity of the method was demonstrated for asteroid 10920 using the MIRI observations combined with data from ground-based telescopes and the European Space Agency's [Gaia](#) mission.

During the analysis of the MIRI data, the team found the smaller interloper in the same field of view. The team's results suggest the object measures 100-200 meters, occupies a very low-inclination orbit, and was in the inner main-belt region at the time of the Webb observations.

"Our results show that even 'failed' Webb observations can be scientifically useful if you have the right mindset and a little bit of luck," elaborated Müller. "Our detection lies in the main asteroid belt, but Webb's incredible

sensitivity made it possible to see this roughly 100-meter object at a distance of more than 100 million kilometers."

The detection of this asteroid — which the team suspects to be the smallest observed to date by Webb and one of the smallest detected in the main belt — would, if confirmed as a new asteroid discovery, have important implications for our understanding of the formation and evolution of the solar system. Current models predict the occurrence of asteroids down to very small sizes, but small asteroids have been studied in less detail than their larger counterparts owing to the difficulty of observing these objects. Future dedicated Webb observations will allow astronomers to study asteroids smaller than one kilometer in size.

What's more, this result suggests that Webb will also be able to serendipitously contribute to the detection of new asteroids. The team suspects that even short MIRI observations close to the plane of the solar system will

always include a few asteroids, most of which will be unknown objects.

To confirm that the object detected is a newly discovered asteroid, more position data relative to background stars is required from follow-up studies to constrain the object's orbit.

"This is a fantastic result that highlights the capabilities of MIRI to serendipitously detect a previously undetectable size of asteroid in the main belt," concluded Bryan Holler, Webb support scientist at the Space Telescope Science Institute in Baltimore, Maryland. "Repeats of these observations are in the process of being scheduled, and we are fully expecting new asteroid interlopers in those images."

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

WEBB SPOTS SWIRLING, GRITTY CLOUDS ON REMOTE PLANET



This illustration shows the swirling clouds identified by the James Webb Space Telescope in the atmosphere of exoplanet VHS 1256 b. Credit: NASA, ESA, CSA, Joseph Olmsted (STScI).

Researchers observing with NASA's James Webb Space Telescope have pinpointed silicate cloud features in a distant planet's atmosphere. The atmosphere is constantly rising, mixing, and moving during its

22-hour day, bringing hotter material up and pushing colder material down. The resulting brightness changes are so dramatic that it is the most variable planetary-mass object known to date. The team, led by Brittany Miles of the University of Arizona, also made extraordinarily clear detections of

water, methane, and carbon monoxide with Webb's data, and found evidence of carbon dioxide. This is the largest number of molecules ever identified all at once on a planet outside our solar system.

Cataloged as VHS 1256 b, the planet is about 40 light-years away and orbits not one, but two stars over a 10,000-year period. "VHS 1256 b is about four times farther from its stars than Pluto is from our Sun, which makes it a great target for Webb," Miles said. "That means the planet's light is not mixed with light from its stars." Higher up in its atmosphere, where the silicate clouds are churning, temperatures reach a scorching 830°C (1,500°F).

Within those clouds, Webb detected both larger and smaller silicate dust grains, which are shown on a [spectrum](#). "The finer silicate grains in its atmosphere may be more like tiny particles in smoke," noted co-author Beth Biller of the University of Edinburgh in Scotland.

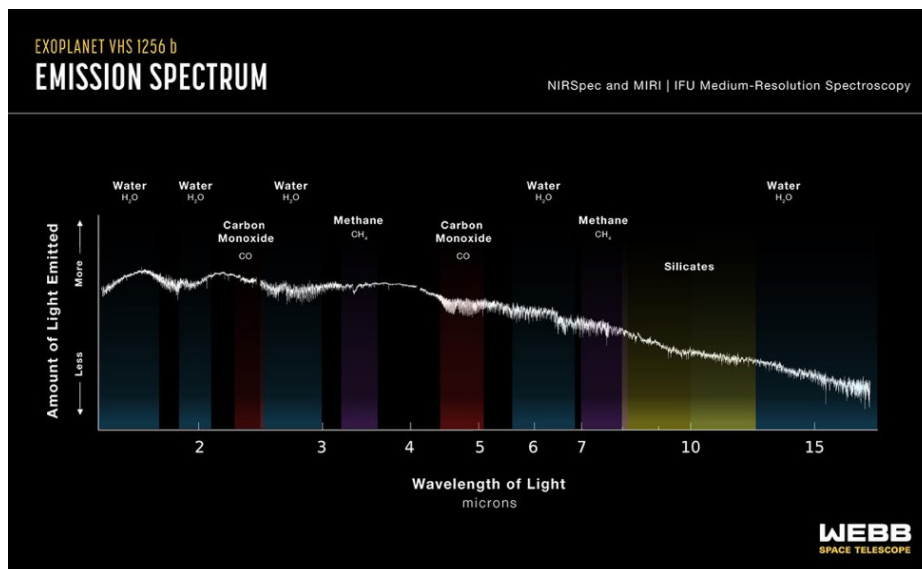
"The larger grains might be more like very hot, very small sand particles."

VHS 1256 b has low gravity compared to more massive [brown dwarfs](#), which means that its silicate clouds can appear and remain higher in its atmosphere where Webb can detect them. Another reason its skies are so turbulent is the planet's age. In astronomical terms, it is quite young. Only 150 million years have passed since it formed, and it will continue to change and cool over billions of years.

In many ways, the team considers these findings to be the first "coins" pulled out of a spectrum that researchers view as a treasure chest of data. They have only begun to identify its contents. "We've identified silicates, but better understanding which grain sizes and shapes match specific types of clouds is going to take a lot of additional work," Miles said. "This is not the final word on this planet — it is the beginning of a large-scale modeling effort to fit Webb's complex data."

Although all the features the team observed have been spotted on other planets elsewhere in the Milky Way by other telescopes, other research teams typically identified only one at a time. "No other telescope has identified so many features at once for a single target," said co-author Andrew Skemer of the University of California, Santa Cruz. "We're seeing a lot of molecules in a single spectrum from Webb that detail the planet's dynamic cloud and weather systems."

The team came to these conclusions by analyzing data known as [spectra](#) gathered by two instruments onboard Webb, the [Near-Infrared Spectrograph](#) (NIRSpec) and the [Mid-Infrared Instrument](#) (MIRI). Since the planet



Instruments onboard the James Webb Space Telescope known as spectrographs, one on its Near Infrared Spectrograph (NIRSpec) and another on its Mid-Infrared Instrument (MIRI), observed planet VHS 1256 b. The resulting spectrum shows signatures of silicate clouds, water, methane, and carbon monoxide. Credit: NASA, ESA, CSA, J. Olmsted (STScI); Science: Brittany Miles (University of Arizona), Sasha Hinkley (University of Exeter), Beth Biller (University of Edinburgh), Andrew Skemer (University of California, Santa Cruz).

orbits at such a great distance from its stars, the researchers were able to observe it directly rather than using the [transit technique](#) or a [coronagraph](#) to take this data.

There will be plenty more to learn about VHS 1256 b in the months and years to come as this team and others continue to sift through Webb's high-resolution infrared data. "There's a huge return on a very modest amount of telescope time," Biller added. "With only a few hours of observations, we have what feels like unending potential for additional discoveries."

What might become of this planet billions of years from now? Since it is so far from its stars, it will become colder over time, and its skies may transition from cloudy to clear.

The researchers observed VHS 1256 b as part of Webb's [Early Release Science program](#), which is designed to help

transform the astronomical community's ability to characterize planets and the disks where they form.

The team's paper, "The JWST Early Release Science Program for Direct Observations of Exoplanetary Systems II: A 1 to 20 Micron Spectrum of the Planetary-Mass Companion VHS 1256-1257 b," was published in [The Astrophysical Journal Letters](#) on March 22.

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

NASA AWARDS MILLIONS TO HISTORICALLY BLACK COLLEGES, UNIVERSITIES

NASA is awarding \$11.7 million to eight Historically Black Colleges and Universities (HBCUs) through the new Data Science Equity, Access, and Priority in Research and Education (DEAP) opportunity. These awards will enable HBCU students and faculty to conduct innovative data science research that contributes to NASA's missions.

Technology advancements in the field of data science, including the growth of artificial intelligence (AI) and machine learning (ML), are poised to significantly impact the work of data scientists and analysts. The awarded projects have up to three years to establish institutes and partnerships to increase the number and research capacity of STEM students at HBCUs, accelerate innovation in a wide range of NASA science, technology, engineering, and mathematic research areas, and prepare the future workforce for data-intensive space-based Earth sciences.

"The increasing use of data science at NASA and beyond really drives home the need for a future workforce with data science knowledge," said Mike Kincaid, associate administrator of NASA's [Office of STEM Engagement](#), which manages MUREP. "With our newest collaboration, NASA created an exciting pathway to find new talent at HBCUs."

The agency's Minority University Research and Education Project (MUREP) and the Science Mission Directorate collaborated on the DEAP opportunity, and selected the following institutions and their proposed projects:

Bethune-Cookman University Inc., Daytona Beach, Florida

NASA MUREP DEAP Institute of Environmental Intelligence for Advanced Space-based Earth Sciences

The project will establish a DEAP Institute focusing on ML-based development of a virtual constellation of satellites that will capture changing water levels, from events such as storm flooding to multi-decadal timescales, such as sea level rise. NASA tracks sea level changes and their causes from space.

Fayetteville State University, Fayetteville, North Carolina

Institute for Multi-agent Perception through Advanced Cyberphysical Technologies (IMPACT)

The IMPACT project will build on existing capacity and collaboration with NASA's Jet Propulsion Laboratory in Southern California, to engage students and faculty in using data science to address scientific questions as one of the key factors to manage NASA's Earth mission research.

Florida A&M University, Tallahassee, Florida

Effects of Gravity on Creeping Salts and Salt Mixtures: Developing Image-based and AI-enhanced Diagnostics for Determining Chemical Compositions



NASA awards 11.7 million to HBCUs to conduct data science research that will contribute to the agency's Science Mission Directorate missions. Credit: NASA/Cory Huston.

This project will rely on AI and ML to better understand the science of concentrated salt solutions and the formation of ring-like deposits called evaporites. Understanding the science of salt concentrations and formation of evaporites will bring new insight into identifying where water may have existed. Water is a critical source NASA researches and explores to better understand other planets' surface geology and the potential future of lunar and martian exploration.

Lincoln University, Jefferson City, Missouri

Using Data Science to Understand Soil, Wildfire, and Social Disparity of Climate Change and Air Pollution

This project aims to provide data science problem-solving, skill development, and professional development of minority and underserved students. Students will utilize existing state-of-the-art ML methods to develop new data analytic approaches to solve some of the core problems in Earth science research.

Morgan State University, Baltimore, Maryland

*Long-Term, High-Resolution Urban
Aerosol Database for Research,
Education, and Outreach*

Through innovative data analysis algorithms, including ML/AI methods, this project will produce a high-resolution, open-access, and user-friendly urban aerosol database focusing on the Baltimore-Washington area. The database will also be used in both classroom teaching and scientific outreach, accompanied by online tools and educational materials bringing new, authentic Earth science education to local schools and communities.

North Carolina Agricultural & Technical State University, Greensboro, North Carolina

*DEAP Institute: Harnessing Data Science
for Flood Monitoring and Management*

Three North Carolina-based HBCUs

will work together on this project developed to harness data science for flood monitoring and management.

North Carolina Central University, Durham, North Carolina

Capacity Building to Support the Machine Learning-Based Detection of Floods and other Natural Hazard Impacts in the Department of Environmental, Earth and Geospatial Sciences at North Carolina Central University

This project will create training, data resources, and opportunities to use ML/AI to identify and measure the impact of flood events and other natural hazards such as earthquakes, hurricanes, drought, wildfires, and more.

Prairie View A&M University, Prairie View, Texas

*DEAP Institute in Research and Education
for Science Translation via Low-
Resource Neural Machine Translation*

This project aims to build an AI-based system that can share interactive, instantaneous, and user-relevant Earth science information, making NASA science more discoverable and accessible to a broad audience.

Administered by OSTEM, MUREP supports and invests in the research, academic, and technology capabilities of Minority Serving Institutions. For more information about NASA's Office of STEM Engagement, visit stem.nasa.gov.

NASA HELPS FUND MINORITY INSTITUTIONS PREPARING STUDENTS FOR COLLEGE



MUREP PSI students constructing a drone during Fayetteville State University's 2022 summer residential experience. Credit: NASA.

High school students from traditionally underrepresented and underserved communities will have a path to pursue careers in STEM with help from NASA.

The agency announced Monday it has selected seven Historically Black Colleges and Universities (HBCUs) and one Predominantly Black Institution (PBI) to receive more than \$3 million in funding to strengthen their support for students in those communities in precollege summer programs around the nation.

[MUREP Precollege Summer Institute](#) (PSIs) uses evidence-based strategies to enhance high school students' precollege performance, prepare them for college entrance, and ultimately help them achieve success in their higher education pursuits and in science, technology, engineering, and math careers.

"This project gives students an opportunity to experience what it's like to live on a college campus, attend classes, and build relationships with professors and

like-minded peers," said Torry Johnson, MUREP project manager. "What makes this program special is that it's tied to NASA research. Students will be participating in engineering design challenges and research related to NASA missions with support from NASA subject matter experts."

The selected institutions and their proposed projects under NASA's MUREP (Minority University Research and Education Project) are:

Albany State University, Georgia

ASU Accelerated Research Training Experience and Mentorship in STEM (ARTEMIS) 2.0 PSI Scholars Program

Albany State University (ASU) proposes a two-week residential camp for students interested in pursuing

a STEM-based career. Using the theme “Mission to Mars,” students will participate in NASA activities related to power generation and transmission, remote and autonomous vehicles and rocket propulsion, the geology of Earth and other planets, and the biology and chemistry of space travel. Students will become immersed in the expectations of life as a STEM student at ASU, gain useful knowledge about the campus, and build support networks to help ensure success in their life and in academics. ASU was awarded \$425,000 for its proposal.

Clayton State University, Morrow, Georgia

Artificial Intelligence Study in Earth Exploration Summer Academy

Clayton State University proposes to host a NASA-themed summer program for minority high school students. This program will provide an eight-day summer residential STEM camp that exposes participants to college life, NASA research, Earth data, and artificial intelligence (AI). Participants will gain an understanding of NASA’s missions and learn how to apply AI technology to solve real-world problems in Earth science. Clayton State University was awarded \$425,000 for its proposal.

Fayetteville State University, North Carolina

Fayetteville State University’s NASA MUREP Precollege Summer Institute: Cutting-Edge Technologies for Examining Climate Change (FSU-CTECC)

Fayetteville State University (FSU) proposes two-week-long residential summer STEM camps over the five-year period of the project. Each year, 20 high school students will be recruited from high schools in Cumberland County and its surrounding counties in North Carolina. Project partners include NASA’s Jet Propulsion Laboratory, NASA’s Goddard Space Flight Center, and multiple academic organizations and industries to provide STEM workshops for the students. FSU was awarded \$423,487 for its proposal.

Lincoln University, Jefferson City, Missouri

Digital Agriculture, Data Science, and Robotics: Applied Research and Training for Enhancing Motivation in Science (DDR-ARTEMIS)

In collaboration with the University of Missouri, Lincoln University proposed two identical and intensive nine-day residential summer camps designed to offer keys for success for the participating students to advance their careers in STEM fields as undergraduate students and beyond. Each summer camp will accommodate 12 students for a total of 24 students each year. The educational program will provide hands-on experience for underrepresented minority students in digital agriculture, data science, and robotics to develop a broad understanding of STEM careers along with professional development activities and interaction with STEM professionals and entrepreneurs. Lincoln University was awarded \$424,403 for its proposal.

Meharry Medical College, Nashville, Tennessee

Collaborative Interactive Data Science Academy

With the goal to stimulate curiosity in the cross-cutting field of data science and emerging technologies, Meharry Medical College proposed a discovery-based summer experience that implements virtual reality, augmented reality, and mixed reality control of robotic systems using NASA geospatial and extraterrestrial big data. This summer program will expose high school students to NASA research and data science tools; build statistical and critical thinking skills; and inspire the next generation of explorers, researchers, and data scientists. Meharry Medical College was awarded \$418,448 for its proposal.

Tuskegee University, Alabama

Tuskegee’s Summer Institute for Increasing Diversity Among Incoming STEM Undergraduates

The focus of Tuskegee’s Summer Institute is to prepare students for college and retain students in biology, chemistry, physics,

and mathematics. The project will equip prospective college students with the basic skills necessary for success in college and close the STEM education gap for students from underserved communities. Tuskegee was awarded \$424,939 for its proposal.

University of Maryland Eastern Shore, Princess Anne

HAWKS MUREP Precollege Summer Institute (PSI)

The University of Maryland, Eastern Shore (UMES) proposes to establish a two-week residential program designed to increase the participation and retention of historically underserved and underrepresented high school students in STEM. Learning activities are aligned to NASA’s themes of space exploration, aeronautics, and Earth science. Students will have the opportunity to visit NASA’s Goddard Space Flight Center. UMES partnered with NASA’s Wallops Flight Facility for mentoring, job shadowing, and involvement in real-life STEM projects, research, and activities. UMES was awarded \$425,000 for its proposal.

University of The Virgin Islands, Charlotte Amalie

The NASA-UVI Pre-College Engineering Summer Institute

The focus of this proposal is to enroll a minimum of 20 students from the public high schools on St. Thomas and St. Croix in a one-week summer residential experience on-campus at the University of the Virgin Islands (UVI). Students will be exposed to the fundamentals of scientific and engineering methods, engage in discussions about career paths, develop relationships with STEM professionals in the U.S. Virgin Islands and NASA, and engage in professional development activities designed to help them prepare for a successful transition to college. UVI was awarded \$424,998 for its proposal.

Administered by NASA’s Office of STEM Engagement, MUREP supports and invests in the research, academic, and technology capabilities of minority-serving institutions. Learn more at stem.nasa.gov.

NASA NAMES TWO DIVERSITY CHAMPIONS FOR AGENCY



Pictured left to right: NASA's Stephen Shih and Elaine Ho. Credit: NASA.

NASA Administrator Bill Nelson announced Monday he is taking additional steps forward to advance diversity, equity, inclusion, and accessibility (DEIA) at the agency. Nelson named Steve Shih to serve in a new position as the agency's first Diversity Ambassador and selected Elaine Ho as the next associate administrator for the Office of Diversity and Equal Opportunity at NASA Headquarters in Washington, effective immediately.

"Now, more than ever, NASA is leading all of humanity on an unprecedented journey of discovery, exploration, and innovation," Nelson said. "To be successful in our missions, diversity, equity, inclusion, and accessibility must continue to be at the forefront. Steve and Elaine's leadership

will help NASA continue to ensure our workforce reflects all of America and to inspire partners throughout our nation — for the benefit of all humanity."

As diversity ambassador, Shih will further NASA's DEIA initiatives by building key strategic alliances with external partners, enabling NASA

to continue being a model agency and leader for DEIA. In this role, Shih will engage NASA's partners — including across the government, private sector, academia, and non-governmental organizations — to learn and promote best practices for NASA to recruit, hire, engage, and retain the most talented individuals from all backgrounds and life experiences. With his experience leading the Office of Diversity and Equal Opportunity since 2017, Shih will build on his three decades of federal expertise and help NASA continue to enable everyone to contribute inclusively to NASA and to the U.S.

As Shih transitions to the role of diversity ambassador, Ho will bring extensive DEIA expertise to the Office of Diversity

and Equal Opportunity. She most recently has served as the deputy associate administrator for NASA's Office of STEM Engagement, leading a wide-ranging portfolio of projects benefiting students, universities, and educational institutions across the country to inspire, engage, and educate the Artemis Generation.

Ho previously served as the chief diversity officer for the Department of Agriculture and Internal Revenue Service, as well as currently serving as a senior advisor for DEIA as a colonel in the Air Force Reserve. Ho also has held several leadership roles in the White House, including senior policy advisor for former First Lady Michelle Obama's Let Girls Learn initiative, chief of staff of the U.S. Digital Service, and deputy chief of staff in the Office of Science and Technology Policy. She recently returned to NASA from the Office of the Vice President's National Space Council, where she served as director of space STEM policy.

Learn more about NASA's Office of Diversity and Equal Opportunity at www.nasa.gov/offices/odeo/home.

LPI-LED PLANETARY REACH PROJECT TO CONDUCT SIX CULTURALLY INCLUSIVE PLANETARY ENGAGEMENT WORKSHOPS IN 2023

Planetary scientists and astrobiologists (including graduate students, post-doctoral researchers, engineers, and technicians) and informal (out-of-school-time) educators are invited to apply to attend a 2023 Culturally Inclusive Planetary Engagement professional

development workshop. During these workshops, scientists and educators are paired together and supported in bidirectional conversations around diversity and inclusion in engaging Black and Latinx audiences in planetary science.

Workshop participants will:

- Explore the importance of building equitable partnerships with organizations, subject matter experts, and informal educators serving Black and Latinx audiences



- Learn evidence-based culturally relevant authentic approaches to nurture connections with Black and Latinx individuals
- Practice planetary science engagement approaches through a culturally inclusive lens

Following the workshop, participants lead hands-on activities during a public engagement event held in collaboration with a local youth-serving organization. In 2023, workshops will be conducted in six locations:

Tulane University, New Orleans, Louisiana (June 8–10, 2023)

- [More Information](#)
- [Apply Now](#)

SETI Institute, Mountain View, California (June 22–24, 2023)

- [More Information](#)
- [Apply Now](#)

Pérez Art Museum Miami, Miami, Florida (August 17–19, 2023)

- [More Information](#)
- [Apply Now](#)

American Museum of Natural History, New York, New York (September TBD)

Boulder, Colorado (September/October TBD)

Puerto Rico (November 2–4, 2023)

More workshop information and links to applications are available on the

[Planetary ReaCH website](#). Space in each workshop is limited to 10 planetary scientists/astrobiologists and 10 informal educators. Stipends are available for participants able to accept them.

Please direct questions to Andy Shaner at shaner@lpi.usra.edu.

For more information, visit www.lpi.usra.edu/planetary-reach/.

Planetary Resources and Content Heroes (ReaCH) is led by the Lunar and Planetary Institute with multiple collaborating institutes and is composed of a diverse team of scientists, educators, evaluators, and diversity experts. ReaCH is supported by NASA under cooperative agreement award number 80NSSC21M0003 within NASA SMD's Science Activation portfolio.

HONORING BLACK ASTRONAUTS DURING BLACK HISTORY MONTH 2023

In honor of Black History Month, NASA recognized the contributions of Black astronauts to our nation's space programs. Coming to NASA from a variety of backgrounds as military pilots,

engineers, scientists, and physicians, these astronauts have made history-making contributions participating in space shuttle missions to perform critical tasks such as deploying and retrieving

satellites, performing spacewalks, conducting science and technology research, and piloting and commanding space shuttle missions. More recently, Black astronauts have played key roles in

the assembly of the International Space Station, performing numerous spacewalks and robotic operations, and conducting research as expedition crewmembers.

Several have distinguished themselves as senior leaders at NASA, including as the agency's administrator.

Learn more about the history of Black astronauts at www.nasa.gov/feature/honoring-black-astronauts-during-black-history-month-2023.

Astronaut	Year of First Flight	Missions	Days in Space
Arnaldo Tamayo Méndez	1980	Soyuz 38/Salyut-6	8
Guion S. Bluford	1983	STS-8; STS-61A; STS-39; STS-53	29
Ronald E. McNair	1984	STS-41B; STS-51L	8
Frederick D. Gregory	1985	STS-51B; STS-33; STS-44	19
Charles F. Bolden	1986	STS-61C; STS-31; STS-45; STS-60	28
Mae C. Jemison	1992	STS-47	8
Bernard A. Harris	1993	STS-55; STS-63	18
Winston E. Scott	1996	STS-72; STS-87	25
Robert L. Curbeam	1997	STS-85; STS-98/ISS; STS-116/ISS	38
Michael P. Anderson	1998	STS-89/Mir; STS-107	25
Stephanie D. Wilson	2006	STS-121/ISS; STS-120/ISS; STS-131/ISS	43
Joan E. Higginbotham	2006	STS-116/ISS	13
B. Alvin Drew	2007	STS-118/ISS; STS-133/ISS	26
Leland D. Melvin	2008	STS-122/ISS; STS-129/ISS	24
Robert L. Satcher	2009	STS-129/ISS	11
Victor J. Glover	2020-2021	Crew Dragon Crew-1/ISS Exp 64/65	167
Sian H. Proctor	2021	Inspiration4	3
Jessica A. Watkins	2022	Crew Dragon Crew-4/ISS Exp 67/68	171

List of Black astronauts who have flown in space.

WOMEN'S HISTORY MONTH 2023: Celebrating Women Astronauts



The five women selected for training to be the first woman in space, Soviet cosmonaut-candidates Valentina L. Ponomareva, left, Tatiana D. Kuznetsova, Irina B. Soloveva, Valentina V. Tereshkova, and Zhanna D. Yorkina, with an unidentified woman at far right.

"A bird cannot fly with one wing only. Human space flight cannot develop any further without the active participation of women." — Valentina Tereshkova

"If we want scientists and engineers in the future, we should be cultivating the girls as much as the boys." — Sally Ride

"International cooperation is very necessary. Chinese have a saying, 'When all the people collect the wood, you will make a great fire.'" — Liu Yang

As of March 2023, 72 women have flown in space. Of these, 44 have worked on the International Space Station as long-duration expedition crewmembers, as visitors on space shuttle assembly flights, or as space flight participants on short-duration missions. NASA recognizes the significant accomplishments of these

women from many nations as well as the pioneering women who preceded them into space. Many other women contributed to the assembly of the station and the research conducted onboard on a daily basis, including those on the ground who served as center directors, managers, flight directors, and in many other roles to pursue the exploration of space. Their achievements will contribute to NASA's efforts to land the first woman and the first person of color on the Moon and possibly send the first crews to Mars in the coming decades. For the full article, visit www.nasa.gov/feature/womens-history-month-2023-celebrating-women-astronauts.

BEING BLACK IN STEM:

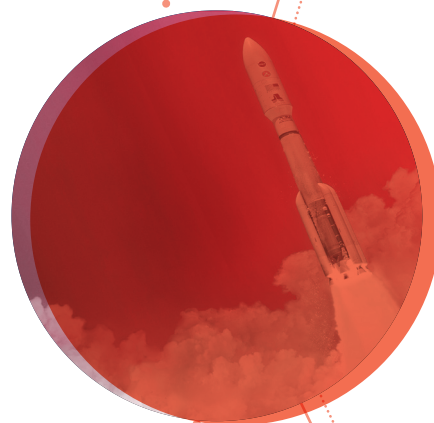
Facing the Barriers Head-On



The Pride in STEM podcast is back for its second season. In this episode, Craig Poku (he/they) is joined by Kemi Oloyede (they/them), and they talk about their career journey, the barriers faced by Black scientists engaging in STEM, and how they have used creativity

to address these barriers. See more of Kemi's work at www.kxmolo.com/.

Listen to the full episode of the Pride in STEM Podcast on [Apple Podcast](#), [Google Podcast](#), and [Spotify](#).



"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.

MEETING HIGHLIGHTS



The annual 13th Planetary Crater Consortium (PCC) Meeting was held as a hybrid meeting from Wednesday through Friday, August 10–12, 2022. The meeting was convened by the Planetary Crater Consortium, with logistics shared between the Lunar and Planetary Institute, Southwest Research Institute (SwRI), and Ursinus College. A total of 126 individuals were registered, with more than 48 active participants at any given time (including up to 23 in-person) spanning time zones from central Europe to Hawai'i.

The PCC annual meeting is open to all planetary and terrestrial scientists interested in any aspect of impact cratering on solar system bodies, including observational, theoretical, experimental, and numerical modeling studies of impact craters on planets, dwarf planets, moons, asteroids, comets, or other small solar system objects. The annual meeting is designed to encourage and provide adequate time for an in-depth discussion of crater-related issues and research topics to enhance collaborations. A primary

goal of the meeting is to provide feedback on works in progress in a relaxed and friendly environment, discuss potential new avenues of collaborative crater research, and present new work and applications of impact crater studies and related topics. As such, most talks had longer, 30-minute slots, and discussion times were set aside in the schedule every day.

The scientific program consisted of 22 talks spanning five different topical sessions: Lunar craters, martian craters, laboratory and modeling experiments, lightning session, and icy bodies. The new lightning session — introduced last year — was designed to give some speakers shorter talks while still fitting them into the schedule, and it continued to be well received. For more information about the meeting, including the program and abstracts, visit the meeting website at www.hou.usra.edu/meetings/crater2022/.

Under the PCC Charter, the PCC annual meeting also contains several business items, including committee reports and the election of a new PCC Council member (Veronica Bray, University of Arizona) to replace one of three who rotate off each year (this year, Jamie D. Riggs, Thomas Jefferson University). The PCC Executive Council agreed to extend the previous year's documentarian by one year (Rachael H. Hoover, SwRI). The role of the non-voting documentarian is to



In-person attendees at the 13th Planetary Crater Consortium Meeting in Boulder, Colorado.

provide documentation of PCC meetings and Executive Council meetings, and to give an early-career person (typically pre-Ph.D.) experience being in the leadership of a professional society.

The annual PCC meeting was a success, thanks to the hard work of the conveners, the organizers, and hosts, and we look forward to the 14th meeting. As of the time of this writing (February 2023),

we have confirmed that our 14th PCC meeting will return to our original home at the U.S. Geological Survey in Flagstaff, Arizona, in August 2023. It will have a hybrid/virtual component as well.

— Text provided by Stuart J. Robbins, Southwest Research Institute



The 2022 Lunar Exploration Analysis Group (LEAG) Annual Meeting was held August 23–25, 2022, at the Johns Hopkins University Applied Physics Lab in Laurel, Maryland, with the option to participate virtually. LEAG was established in 2004 to support NASA in providing analysis of scientific, technical, commercial, and operational issues supporting lunar exploration objectives and their implications for lunar architecture planning and activity prioritization.

Over 300 in-person and virtual attendees participated in the meeting from across the U.S. and internationally. The meeting featured invited updates on several topics including the Portable Remote Imaging SpectroMeter (PRISM), Artemis, the Apollo Next Generation Sample Analysis Program (ANGSA), the Lunar Discovery and Exploration Program (LDEP), Commercial Lunar Payload Services (CLPS), NASA Headquarters, international agencies, and community diversity, equity, inclusion, and accessibility (DEIA) efforts.

The meeting hosted several contributed sessions, focusing on highlights discussing sample analysis, lunar resources,

instrumentation and payloads, lunar exploration infrastructure, and mission updates and concepts. The meeting also hosted a group brainstorming discussion activity to discuss science themes for lunar exploration from the Decadal Survey. LEAG Service Awards were given to Dr. Carle Pieters and Dr. Jeffrey Taylor to recognize their exemplary service to LEAG and the entire lunar science and exploration community.

The meeting also engaged and showcased the early-career lunar community by providing travel awards to 16 early-career researchers, including the Larry Taylor Travel Award, three B. Ray Hawke Career Development Awards (sponsored by the Solar System Exploration Research Virtual Institute, or SSERVI), and 13 Analysis/Assessment Group (AG) travel grants (provided by NASA). The meeting also included a featured early-career presentation given by Ph.D. student Nandita Kumari and a mentoring program that paired early-career participants with more senior members of the LEAG Executive Committee (ExComm) and the broader lunar community. The meeting also included networking opportunities

for in-person participants via a coffee hour meet-and-greet with the LEAG ExComm and a welcome reception.

Findings were drafted at the meeting and sent to the LEAG community for input, resulting in six actionable findings regarding (1) development of the Integrated Lunar Strategy; (2) the importance of sample return from the South Pole-Aitken Basin; (3) engagement of the Commercial Advisory Board (CAB) with the CLPS providers; (4) plans for post-Artemis III exploration; (5) the need for a joint Specific Action Team with the Extraterrestrial Materials Analysis Group (ExMAG) regarding needs for lunar sample return; and (6) the need for a joint Specific Action Team with the Mapping and Planetary Spatial Infrastructure Team (MAPSIT) for data management and archiving approaches. Finalized findings are available on the meeting website.

To view the program, abstracts, recorded presentations, and findings, visit the workshop website at www.hou.usra.edu/meetings/leag2022/.

— Text provided by Erica Jawin, National Air and Space Museum/Smithsonian Institution

OPPORTUNITIES FOR STUDENTS

INTERNSHIPS AND TRAINING PROGRAMS

PH.D. POSITIONS IN SPACE PHYSICS AT UMEÅ UNIVERSITY

The Department of Physics at Umeå University in Sweden offers two Ph.D. positions in space physics. One project focuses on studying terrestrial magnetosheath jets with Associate Professor Maria Hamrin. The other project is

modeling magnetosphere-interior coupling at Mercury with Dr. Shahab Fatemi. The deadline to apply to either position is April 15, 2023. Visit [open positions](#) to learn more.

ESA ARCHIVAL RESEARCH VISITOR PROGRAM

To increase the scientific return from its space science missions, the European Space Agency (ESA) welcomes applications from Ph.D. students and scientists interested in pursuing

research projects based on data publicly available in the ESA Space Science Archives. The deadline to apply is April 30, 2023. Visit [Archival Research Visitor Program](#) to learn more.

NASA SUMMER SCHOOL ON SATELLITE OBSERVATIONS AND CLIMATE MODELS

Join the Jet Propulsion Laboratory's Center for Climate Sciences and the Keck Institute for Space Studies for NASA's Summer School on using satellite observations to advance climate models. Each year the Center for Climate Sciences brings together

the next generation of climate scientists — approximately 25 graduate students and postdocs from around the world — to engage with premier climate scientists. The deadline to apply is May 1, 2023. Visit [Center for Climate Sciences](#) to learn more.

OFFICE OF SCIENCE GRADUATE STUDENT RESEARCH (SCGSR) PROGRAM

The SCGSR program provides supplemental funds for graduate students to conduct part of their thesis research at a host Department of Energy (DOE) laboratory/facility in collaboration with a DOE laboratory scientist during a 3- to 12-month award period. The opportunity is expected

to advance the graduate students' research projects by providing access to the expertise, resources, and capabilities available at the DOE laboratories/facilities. The deadline to apply is May 3, 2023. Visit [SCGSR](#) to learn more.

FIELD TRAINING AND RESEARCH PROGRAM IN THE SAN FRANCISCO VOLCANIC FIELD

The Field Training and Research Program in the San Francisco Volcanic Field, near Flagstaff, Arizona, is a week-long field class and research project in the sites used to train astronauts and used by NASA for lunar mission simulations. The program will provide

students with an opportunity to assist with a research project in the volcanic field. The next edition of this field course will be September 23-30, 2023. Applications close on June 5, 2023. Visit [Center for Lunar Science and Exploration](#) 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 deadline to apply is June 16, 2023. Visit [Dragonfly Student & Early Career Investigator Program](#) to learn more.

SCHOLARSHIPS AND FELLOWSHIPS

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 atmospheric and space science, geophysics, petrology and geochemistry, and more. Visit [AGU Travel and Research Grants](#) to learn more.

2023 BLACK IN ASTRO TRAVEL GRANTS

The 2023 Black In Astro Travel Grants were developed to support traditionally marginalized students in the space sciences. Black In Astro will be supporting six travel grants of \$500 each to support travel, registration, and lodging expenses for a space-related workshop, conference, or winter/summer

school of the recipient's choice. Applicants must be enrolled in an accredited university in the United States in either a Master's or Ph.D. program. The deadline to apply is May 1, 2023. Visit [2023 Black In Astro Travel Grants](#) to learn more.

EXPANDING REPRESENTATION IN GEOSCIENCES SCHOLARSHIP

The goal of Geological Society of America's Expanding Representation in Geosciences (ERG) Scholarship is to foster the success of diverse students and to encourage

their persistence in the society as members, role models, and future leaders in the geosciences. The deadline to apply is May 31, 2023. Visit [GSA](#) to learn more.

ON TO THE FUTURE (OTF) PROGRAM

The Geological Society of America's On To the Future (OTF) program supports students from diverse communities to attend the annual geoscience meeting, GSA Connects, by offering partial travel funding if attending in-person, full or online meeting

registration, one-year membership, mentorship, and special sessions with leadership during the meeting. The deadline to apply is May 31, 2023. Visit [On To the Future](#) 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](#)

[JHU APL Doctoral Level Opportunities](#)

[Center for Astrophysics Fellowships and Visiting Scientist Positions](#)

[Smithsonian Institution Fellowship Program](#)

[SwRI Postdoctoral Positions](#)

[U.S. National Labs Postdoctoral Positions](#)

[AGU Job Board Postdoctoral Positions](#)

[LIGO Postdoctoral Positions](#)

SPOTLIGHT ON EDUCATION

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](#).



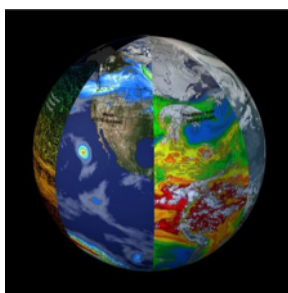
NASA ANNOUNCES FIRST ARTEMIS CREW

On April 3, 2023, NASA and the Canadian Space Agency (CSA) announced the four astronauts who will venture to the Moon on Artemis II, the first crewed mission through NASA's Artemis

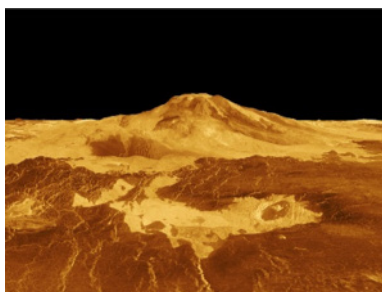
program. NASA astronauts Christina Hammock Koch, Reid Wiseman, Victor Glover, and CSA astronaut Jeremy Hansen will be the first astronauts to return to orbit around the Moon in more than 50 years. Visit the [Artemis II Crew](#) to learn more.

EARTH DAY CELEBRATIONS

Connect audiences to new perspectives, exciting innovations, and inspiring stories from NASA's continued efforts to explore space and understand our place in the universe. Visit Earth Day lessons and activities from NASA/JPL. Visit NASA Citizen Science to explore ways to contribute to NASA Earth Science.



NEW FINDINGS REVEAL VOLCANISM ON VENUS



Maat Mons is displayed in this computer generated three-dimensional perspective of the surface of Venus. This NASA Magellan image was released on April 22, 1992. Using decades-old data collected

by NASA's Magellan mission, scientists have detected a recent volcanic eruption on Venus' surface, confirming – for the first time – that it is a geologically active planet. This discovery adds to the excitement around NASA's upcoming missions to Venus, [VERITAS](#) and [DAVINCI](#), which are slated to launch in the next decade. View the [news release](#) to learn more about the discovery and its implications.

OPPORTUNITIES AND RESOURCES FOR STEM OUTREACH AND PROFESSIONAL DEVELOPMENT



CULTURALLY INCLUSIVE PLANETARY ENGAGEMENT: WORKSHOPS IN 2023

Planetary scientists and astrobiologists (including graduate students, postdoctoral researchers, engineers, and

technicians) and informal (out-of-school time) educators are invited to apply to attend a 2023 Culturally Inclusive Planetary Engagement professional development workshop organized by the LPI. During these workshops, scientists and educators are paired together and supported in bi-directional conversations around diversity and inclusion in engaging Black and Latinx audiences in planetary science. Visit [2023 Culturally Inclusive Planetary Engagement Workshops](#) to learn more.



SCIENTISTS IN PARKS

The Scientists in Parks Program seeks motivated applicants to complete numerous exciting projects in America's national parks. The program is committed to providing all aspiring professionals, especially those underrepresented in science, with a unique opportunity to work

on important real-world projects while building professional experience and a lifelong connection to America's national parks. The next application period will open in May 2023 for positions starting between October 2023 and April 2024. Visit [current positions](#) to learn more.

CITIZEN SCIENCE "DARK ENERGY EXPLORERS" PROJECT

Dark Energy Explorers | Science Mission Directorate Dark energy makes the whole universe expand faster and faster. But what causes this spectacular process? The [Dark](#)



[Energy Explorers](#) project needs the help of citizen scientists to solve this puzzle. You and your audiences can help by looking through images of distant galaxies and other data to help build a map of the universe, focusing on regions about 10 billion light-years away. Visit [Dark Energy Explorers](#) to learn more.



BECOME A GLOBE SCIENTIST

Precipitation Education GLOBE is a worldwide science and education program supported by NASA, NSF, and NOAA that connects students, teachers,

and STEM professionals to advance the understanding of Earth as a system. The GLOBE International STEM Network (GISN) is the bridge connecting the researchers of today with those of tomorrow. GISN scientists promote Earth science in schools, act as mentors, or volunteer to form meaningful relationships with students and teachers. Visit [GISN](#) 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.



Credit: USRA.

ALEXANDER J. DESSLER

1928–2023

Pioneering space scientist Alexander Dessler, who taught at Rice University for 30 years after founding the first university department dedicated to the study of space science at the height of the U.S.-Soviet space race, died April 9 at age 94 in Bryan, Texas.

Dessler was an esteemed member of the scientific community and had a long and distinguished career in space science. Among his awards was the Arctowski Medal of the U.S. National Academy of Sciences, with the citation “For his notable imagination in framing many of space sciences most basic conceptions about the solar wind and interplanetary magnetic field and their interactions with the magnetospheres of Earth and other planets at the beginning of the Space Age.”

Dessler received a B.S. in physics from the California Institute of Technology in 1952 and a Ph.D. in Physics from Duke University in 1956. He began his career at Lockheed Missiles and Space Company. In 1963, while at the Southwest Center for Advanced Studies, now the University of Texas at Dallas, he was recruited by Rice University president Kenneth S. Pitzer to

found the world’s first university space science department as a response to President John F. Kennedy’s Moon speech, delivered at Rice on September 12, 1962. The Space Science Department at Rice was the first truly multidisciplinary department at the university, bringing together astronomy, atmospheric science space physics, planetary science, and atomic and molecular physics.

Dessler was an emeritus professor of Space Physics and Astronomy at Rice University, active from 1963 to 1992. During his years at Rice, he also served as the second president of the Universities Space Research Association (USRA) from 1976 to 1981 and as chair of the USRA Council of Institutions from 1975 to 1976. During his tenure at USRA, he championed groundbreaking research in a wide range of space science disciplines. Dessler made lasting contributions to the study of the magnetic fields of the Sun, Earth, and other planets, and to the study of the “solar wind” of charged particles that stream from the Sun and dominate a region of space far beyond the orbit of Pluto. He introduced the concept of this Sun-dominated region of space and coined its name, “heliosphere.”

Dessler served three terms as chair of the Space Science Department and retired in 1992. His educational innovations included the use of Keller-method inquiry-based self-paced instruction starting in 1970, and he was

instrumental in encouraging women and minorities to participate in science.

In 1993, Dessler was a Senior Research Scientist at the Lunar and Planetary Laboratory, University of Arizona, until retiring from that position in 2007. He then served as an adjunct professor of Space Physics at Texas A&M University.

One of Dessler’s major contributions to USRA was the development of its organizational structure, moving the headquarters from Texas to the Washington, DC area and initiating the use of science councils for each program or institute. He also formed a task force on microgravity materials research, recommending that NASA begin research in this new field. After NASA implemented Dessler’s recommendation, he established a new USRA program in microgravity science in support of NASA Headquarters. USRA also began work in the atmospheric sciences during his tenure.

“Alex will be remembered for his unwavering dedication and tireless efforts to advance space science research,” said Dr. Jeffrey Isaacson, President and CEO of USRA. “His legacy is a testament to the numerous contributions he made to that field and to USRA.”

— Portions of text courtesy of USRA and Rice University



Credit: Arizona State University.

JACK FARMER

1947–2023

and Aeronautics, Committee on Science, House of Representatives, One Hundred Seventh Congress.

Farmer was instrumental in promoting the exploration for a martian fossil record and in the selection of the

landing sites for Mars Pathfinder and the Mars Exploration Rovers. He served on the science definition teams for the Mars Odyssey and Mars Reconnaissance Orbiter missions, was a participating scientist on the Mars Exploration Rover mission, and was a member of the CheMin instrument team on the Mars Science Laboratory mission, which landed at Gale Crater on Mars on August 6, 2012.

Farmer served as a past director of ASU's NASA-funded Astrobiology Program. He was a charter member of the Executive Council of NASA's Astrobiology Institute (NAI) from 1998 to 2003 and chairperson of the NAI Mars Focus Group (2000–2003) and of the community-based Mars Exploration Program Analysis Group (MEPAG) in 2003. He was also an active member of the Geological Society of America (GSA) and was co-founder and past chairperson for GSA's Geobiology/Geomicrobiology Division and a recipient of the Division's 2012 Award for Outstanding Contributions to the fields of Geobiology and Geomicrobiology. He was a Sequoyah Fellow of the American Indian Science and Engineering Society (AISES) and an Associate Editor of the journals *Astrobiology* and the *International Astrobiology Journal*.

Farmer was also a past member of NASA's Space Sciences Advisory Committee and served on several National Research Council (NRC) boards and committees, including the Space Studies Board (SSB), the Committee to Review the NASA Astrobiology Institute, the Committee for the Review of the NASA Science Mission Directorate Science Plan, and the Committee on an Assessment of Balance in NASA's Science Programs. He recently chaired the NRC SSB's Committee on the Review of Planetary Protection Requirements for the Mars Sample Return Missions Space Studies Board, Division on Engineering and Physical Sciences of the National Research Council.

Farmer was part Native American (Chickasaw and Cherokee) and proudly engaged with tribal communities. Wearing his "Dr. Rock" name badge, he did not hesitate to share his passion for the beauty of geology in many public outreach efforts over the years. He was also a kind and empathetic mentor, always striving to help guide his students toward excellence and opening up opportunities for them to get involved in exciting mission-based, field, and lab projects. He had a deep passion for exploring varied field environments, collecting samples in situ that could be studied in the lab, and instilling in his students an understanding of their contextual environment.

A kind, patient man who left a positive impact in his community, Farmer will be remembered fondly as a compassionate and skilled scientist whose legacy will live on in his students and colleagues.

Jack "Dr. Rock" Farmer, former professor of geobiology in the School of Earth and Space Exploration at Arizona State University (ASU), passed away on February 22, 2023. His research interests included biological mediation of sedimentary processes, the microbial fossil record of the Precambrian biosphere, and the origin and early evolution of animals.

Farmer's career spanned nearly 50 years as a paleontologist and an astrobiologist, and he helped pioneer the field of exopaleontology. Throughout his career, he played crucial roles in contributing to the development of NASA's exploration strategies, particularly in the search for fossil biosignatures on Mars. Much of his research focused on understanding the factors that control biosignature preservation and how this knowledge can be translated into strategies for the search for evidence of past life on the Precambrian Earth or other planets, like Mars.

Prior to joining the faculty at ASU, Farmer was on the faculty of the Department of Earth and Space Exploration at UCLA (1986–1991) and a research scientist in the Exobiology Branch of NASA's Ames Research Center (1991–1998). In 2001, he testified on "Life in the Universe" before the Subcommittee on Space

— Portions of text courtesy of Arizona State University and colleagues Charlene Estrada, Marisol Juarez Rivera, Jon Lima-Zaloumis, Jorge Nunez, Svetlana Shkolyar, and Kathleen Campbell



Credit: Photo courtesy of J. Wardarski/The State Press.

CARLETON B. MOORE

1932–2023

Carleton Bryant Moore, Emeritus Regents Professor in the School of Molecular Sciences and the School of Earth and Space Exploration (SESE) at Arizona State University (ASU), passed away on Friday, February 10, 2023, at the age of 90 in Mesa, Arizona.

Moore was a pioneering researcher in the field of meteorite studies and the founding Director of the ASU Center for Meteorite Studies, which houses the world's largest university-based meteorite collection. He helped train the NASA Apollo astronauts who were candidates for missions to the Moon on what type of samples to collect while on the Moon. He was credited with being the first scientist to detect the different types of carbon in the returned lunar samples. Moore and his team measured the carbon contents of the returned Apollo 12, 14, 15, 16, and 17 samples in the Lunar Receiving Laboratory in Houston. He was also one of the researchers who identified the first extraterrestrial amino acids in freshly fallen meteorites. For his contribution to meteorite research, the International Astronomical Union named an asteroid, 5046 Carletonmoore, in his honor. In addition, a mineral, carletonmooreite, was named for him in 2021.

Moore was born September 1, 1932, in New York City and grew up in Hempstead, New York, on Long Island. He was educated at Hempstead Public

Schools, graduating in 1951. He then attended Alfred University in Alfred, New York, where he studied ceramic engineering and received a B.S. degree in Glass Technology from the New York State College of Ceramics. Shortly after, Moore started work at Brookhaven National Laboratory with Oliver Schaeffer and Nobel Laureate Raymond Davis in the summer of 1955 on a project using cosmic-ray exposure to determine rock ages before beginning his graduate studies at the California Institute of Technology (Caltech) in Pasadena, California. At Caltech, Moore's graduate studies were primarily in chemistry but also included a minor in geology under the direction of thesis advisor Harrison Brown, during which time he first studied meteorite chemistry. He completed his Ph.D. in Chemistry in 1960. His first position was at Wesleyan University in Middleton, Connecticut, where he taught from 1960 to 1961.

Moore was contacted by ASU in 1961 to become the founding director of the university's Center for Meteorite Studies in the Department of Chemistry. ASU had just acquired the large meteorite collection from Harvey Nininger, and Moore was put in charge of expanding the collection and conducting research on its unique extraterrestrial samples.

Moore authored 160 publications on meteorite research and a frequently

cited article on the removal of arsenic from water. He also held a patent for an artificial desert varnish that helped mend vandalism to petroglyphs and excavation scars along highways. From 1963 to 1987, Moore acquired 35 research grants from NASA, The National Science Foundation (NSF), and the United States Geological Survey (USGS) related to the study of asteroids, lunar samples, geology, and materials science. Moore's work provided the foundation for the continued development of the Center for Meteorite Studies as well as the growth of astrophysics and planetary geology at ASU.

Moore spent considerable time at NASA's Johnson Space Center performing carbon analysis on the returned lunar samples and assisting with the development of the lunar and meteorite educational disk project, in which lunar and meteorite samples are available for study by students in classrooms throughout the world. In 1969, Moore became editor of the journal *Meteoritics*, a position he held for 20 years as a member, fellow, and president of the Meteoritical Society. In 1984, during Moore's leadership, *Meteoritics* won the Citation Index Impact Award.

Moore also taught thousands of undergraduates in chemistry and geology during his 44-year career at ASU and was particularly proud of

having served as the thesis advisor to 36 M.S. and Ph.D. graduate students during his tenure. In 2003, he retired from ASU and became a member of ASU's Emeritus College. He had served as the director for the Center for Meteorite Studies for 42 years, continuously holding the same administrative position his entire career. Under his leadership, the Center for Meteorite Studies increased its meteorite holdings from 578 specimens

to over 1700 samples, creating a valuable resource for researchers and students at ASU and around the world.

Moore was also passionate about supporting environmental causes, including the Boyce Thompson Arboretum, Arizona and Vermont chapters of The Nature Conservancy, and Audubon Arizona. He had recently received his 50-year membership certificate

from the Sierra Club. He especially enjoyed spending summers in Estes Park, Colorado, with his family, exploring "every single boulder and rock" in Rocky Mountain National Park. In addition, he liked sharing his interest in meteorites with local elementary school students and would randomly surprise children by gifting them tiny meteorites as they walked past.

— Text courtesy of *The Arizona Republic*



Credit: Museum für Naturkunde.

DIETER STÖFFLER

1940–2023

It is with profound sadness that we have to report that our dear friend, mentor, and colleague Dieter Stöffler passed away on the evening of Wednesday, April 5, 2023. Stöffler had retired from the Museum für Naturkunde in Berlin in 2004 but remained very active in research and contributed to postgraduate supervision until about 2018, when he became ill. He was 83 years old.

Stöffler must be considered a true beacon of planetary science in general, and one of the outstanding members of the Meteoritical Society. We assume that his name is well known to the majority of members as synonymous with the Ries impact crater, shock metamorphism, lunar science, meteoritics, and lithopanspermia.

Stöffler enjoyed a truly exceptional career. From 1974 to 1987, he was a professor of Petrography and Economic Geology at the Westfälische Wilhelms-Universität (WWU) in Münster. Then he became the founding director of the

Institute of Planetology and Professor of Cosmic Mineralogy at the WWU. In 1993 he transferred to the Museum für Naturkunde in Berlin and became a professor of Mineralogy and Petrography at Humboldt Universität zu Berlin (HUB). He was director of the museum until 1999, then director of the HUB Institute of Mineralogy until 2004, when he officially retired and became professor emeritus. Milestones achieved during this time were the establishment of the Münster Institute of Planetology and the restoration of the East Berlin Museum für Naturkunde to a world-class research and outreach institution. He successfully supervised no less than 20 diplomas/M.Sc. theses and 30 doctoral projects, published extensively, and provided the funding for a host of prestigious research projects.

Foremost among his research accomplishments is Stöffler's seminal work on shock metamorphism. He and Wolf von Engelhardt established the concept of progressive shock metamorphism at — where else? — the Ries crater. This was followed by a huge number of petrographic studies on terrestrial impactites, lunar breccias, and meteorites. His shock classifications for major rock-forming minerals have been put to use by an entire generation of researchers since. His petrographic findings were calibrated by a series of

shock recovery experiments. And, in the last decades, numerical modeling was widely employed by his group in cratering and shock studies. Stöffler's legacy was built on the application of four lines of research: crater geological, petrographic, shock experimental, and numerical modeling studies.

Over five decades of active research, with numerous postgraduate students and post-docs, and in frequent collaboration with often international colleagues, Stöffler completed numerous projects, some of which involved large groups in the form of consortia. Some of the most memorable achievements of this work included crater studies: Sudbury, Haughton, West Clearwater, and a suite of Scandinavian craters. But throughout his career, Ries played a feature role.

Stöffler was the Principal Investigator of the International Continental Scientific Drilling Program's Yaxcopoil-1 Drilling Consortium at Chicxulub. He classified Apollo rock collections from the Moon and extensively researched the shock effects and shock histories of meteorites. He was involved with pilot studies regarding asteroid and comet sampling missions, in close collaboration with European Space Agency and NASA committees. The successful Rosetta mission to comet 67P/Churyumov-

Gerasimenko was initially based on Stöffler's groundbreaking committee work. Together with scientists from the Deutsches Institut für Luft- und Raumfahrt (DLR) and Ernst-Mach-Institut für Kurzzeit-Dynamik, Stöffler developed a test program for the lithopanspermia hypothesis that suggested that primitive lifeforms could sustain high shock conditions, a fundamental requirement for transfer of life between planetary bodies.

No tribute to Stöffler would be complete without recognizing his dedication to public education and outreach. He spearheaded the establishment of a first-class planetary science museum in the city of Nördlingen, in the Ries crater, and followed this up by the development of the Zentrum für Ries-Krater-Forschung in Nördlingen (ZERIN) facility. These institutions have since been the

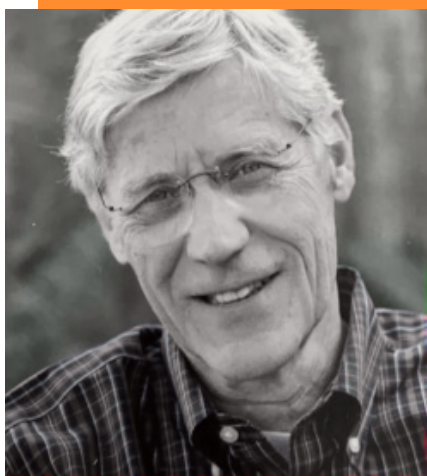
foundation for the creation of the national Geopark Ries — ultimately becoming a Global Geopark Ries in 2021.

During his career, Stöffler was the recipient of national and international recognition for his achievements. In 1989, he received a highly prestigious Gottfried-Wilhelm-Leibniz-Price from the German Science Foundation. In 1991, he received a Letter of Honor from the City of Nördlingen for achievements in Ries crater research, and the asteroid 4283(1988) was named "Stöffler" in his honor by the International Astronomical Union. The Barringer Medal for Impact Cratering Research was bestowed on Stöffler by the Meteoritical Society in 1993, and in 1996 he was elected a Fellow of the Society. In Germany, Stöffler was elected a Member of the Berlin-Brandenburg Academy of

Sciences in 1995 and a member of the German National Academy of Sciences Leopoldina in 1998. Finally in 2003, he received the Ries Cultural Award for outstanding achievements in Ries crater research. Stöffler served the Meteoritical Society for many years, serving as president of the society from 1997 to 1998 and helping to organize the annual meeting in Berlin in 1996.

Stöffler taught us all so much, including how to do science right. His dedication to science and education, always striving for the best possible outcome, is an example for us all. He has been a cornerstone in many of our lives, and will be missed by us all.

— Text courtesy of Wolf Uwe Reimold, Natasha Artemieva, Lutz Hecht, Thomas Kenkmann, Falko Langenhorst, and Kai Wünnemann



Credit: Stanford University.

George Leonard (Len) Tyler, professor of electrical engineering at Stanford University and leader of numerous studies of the planets of the solar system, passed away in Port Townsend, Washington, at the age of 82. The cause was late-stage Alzheimer's disease.

Tyler was best known for pioneering and perfecting the science of radio occultation, where radio signals pass

GEORGE LEONARD TYLER 1940–2023

through planetary atmospheres and bounce off the harder surfaces below to map the underlying structures. In 1968, as a young research assistant, Tyler first appeared in a Stanford News report about his studies of the soil on the surface of the Moon. In subsequent years, working through NASA's Jet Propulsion Laboratory, Tyler would lead successful studies of Mars, the rings of Jupiter and Saturn, and the structure of Neptune, among other explorations of Earth's solar system siblings.

"He was the premier expert in radio science for several decades — the person NASA chose to lead radio exploration of the planets and moons," said Howard Zebker, professor of electrical engineering and of geophysics, a one-time advisee, and later colleague of Tyler's at Stanford.

As a leader in the specialized field of radio science, Tyler explored each of the

main bodies in the solar system, the last being Pluto as Principal Investigator (PI) during development of the Radio Science Experiment (REX) on New Horizons. During his career, he also investigated radio wave scattering from Earth's ocean surfaces and was a PI or Co-I on the Viking, Voyager, Magellan, Mars Global Surveyor, and Mars Express missions. Former colleagues noted that Tyler joked that he had "visited every planet in the solar system" and "never met an asteroid that he didn't like." In fact, asteroid 195405 was permanently assigned his name in recognition of his contributions to the study of Pluto and the Kuiper belt.

More information about Tyler's life and legacy is available at stanford.io/40G8OgO.

— Text courtesy of Stanford University



Credit: Dignity Memorial.

Jack Langford Warren, who played an important role in the curatorial and clean room facilities at the Johnson Space Center (JSC; formerly called the Manned Spacecraft Center) during the Apollo program, lost his battle with cancer on February 1, 2023.

Warren was born in Beaumont, Texas, and at the age of 17, while still in high school, began working on workover rigs in the oilfield, eventually becoming

JACK LANGFORD WARREN 1941–2023

a derrick man. This work experience proved to be an important reason why he was hired by Brown & Root-Northrop in 1966 to work in the newly created facilities in Building 32 at JSC. The vacuum chamber created for the Apollo spacecraft was seven stories tall, and the engineers recognized that the type of mechanical engineering experience gained from working on small platforms 60 to 90 feet above the ground with just a rigging belt would be perfect for the work to be performed for the Apollo mission.

After working in Building 32 for a year, Warren was transferred to the Building 36 clean room, which at the time was the largest laminar flow clean room in the world. After working there for a few months, he was transferred to Building 37, the Lunar Receiving Laboratory, where he had the honor of getting to open the first box of Moon rocks brought back to Earth in 1969. In his 45-year career at

JSC, Warren also participated in other space missions, including the Cosmic Dust Project, Genesis Project, Stardust Project, Muir Project, and others. One of the highlights of his career came when Stephen Hawking asked to see the lab that handled the Stardust samples.

Warren was recognized by NASA in 2012 for Exceptional Public Service. For more information about his fascinating experiences during the Apollo years, read the interview conducted with him in 2008 as part of NASA's Oral History Project: historycollection.jsc.nasa.gov/JSCHistoryPortal/history/oral_histories/WarrenJL/WarrenJL_8-12-08.htm.

— Portions of text courtesy of NASA

NASA ADMINISTRATOR SELECTS NEW HEAD OF SCIENCE



Dr. Nicola Fox began serving as the associate administrator for the agency's Science Mission Directorate at NASA Headquarters in Washington on February 27, 2023. Credit: NASA/Aubrey Gemignani.

NASA Administrator Bill Nelson announced Dr. Nicola Fox will serve as the associate administrator for the agency's Science Mission Directorate at NASA Headquarters in Washington.

"As the director of our Heliophysics Division, Nicky was instrumental in expanding the impacts and awareness of NASA's solar exploration missions and I look forward to working with her as she brings her talents, expertise, and passion to her new role," Nelson said.

As NASA's head of Science, Fox's portfolio includes more than 100 NASA missions to explore the secrets of the universe, missions that assess questions as far ranging as how hurricanes form on Earth, how we can support astronauts on the Moon, and whether we are alone in the universe. She also will be responsible for fostering an inclusive, welcoming atmosphere and supporting a diverse team of scientists and engineers around the country at all stages of their careers.

Fox began her NASA career in 2018 leading the Heliophysics Division, overseeing the agency's efforts to study the Sun and how its constant solar wind affects Earth and other planets. Prior to that, she worked at the Johns Hopkins University Applied Physics Laboratory, where she was the chief scientist for heliophysics and the project scientist for NASA's Parker Solar Probe.

Throughout her career, Fox has authored numerous scientific articles and papers, in addition to delivering science presentations worldwide. In 2021, she was awarded the American Astronautical Society's Carl Sagan Memorial Award for her demonstrated leadership in the field of heliophysics with extensive project, program, and supervisory experience. She also is a recipient of NASA's Outstanding Leadership Medal, awarded in 2020.

Learn more about NASA's science missions at science.nasa.gov/.

NASA'S JOE ACABA TO SERVE AS AGENCY'S CHIEF ASTRONAUT

NASA has appointed veteran astronaut Joe Acaba as chief of the Astronaut Office at the agency's Johnson Space Center in Houston. A decorated veteran of multiple spaceflights, as well as a former U.S. Marine and former educator, Acaba is the first person of Hispanic heritage selected to lead the office.

Acaba takes the place of NASA astronaut Drew Feustel, who spent two years as deputy chief and has

been acting chief of the office since NASA astronaut Reid Wiseman left the post late last year.

In his new role, Acaba will be responsible for managing astronaut resources and operations. He also will help develop astronaut flight crew operation concepts and make crew assignments for future spaceflight missions, including astronauts assigned to fly on Artemis missions.

A veteran of three spaceflights, Acaba was born in Inglewood, California. He earned a bachelor's degree in geology at the University of California in Santa Barbara, one master's degree in geology from the University of Arizona, and one in education, curriculum, and instruction from Texas Tech University. Before his selection as an astronaut candidate in 2004, Acaba spent time in the U.S. Marine Corps Reserves and the Peace Corps, worked as a hydrogeologist, and taught high school and middle school.

Acaba spent 306 days in space, serving as mission specialist on space shuttle Discovery's STS-119 mission and as flight engineer aboard the International Space Station for Expeditions 31 and 32 in 2012, as well as Expeditions 53 and 54 in 2017 and 2018. During that time, he took part in three spacewalks building and upgrading the space station and supported the arrival of the first commercial resupply spacecraft, SpaceX's Dragon, in May 2012. He was aboard the station when its standard crew complement increased from three to six, enabling NASA and its international partners to double the amount of time dedicated to research. Since returning to Earth, he has supported the astronaut office in a number of roles, including director of operations in Russia and chief of the Vehicle Integration Test Office.



NASA astronaut Joe Acaba. Credit: NASA/Bill Ingalls.

Wiseman served as chief astronaut for two years before stepping down on November 14, 2022, to return to the pool of astronauts eligible for flight assignments. Feustel will continue to support the Astronaut Office.

Follow Acaba on [Twitter](#). View Acaba's complete biography at www.nasa.gov/astronauts/biographies/joseph-m-acaba.

NASA ADMINISTRATOR NAMES NEW GODDARD CENTER DIRECTOR



Director of Goddard Space Flight Center Dr. Makenzie Lystrup poses for a photo following her swearing-in ceremony Thursday, April 6, 2023, at the Mary W. Jackson NASA Headquarters building in Washington. Credit: NASA/Keegan Barber.

NASA Administrator Bill Nelson has named Dr. Makenzie Lystrup director of the agency's Goddard Space Flight Center in Maryland, effective immediately. She will make history as the first female center director at Goddard.

Lystrup succeeds Dave Mitchell, who has served as Goddard's acting center director since January 2023, and now resumes his duties as the agency's chief program management officer at NASA Headquarters in Washington.

Goddard Space Flight Center is one of NASA's largest field

centers. Its sites include the primary campus in Greenbelt, Maryland, as well as Wallops Flight Facility in Virginia, the Katherine Johnson Independent Verification & Validation Facility in West Virginia, the Goddard Institute for Space Studies in New York, the White Sands Complex in New Mexico, and the Columbia Scientific Balloon Facility in Texas. Goddard

is responsible for the oversight and execution of a \$4 billion portfolio and is home to the nation's largest concentration of scientists, engineers, and technologists dedicated to Earth and space science. Its workforce consists of more than 10,000 employees, both civil servants and contractors.

Prior to joining NASA, Lystrup was vice president and general manager of civil space at Ball Aerospace, where she was responsible for the company's portfolio of civil space systems that span across all science fields, operational weather and Earth observation, as well as advanced technologies development objectives. In this role, she led Ball's contributions to several missions, such as NASA's James Webb Space Telescope, Imaging X-ray Polarimetry Explorer (IXPE), Landsat 9, and the Roman Space Telescope.

Lystrup has also served as senior director for Ball's Civil Space Advanced Systems and Business Development, where she managed new business activities for NASA, NOAA, and other civilian U.S. government agencies as well as for academia and other science organizations.

For more information on Lystrup, please see her biography online at go.nasa.gov/43cQOgn.

CHANGES AHEAD AS NASA'S HUMAN SPACEFLIGHT HEAD PLANS RETIREMENTGODDARD CENTER DIRECTOR

Kathryn Lueders, the associate administrator of NASA's Space Operations Mission Directorate, announced she will retire from the agency at the end of April. Lueders' current deputy and astronaut, Ken Bowersox, will become the new head of Space Operations, effective Monday, May 1.

During her 31 years with the agency, Lueders provided strategic guidance for NASA's human exploration of space, as well as operations that allow the agency to launch science missions to learn about Earth and the universe. Her efforts have helped NASA foster significant change in how it partners with American industry to support and expand research onboard the International Space Station with crewed and cargo transportation to and from the station.

Lueders started her NASA career at the White Sands Test Facility in Las Cruces, New Mexico, where she was the Shuttle Orbital Maneuvering System and Reaction Control Systems Depot manager. She quickly demonstrated her engineering expertise, leading her through positions in the International Space Station Program and eventually to serve as manager of the Commercial Crew Program at NASA's Kennedy Space Center in Florida before joining NASA Headquarters in Washington.

Her many honors include several NASA achievement awards, the Distinguished Presidential Rank Award, and the Distinguished Service Medal. In addition, she is a 2022 National Academy of Engineering member, a 2020 SpaceNews Government Leader of the Year, an inductee to the 2021 Space and Satellite Hall of Fame, and recipient of the 2021 American Astronomical Society Spaceflight Achievement Award, 2020 Woman in Aerospace Leadership Award, 2022 Space Pioneer Award by the National Space Society, and IAASS' 2019 Leonardo da Vinci Lifetime Achievement Award.



NASA's Kathryn Lueders and Ken Bowersox. Credit: NASA.

Upon Lueders' retirement, Bowersox will take the lead for the mission directorate. His operations experience, including being the acting associate administrator of the former Human Exploration and Operations Mission Directorate, will allow NASA to build on its success in human space exploration.

As an astronaut, Bowersox flew five orbital missions for NASA, including two Hubble Space Telescope servicing missions. He served as commander of the sixth expedition at the space station. Following his station mission, Bowersox served as the director of flight operations at NASA's Johnson Space Center in Houston. He also has experience working with American industry and serving on the NASA Advisory Council as chair of the Human Exploration and Operations Committee.

Learn more about Bowersox's experience in his biography online at www.nasa.gov/offices/heo/bowersox-bio.html.

NASA NAMES ASTRONAUTS TO NEXT MOON MISSION, FIRST CREW UNDER ARTEMIS

NASA and the Canadian Space Agency (CSA) announced the four astronauts who will venture around the Moon on Artemis II, the first crewed mission on NASA's path to establishing a long-term presence at the Moon for science and exploration through Artemis.

"The Artemis II crew represents thousands of people working tirelessly to bring us to the stars. This is their crew, this is our crew, this is humanity's crew," said NASA Administrator Bill Nelson. "NASA astronauts Reid Wiseman, Victor Glover, and Christina Hammock Koch, and CSA astronaut Jeremy Hansen,

each has their own story, but, together, they represent our creed: E pluribus unum – out of many, one. Together, we are ushering in a new era of exploration for a new generation of star sailors and dreamers – the Artemis Generation.”

The crew assignments are as follows: [Commander Reid Wiseman](#), [Pilot Victor Glover](#), [Mission Specialist 1 Christina Hammock Koch](#), and [Mission Specialist 2 Jeremy Hansen](#). They will work as a team to execute an ambitious set of demonstrations during the flight test.

The approximately 10-day Artemis II flight test will launch on the agency’s powerful Space Launch System rocket, prove the Orion spacecraft’s life-support systems, and validate the capabilities and techniques needed for humans to live and work in deep space.

The flight, set to build upon the successful uncrewed Artemis I mission completed in December, will set the stage for the first woman and first person of color on the Moon through the Artemis program, paving the way for future long-term human exploration missions to the Moon, and eventually Mars. This is the agency’s Moon to Mars exploration approach.

For more information about the crew, visit www.nasa.gov/specials/artemis-ii.



The crew of NASA’s Artemis II mission (left to right): NASA astronauts Christina Hammock Koch, Reid Wiseman (seated), Victor Glover, and Canadian Space Agency astronaut Jeremy Hansen. Credit: NASA.

PRESIDENT’S FISCAL YEAR 2024 BUDGET STRENGTHENS NASA, SPACE ECONOMY



The Biden-Harris Administration released the [President’s Budget for Fiscal Year 2024](#), and it will allow NASA to continue exploring the secrets of the universe for the benefit of all through Artemis, the Mars Sample Return mission, and other efforts.

The budget allows NASA to monitor and protect the planet, advance sustainable aviation, better support orbital debris management, develop innovative new technologies, and inspire the Artemis Generation.

To watch Administrator Nelson’s State of NASA remarks, which coincide with the release of the agency’s budget proposal, visit www.youtube.com/watch?v=yTVxElrVfB0.

The budget details a blueprint to strengthen the economy, including supporting NASA’s investments in public/private partnerships. At NASA, the budget will:

- **Build on the successful Artemis I mission and pave the way for a long-term presence at the Moon.** The budget’s \$8.1 billion to enable unprecedented lunar exploration activities also will prepare for the next giant leap, sending astronauts to Mars, through NASA’s Moon to Mars exploration approach.
- **Further new scientific discovery in our solar system and beyond.** The budget provides \$949 million for the U.S.-led Mars Sample Return mission, which will return rock and soil samples to Earth to expand our understanding of the solar system and pave the way for human exploration. The budget’s almost \$2.5 billion for Earth Science includes the Earth System Observatory and will provide open access

to actionable data and information on climate change and natural hazards for scientists, decision-makers, and the public.

- **Support a future in low-Earth orbit.** Regular crewed missions to the International Space Station will enable multiple commercial partners to build a robust space economy where NASA is one of many customers. The budget also invests \$39 million to better understand the orbital debris environment and explore approaches to ensure safe access to space.
- **Advance U.S. leadership in technology innovation in aviation and space.** The budget invests more than \$500 million in a suite of technologies that will help meet the administration's goal of net-zero carbon emissions from the aviation sector no later than 2050. The budget's \$1.39 billion to support the research and development of new technologies will advance our space exploration capabilities

and create jobs through the growth of commercial space companies that will both use and provide new technologies.

- **Engage diverse learners in NASA's mission to create our nation's next generation of scientists, engineers, and explorers – the Artemis Generation.** The budget's \$158 million for NASA's Office of STEM Engagement will engage more students through enhanced partnerships and platforms. This includes expanding opportunities for students from underrepresented communities.

Building on the President's strong record of fiscal responsibility, the budget more than fully pays for its investments by reducing deficits over the next decade.

For more information on NASA's fiscal year 2024 discretionary request, visit www.nasa.gov/budget.

NEW PROGRAM OFFICE LEADS NASA'S PATH FORWARD FOR MOON, MARS



Through Artemis, NASA will land the first woman and the first person of color on the Moon, paving the way for a long-term, sustainable lunar presence to explore more of the lunar surface than ever before and prepare for future astronaut missions to Mars. Credit: NASA.

NASA has established the new Moon to Mars Program Office at NASA Headquarters in Washington to carry out the agency's human exploration activities at the Moon and Mars for the benefit of humanity. Amit Kshatriya will serve as the agency's first head of the office, effective immediately.

This new office resides within the Exploration Systems Development Mission Directorate, reporting to its Associate Administrator Jim Free.

As directed by the 2022 NASA Authorization Act, the Moon to Mars Program Office focuses on hardware development, mission integration, and risk management functions for programs critical to the agency's exploration approach that uses Artemis missions at the Moon to open a new era of scientific discovery and prepare for human missions to Mars. This includes the Space Launch System rocket, Orion spacecraft, supporting ground systems, human landing systems, spacesuits, Gateway, and more related to deep space

exploration. The new office will also lead planning and analysis for long-lead developments to support human Mars missions.

Kshatriya previously served as acting deputy associate administrator for Common Exploration Systems Development, providing leadership and integration across several of the programs that now fall within the new office.

Lakiesha Hawkins will serve as the deputy for the Moon to Mars Program Office. As deputy, Hawkins will support Kshatriya in all aspects of the office's day-to-day management and operations. Steven Creech will serve as the technical deputy for the office and will be responsible for ensuring technical issues are identified and brought to resolution across all of the offices and programs under the Moon to Mars Program Office.

Updates to the mission directorate also include the Strategy and Architecture Office, which develops the integrated master plan based on the agency [Moon to Mars Objectives](#), alongside NASA's Science, Space Technology, and Space Operations Mission Directorates. With these changes, NASA will continue to lead the nation in exploration while also building a coalition of international partners in deep space with the Artemis Accords.

Since establishing its [Exploration Systems Development Mission Directorate](#) in September 2021, NASA has worked

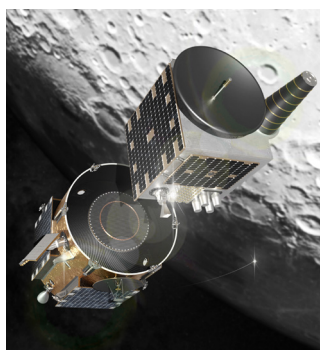
diligently to assess and align its two human spaceflight organizations while remaining focused on Artemis and other agency mission priorities including International Space Station operations, commercial crew and cargo, and more.

The [Space Operations Mission Directorate](#) remains responsible for all low-Earth orbit space operations and is focused on the space station, space communications, and navigation supporting all NASA human and science exploration missions, as well as continued development of a vibrant and expanding commercial space economy closer to home. Space Operations also manages the Launch Services Program, Commercial Crew Program, Commercial Low Earth Orbit Development Program, Human Spaceflight Capabilities, and other associated resources.

Other organizational updates include a business function for each mission directorate to manage administrative processes and financial formulation, and the exploration operations function will report to the Moon to Mars Program to maximize efficiency for integrated risk management with the relevant hardware programs supporting Artemis missions.

To learn more about Kshatriya, visit his bio online at www.nasa.gov/feature/amit-kshatriya.

NASA PICKS FIREFLY AEROSPACE FOR ROBOTIC DELIVERY TO FAR SIDE OF MOON



Rendering of Firefly's Blue Ghost transfer vehicle deploying the European Space Agency's Lunar Pathfinder satellite to lunar orbit. ESA's Lunar Pathfinder is designed and developed by Surrey Satellite Technology Limited. ESA collaborated with NASA for delivery through the CLPS initiative. Credit: Firefly Aerospace.

To carry multiple payloads to the far side of the Moon, including a satellite to orbit that area, NASA has selected Firefly Aerospace of Cedar Park, Texas. The commercial lander will deliver two agency payloads, as well as a communication and data relay satellite for lunar orbit, which is a European Space Agency (ESA) collaboration with NASA.

The contract award, for just under \$112 million, is a commercial lunar delivery targeted to launch in 2026 through

NASA's Commercial Lunar Payload Services, or [CLPS](#), initiative, and part of the agency's Artemis program.

This delivery targets a landing site for the two payloads on the far side of the Moon, a place that permanently faces away from Earth. Scientists consider this one of the best locations in the solar system for making radio observations shielded from the noise generated by our home planet. The sensitive observations need to take place during the 14-Earth-day-long lunar night.

One of these payloads delivered to the lunar surface aims to take advantage of this radio-quiet zone to make low-frequency astrophysics measurements of the cosmos, focusing on a time known as the "Dark Ages," a cosmic era that began some 370,000 years after the Big Bang and lasted until the first stars and galaxies formed. Since there is no line of sight and no direct communication with Earth from the far side of the Moon, Firefly also is required to provide communication services.

Firefly is responsible for end-to-end delivery services, including payload integration, delivery from Earth to the surface and orbit of the Moon, and NASA payload operations for the first lunar day. This is the second award to Firefly under the CLPS initiative. This award is the ninth surface delivery task award issued to a CLPS vendor, and the second to the far side.

The three payloads slated for delivery are expected to weigh in total about 494.5 kilograms (1,090 pounds). These payloads are Lunar [Surface Electromagnetics Experiment-Night \(LuSEE-Night\)](#), [Lunar Pathfinder](#), and User Terminal (UT).

Commercial deliveries to the lunar surface with several providers continue to be part of NASA's exploration

efforts. Future CLPS deliveries could include more science experiments and technology demonstrations that further support the agency's Artemis program.

Learn more about CLPS at www.nasa.gov/CLPS.

NASA SELECTS BLUE ORIGIN TO LAUNCH MARS' MAGNETOSPHERE STUDY MISSION

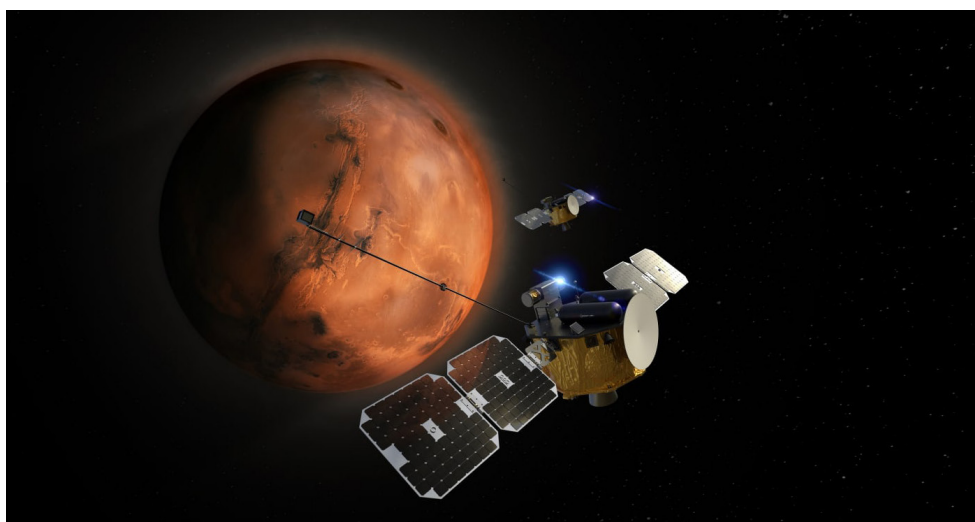


Illustration of the ESCAPEDE spacecraft in orbit around Mars. Credit: Rocket Lab USA/UC Berkeley.

NASA has awarded Blue Origin, LLC of Kent, Washington, a task order to provide launch service for the agency's Escape and Plasma Acceleration and Dynamics Explorers ([ESCAPEDE](#)) mission as part of the agency's Venture-Class Acquisition of Dedicated and Rideshare ([VADR](#)) launch services contract.

ESCAPEDE will launch on Blue Origin's New Glenn rocket from Space Launch Complex-36 at Cape Canaveral Space Force Station in Florida. The launch is targeted for late 2024. Blue Origin is one of 13 companies NASA selected for VADR contracts in 2022. NASA's Launch Services Program, based at the agency's Kennedy Space Center in Florida, manages the VADR contracts. As part of VADR, the fixed-price indefinite-delivery/indefinite-quantity contracts have a five-year ordering period with a maximum total value of \$300 million across all contracts.

ESCAPEDE will study Mars' magnetosphere, the magnetized area of space around the planet, using two identical small spacecraft which will provide simultaneous two-point observations. The spacecraft will help provide researchers a better understanding of how the magnetosphere interacts with the solar wind and how energy and plasma enter and leave the magnetosphere. Each satellite will carry three instruments: a

magnetometer for measuring magnetic field, an electrostatic analyzer to measure ions and electrons, and a Langmuir probe for measuring plasma density and solar extreme ultraviolet flux.

It will take ESCAPEDE about 11 months to arrive at Mars after leaving Earth's orbit, where both spacecraft will spend several months adjusting their orbits before they are in position to best capture data about the magnetosphere. Studying different magnetospheres gives scientists a better understanding of space weather, which can protect astronauts and satellites both as they orbit Earth and explore the solar system. ESCAPEDE is part of the NASA Small Innovative Missions for Planetary Exploration program.

Building on NASA's previous procurement efforts to foster the development of new launch vehicles for NASA payloads, VADR provides FAA-licensed commercial launch services for payloads that can tolerate higher risk. By using a lower level of mission assurance and commercial best practices for launching rockets, these highly flexible contracts help broaden access to space through lower launch costs.

NEW INTERACTIVE MOSAIC USES NASA IMAGERY TO SHOW MARS IN VIVID DETAIL

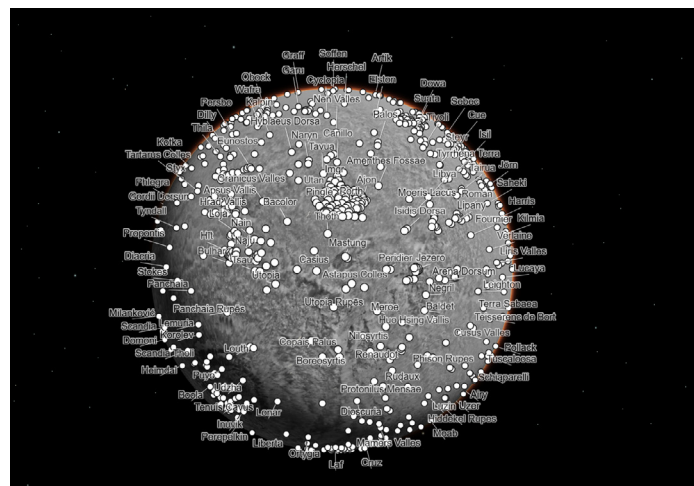
Cliffsides, impact craters, and dust devil tracks are captured in mesmerizing detail in a new mosaic of the Red Planet composed of 110,000 images from NASA's Mars Reconnaissance Orbiter ([MRO](#)). Taken by the veteran spacecraft's black-and-white Context Camera, or CTX, the images cover nearly 25 square meters (270 square feet) of surface per pixel.

That makes the [Global CTX Mosaic of Mars](#) the highest-resolution global image of the Red Planet ever created. If it were printed out, this 5.7 trillion-pixel (or 5.7 terapixel) mosaic would be large enough to cover the Rose Bowl Stadium in Pasadena, California.

The product of Caltech's [Bruce Murray Laboratory for Planetary Visualization](#), the mosaic took six years and tens of thousands of hours to develop. It is so detailed that more than 120 peer-reviewed science papers have already cited a beta version. But the mosaic is also easy enough for anyone to use.

"I wanted something that would be accessible to everyone," said Jay Dickson, the image processing scientist who led the project and manages the Murray Lab. "Schoolchildren can use this now. My mother, who just turned 78, can use this now. The goal is to lower the barriers for people who are interested in exploring Mars."

CTX is among three cameras onboard MRO, which is led by NASA's Jet Propulsion Laboratory in Southern California. One of those cameras, the High-Resolution Imaging Science Experiment ([HiRISE](#)), provides color images of surface features as small as a dining room table. In contrast, CTX provides a broader view of the terrain around those features, helping scientists understand how they're related. Its ability



The Global CTX Mosaic of Mars allows scientists and the public to explore the planet like never before. It includes different layers of data that can be turned on or off, like these labels for named geographic features on the planet. Credit: NASA/JPL-Caltech/MSSS.

to capture larger expanses of the landscape has made CTX especially useful for [spotting impact craters](#) on the surface. A third camera, the Mars Color Imager ([MARCI](#)), led by the same team that operates CTX, produces a daily global map of Mars weather at a much lower spatial resolution.

The mosaic was funded as part of NASA's Planetary Data Archiving, Restoration, and Tools (PDART) program, which helps develop new ways to use existing NASA data. The scientific products of extended missions like MRO make this data more accessible.

NASA RECEIVES NINE 2023 WEBBY AWARD NOMINATIONS

The last time NASA sent a spacecraft to the Moon that was built to carry people, the internet didn't exist. Its predecessor was a small network that connected a handful of servers at universities and military bases. That was 1972, and the system had only just developed the capability to send what people were calling "e-mail." Fifty years later, NASA took the world's online population to the Moon virtually as the

Artemis I mission sent the Orion spacecraft around the Moon in preparation for landing humans there later this decade.

The internet also watched unfolding (literally) developments as members of the James Webb Space Telescope deployed the spacecraft's components before starting to gather images, which, when they arrived, provided a look back in time 13 billion

years. Throughout the year, NASA's social media spread the news about all of the agency's programs and people across a variety of platforms that encompassed all forms of digital media: text, imagery, video, audio, and augmented reality.

NASA Nominees for Webby Awards

- [29 Days on the Edge](#)– We launched the James Webb Space Telescope. Then we had to get it working from a million miles away. (Technology video)
- [Artemis I: Taking the Internet to the Moon and Back](#)– Taking a few million friends along for the ride. (Social media campaign)
- [How Hubble Images Are Made](#)– As a cosmic photographer, NASA's Hubble Space Telescope has taken over a million snapshots. Here's how those images are made. (Science and education video)
- [NASA Webb Telescope Launch through Streaming](#)– 10-video playlist of major milestone events for the telescope. (Social events and live streaming)
- [NASA's Eyes on Asteroids](#)– Visualization of the asteroids in our solar system. (Website, best data visualization)
- [NASA's Social Media: Sustaining Creating a Community of Explorers](#)– With millions of followers, NASA's flagship social media accounts provide the agency with a collective audience that spans platforms and diverse groups of people. (Best Overall Social Presence – Brand)
- [NASA's James Webb Space Telescope Unfolds the Universe](#)– Keeping the world up to date on how the telescope was launched and deployed. (Social media campaign)

- [NASA's Jet Propulsion Laboratory Website](#)– The online gateway to the home of NASA research into the planets and Earth science. (Science website)

- ["On a Mission" podcast series](#)– Stories about NASA missions, told through the lives of those who make space exploration possible. (Science and education podcast)



Credit: Webby Awards.

NASA Honorees

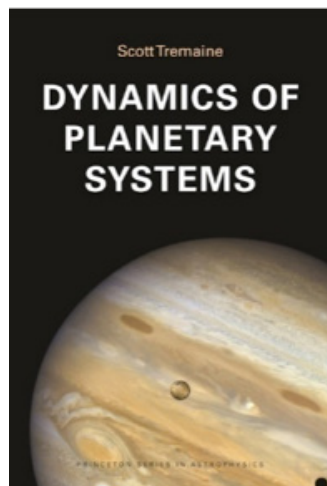
Two other NASA properties were Webby honorees, which are recognized for their excellence but are not eligible for awards.

[NASA's Exoplanet Exploration Program](#) was honored for its approach to accessible technology, and the James Webb Space Telescope's social media program was also honored in the general social category.

The Webby Awards are presented by the International Academy of Digital Arts and Sciences which "recognizes excellence in digital creativity, establishing best practices on a yearly basis – continually pushing the standards of web development higher," according to its website.

See the [full list of past NASA Webby Award winners and nominees](#).

NEW AND NOTEWORTHY

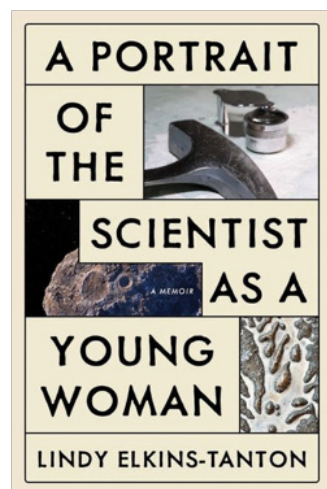


DYNAMICS OF PLANETARY SYSTEMS

By Scott Tremaine

Princeton University Press, 2023, 640 pp., Hardcover. \$150.00. www.press.princeton.edu

Celestial mechanics — the study of the movement of planets, satellites, and smaller bodies such as comets — is one of the oldest subjects in the physical sciences. Since the mid-twentieth century, the field has experienced a renaissance due to advances in space flight, digital computing, numerical mathematics, nonlinear dynamics, chaos theory, and the discovery of exoplanets. This modern, authoritative introduction to planetary system dynamics reflects these recent developments and discoveries and is suitable for advanced undergraduate and graduate students as well as researchers. The book treats both traditional subjects, such as the two-body and three-body problems, lunar theory, and Hamiltonian perturbation theory, as well as a diverse range of other topics, including chaos in the solar system, comet dynamics, extrasolar planets, planetesimal dynamics, resonances, tidal friction and disruption, and more. This book provides readers with all the core concepts, tools, and methods needed to conduct research in the subject.

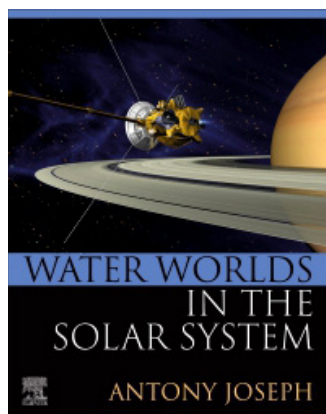


A PORTRAIT OF THE SCIENTIST AS A YOUNG WOMAN

By Lindy Elkins-Tanton

William Morrow, 2022, 272 pp., Hardcover. \$29.99. www.harpercollins.com

Deep in the asteroid belt between Mars and Jupiter, three times farther from the sun than the Earth is, orbits a massive asteroid called (16) Psyche. It is one of the largest objects in the belt, potentially containing the equivalent of the world's total economy in metals, though they cannot be brought back to Earth. But (16) Psyche has the potential to unlock something even more valuable: the story of how planets form, and how our planet formed. Soon we will find out, thanks to the extraordinary work of Lindy Elkins-Tanton, the Principal Investigator of NASA's \$800 million Psyche mission and the second woman ever to be awarded a major NASA space exploration contract. The journey that brought her to this place is extraordinary. Amid a childhood of terrible trauma, Elkins-Tanton fell in love with science as a means of healing and consolation. But still, she wondered, was forced to wonder: as a woman, was science "for her"? In answering that question, she takes us from the wilds of the Siberian tundra to the furthest reaches of outer space, from the Mayo Clinic, where she battled ovarian cancer while writing the Psyche proposal, to NASA's Jet Propulsion Laboratory, where her team brought that proposal to life. *A Portrait of the Scientist as a Young Woman* is a memoir that explores how a philosophy of life can be built from the tools of scientific inquiry. It teaches us how to approach difficult problems by asking the right questions and truly listening to the answers — and how we may find meaning through exploring the wonders of the universe around us.



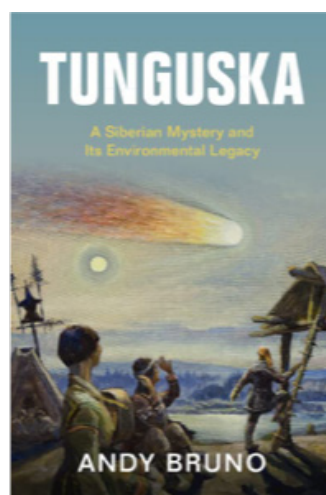
WATER WORLDS IN THE SOLAR SYSTEM:

In Search of Habitable Environments and Life

By Antony Joseph

Elsevier, 2022, 844 pp., Paperback. \$175.00. www.elsevier.com

Water Worlds in the Solar System: In Search of Habitable Environments and Life is a comprehensive reference on the formation, availability, habitability potential, and astrobiological implications of water in the solar system. The book provides an understanding of the importance of water on Earth to elucidate potential water and biosignature sources on other bodies in the solar system. It covers processes involved in the formation of Earth and its Moon, the genesis of water on those bodies, events on early Earth, and other processes that are applicable to celestial bodies in the solar system, directly correlating data available on the water on other bodies to over 15 Earth analogue sites. This book forms a comprehensive overview on water in the solar system, from formation to biosignature and habitability considerations. It is ideal for academics, researchers, and students working in the field of planetary science, extraterrestrial water research, and habitability potential.



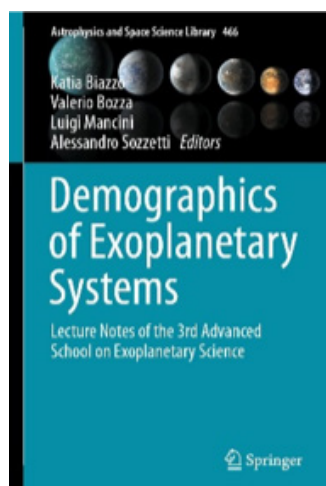
TUNGUSKA:

A Siberian Mystery and Its Environmental Legacy

By Andy Bruno

Cambridge University Press, 2022, 324 pp., Hardcover. \$39.99. www.cambridge.org

In 1908, thunderous blasts and blazing fires from the sky descended upon the desolate Tunguska territory of Siberia. The explosion knocked down an area of forest larger than London and was powerful enough to obliterate Manhattan. The mysterious nature of the event has prompted a wide array of speculation and investigation, including from those who suspected that aliens from outer space had been involved. In this deeply researched account of the Tunguska explosion and its legacy in Russian society, culture, and the environment, Andy Bruno recounts the intriguing history of the disaster and researchers' attempts to understand it. Taking readers inside the numerous expeditions and investigations that have long occupied scientists, he foregrounds the significance of mystery in environmental history. This engaging and accessible account shows how the explosion has shaped the treatment of the landscape, how uncertainty allowed unusual ideas to enter scientific conversations, and how cosmic disasters have influenced the past and might affect the future.



DEMOGRAPHICS OF EXOPLANETARY SYSTEMS:

Lecture Notes of the 3rd Advanced School on Exoplanetary Science

Edited by Katia Biazzo, Valeria Bozza, Luigi Mancini, and Alessandro Sozzetti

Springer, 2022, 291 pp., Hardcover. \$159.99. www.springer.com

This book provides a detailed, state-of-the-art overview of key observational and theoretical aspects of the rapidly developing and highly interdisciplinary field of exoplanet science, as viewed through the lenses of eight world-class experts. It equips readers with a broad understanding of the complex processes driving the formation and the physical and dynamical evolution of planetary systems. It juxtaposes theoretical modeling with the host of techniques that are unveiling the exceptional variety of observed properties of close-in and wide-separation extrasolar planets. By effectively linking ingenious interpretative analyses to the main factors shaping planetary populations, the book provides the most coherent picture to date of the demographics of exoplanetary systems. It is an essential reference for Ph.D. students and early-stage career researchers, while the scope and depth of its source material also provide excellent cues for graduate-level courses.

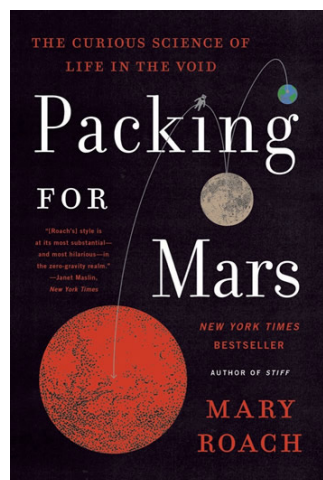


HOW TO DO RESEARCH AND HOW TO BE A RESEARCHER

By Robert Stewart

Oxford University Press, 2023, 272 pp., Hardcover. \$25.00. www.academic.oup.com

The principles underlying humanity's past and continuing acquisition of knowledge are straightforward and are illustrated here across academic fields, from history to quantum physics — stories of clever and inventive people with good ideas, but also of personalities, politics, and power. This book draws together these strands to provide an informal and concise account of knowledge acquisition in all its guises. Having set out what research hopes to achieve, and why we are all researchers at heart, early chapters describe the basic principles underlying this — ways of thinking that may date back to the philosophers of the Athenian marketplace but are still powerful influences on the way research is carried out today. Drawing on a broad range of disciplines, the book takes the reader well beyond the pure "scientific method," which might work well enough in physics or chemistry but falls apart in life sciences, let alone humanities. Later chapters consider the realities of carrying out research and the ways in which these continue to shape its progress — researchers and their personalities, their employers, funding, publication, political forces, and power structures.



PACKING FOR MARS:

The Curious Science of Life in the Void

By Mary Roach

W. W. Norton & Company, 2022, 352 pp., Paperback. \$16.95. www.wwnorton.com

Mary Roach, “America’s funniest science writer” (*Washington Post*), explores the irresistibly strange universe of space travel and life without gravity in *Packing for Mars*. From the Space Shuttle training toilet to a crash test of NASA’s new space capsule, Mary Roach takes us on a surreally entertaining trip into the science of life in space and space on Earth.



SIX-INCH PERCIVAL LOWELL MARS GLOBE

Developed for *Astronomy Magazine*

\$34.95. myscienceshop.com

Astronomy magazine has partnered with the Lowell Observatory to create a truly unique globe. This high-quality, injection-molded six-inch globe clearly depicts the intricate details Percival Lowell included on his 1911 Mars drawing. Among the most intriguing artifacts in the Putnam Collection Center at Lowell Observatory are a series of small Mars globes created by Percival Lowell himself. Their most striking aspect is their tangle of intersecting straight lines, which represent the famous “canals” on Mars. Lowell famously thought they were the work of intelligent beings who created a vast irrigation system to pump water from the polar caps to grow crops in the equatorial regions. This replica of one of the Lowell Mars globes was chosen for its high aesthetic value. It is highly detailed and made of long-lasting durable plastic with just a single seam between hemispheres. The globe comes with an acrylic base with a built-in magnifier and an informational flyer.

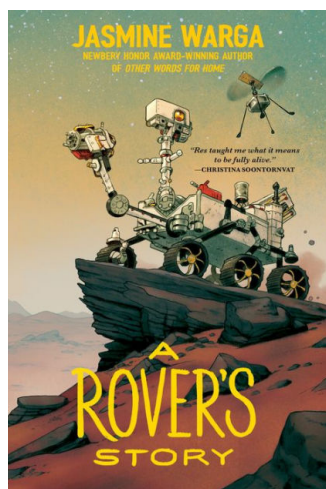


THE MOON: Discover the Mysteries of Earth’s Closest Neighbor

By Sanlyn Buxner, Pamela Gay, and Georgiana Kramer

DK Children, 2022, 80 pp., Hardcover. \$14.99. www.dk.com

Discover the mysteries of Earth’s closest neighbor in this incredible guide to the Moon. This book is the perfect introduction for young readers who want to learn about every aspect of the Moon. It features breakdowns of the Moon’s formation and geography, the lunar phases, a history of NASA’s Apollo missions, the Moon’s effect on Earth’s tides and nocturnal animals, recent scientific discoveries, and much more. This fascinating guide introduces children to the Moon’s past, present, and future, through stunning illustrations, photographs, and fascinating information. Packed with mind-blowing facts, this book is perfect for space lovers everywhere. For ages 7 to 9.



A ROVER'S STORY

By Jasmine Warga

Balzer + Bray, 2022, 320 pp., Hardcover. \$17.99. www.harpercollins.com

Meet Resilience, a Mars rover determined to live up to his name. Res was built to explore Mars. He was not built to have human emotions. But as he learns new things from the NASA scientists who assemble him, he begins to develop humanlike feelings. Maybe there's a problem with his programming.... Human emotions or not, launch day comes, and Res blasts off to Mars, accompanied by a friendly drone helicopter named Fly. But Res quickly discovers that Mars is a dangerous place filled with dust storms and giant cliffs. As he navigates Mars's difficult landscape, Res is tested in ways that go beyond space exploration. As millions of people back on Earth follow his progress, will Res have the determination, courage, and resilience to succeed... and survive? For ages 8 – 12.



SPACE MISSION MATCHING GAME

Produced by Chronicle Books

\$14.99. www.chroniclebooks.com

Your mission: Match! Play! Blastoff! Space mission patches celebrating NASA's most notable voyages into space exploration offer hands-on opportunities to hone memory skills and learn about NASA's most awe-inspiring journeys to date. Marvel at historic patches that commemorate the very first Mars rovers, the Apollo 11 mission, the launch of the International Space Station, and more. Just remember where you last spotted each mission memento to win. Interstellar explorers will want to launch into this game again and again! For ages 4 and up.



ECLIPSE FLASHCARDS

Developed for Astronomy Magazine

\$12.99. myscienceshop.com

Prepare for the next eclipse with this set of flashcards that features 34 key terms, concepts, and facts relating to solar eclipses. Each card features a different eclipse term or concept and is represented with detailed diagrams and stunning photos. Terms and concepts such as angular diameter, apogee, Bailey's beads, penumbra, Saros cycle, and more are included. The set includes 34 full-color 4-inch-by-6-inch cards.

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.

Dr. Paul Schenk,

Scientific Editor (schenk@lpi.usra.edu)

Renée Dotson,

Production Editor (rdotson@lpi.usra.edu)

For general inquiries, email lpibed@lpi.usra.edu.

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