HOW NASA'S PLANETARY SCIENCE DIVISION OBTAINS COMMUNITY FEEDBACK

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HOW NASA'S PLANETARY SCIENCE DIVISION OBTAINS COMMUNITY FEEDBACK

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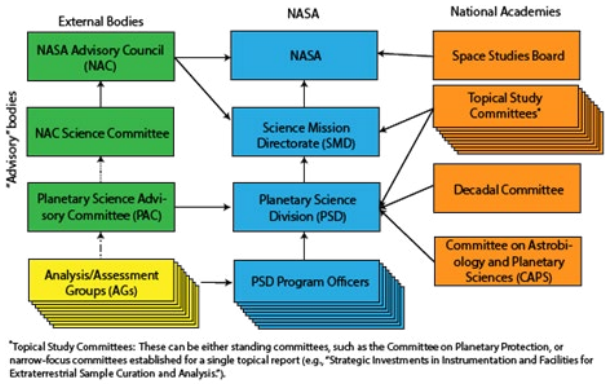
Federal Advisory Committee Act (FACA)-authorized advisory committees provide advice to NASA at several different levels, with the Planetary Science Advisory Committee (PAC) providing advice specific to the Planetary Science Division (PSD). The Planetary Analysis/Assessment Groups (PAGs or AGs) provide additional feedback to NASA, both through their NASA liaisons and by providing findings to the PAC for deliberation. Together, these groups articulate scientific drivers and the needs of the community that PSD can feed into strategic planning, and therefore serve a valuable function for the agency.

Context

NASA was established by the National Aeronautics and Space Act of 1958; in the Declaration of Policy and Purpose of the Act, the first objective listed is "the expansion of human knowledge of phenomena in the atmosphere and space." Later in the Act, it also directs NASA "to appoint such advisory committees as may be appropriate for purposes of consultation and advice to the Administration in the performance of its functions." Such advisory committees continue to be used by NASA; further, within the Science Mission Directorate (SMD), several divisions have established Analysis Groups and/or Assessment Groups to provide a path for community feedback to NASA.

At the highest level, the NASA Advisory Council (NAC) is a FACA advisory committee that provides advice directly to NASA's Administrator. The NAC also has five committees, including the Science Committee; each of these committees is chaired by a member of the NAC and provides advice and recommendations to the full NAC, which can in turn provide advice to the individual NASA Directorates. Within SMD, each of the Divisions receives advice and recommendations by a dedicated advisory committee; PSD is served by the PAC. All of these committees fall under FACA, a law passed in 1972.



NASA's Planetary Science Analysis/Assessment Groups serve a vital role in providing feedback between NASA and the planetary science community.

FACA committees are established to provide information and advice on a broad range of issues affecting federal policies and programs. Per the U.S. General Services Administration (GSA), they should

- Provide advice that is relevant, objective, and open to the public
- Act promptly to complete their work
- Comply with reasonable cost controls and record-keeping requirements.

Federal agencies may receive advice from groups established under FACA; there are ~1,000 FACA committees government-wide, and new advisory committees "can be created only when they are essential to the performance of a duty or responsibility conveyed upon the executive branch by law" (GSA).

The Planetary Science Advisory Committee (PAC)

The PAC was rechartered in 2021: the full PAC Charter can be found at science.nasa.gov/science-red/s3fs-public/atoms/files/PAC_Charter_2021_TAGGED.pdf. The most important part of the charter, however, is this:

> **3.** Objectives and Scope of Activities: The PAC shall draw on the expertise of its members to provide advice and make recommendations to the Director, Planetary Science Division, Science Mission Directorate, NASA

The Mapping and Planetary Spatial Infrastructure Team (MAPSIT) was established by NASA and the planetary science community in the fall of 2014, following recommendations from the Planetary Science Subcommittee of the Science Committee of the NASA Advisory Council. Originally named the Cartography Research Assessment Group (CRAG), the MAPSIT name was adopted in the fall of 2015 to be more inclusive of all aspects of spatial data analysis and associated infrastructure.

Headquarters (hereinafter, "Director, Planetary Science Division") on planetary science programs, policies, plans, and priorities. The PAC's recommendations and analysis can be used to inform decisions on the programmatic scope and priorities, as well as the implementation of planetary science programs. In addition, the PAC will provide a regular forum for broad discussion of planetary science and the role of planetary science within and outside of NASA.

The PAC consists of 13 members, each serving up to a 3-year term. In the spring of each year, NASA Headquarters (HQ) issues a call for nominations (including self-nominations) for individuals to serve on the PAC. PSD carefully evaluates all the nominations and recommends a slate of new PAC members to the Associate Administrator for SMD; in so doing, PSD strives to ensure that the PAC is diverse on multiple axes, including scientific expertise, institution type, career stage, and other factors identified in the President's 2021 *Memorandum on Restoring Trust in Government Through Scientific Integrity and Evidence-Based Policymaking*. New members are notified over the summer, and terms for new members start on October 1.

All members of the PAC are either civil servants or are designated as special government employees; as such, they must take ethics training prior to participation in any PAC activities, and they must submit financial disclosures to allow identification of any potential conflicts of interest. Both ethics training and financial disclosures are repeated on an annual basis. Any PAC members with an identified conflict of interest must recuse themselves from any discussion of those topics in the PAC meeting (i.e., the principal investigator for a mission should not participate in any PAC discussion/deliberation regarding that mission).

The PAC typically meets three times per year. All PAC meetings are announced publicly through the Federal Register with an attached agenda. Typically, notices are through the Federal Register about two months prior to the meeting. As required by FACA, every meeting is open to the public to ensure transparency of PAC deliberations. (Some meetings may be held in private provided that the meeting meets very specific criteria as laid out in FACA, but PAC meetings generally do not meet these criteria.) SMD currently supports this through video teleconferencing. During each meeting, the PAC strives to rigidly adhere to the agenda so that individuals can anticipate the timing of discussions. Only PAC members and speakers are allowed to ask questions or provide commentary during the meeting; each meeting also includes a short public comment period during which members of the public can ask questions of the speakers.

During the meeting, the PAC discusses any potential findings or recommendations. The PAC can only make a formal finding if the core substance of the finding was discussed during an open session of the PAC. Again, this is to ensure transparency as required by FACA. Following the PAC meeting, PAC members can discuss and revise the exact wording of findings, provided that the final finding does not deviate significantly from the discussion during the public session. It is important to note that the PAC is a consensus body; any finding represents the consensus of the entire PAC.

Each meeting also has a professional notetaker in attendance to provide minutes. The minutes are sent to the Executive Secretary of the PAC (a NASA HQ civil servant) who distributes them to all speakers to verify their accuracy. The minutes are posted on the NASA PAC website, along with all the presentations given to the PAC for public view. The PAC findings, when complete, are delivered to PSD and are also posted on the site. PAC findings should be submitted within 90 days of the meeting.

The most recent addition to the list of planetary AGs is the Mercury Exploration Assessment Group (MExAG), a community-based, interdisciplinary body that was established by NASA in 2020 to provide science input and analysis needed to plan and prioritize Mercury research and exploration activities.

As a FACA committee, the PAC is an independent advisory group. PSD does not restrict the PAC's topics of discussion in any way but does try to highlight topics where advice is desired. It is important to remember, however, that the PAC makes findings and recommendations. (Findings are observations made by the PAC that do not request a response; e.g., "The PAC commends NASA on the successful landing of Perseverance." Recommendations advise a course of action for PSD and should receive an official NASA response.) While the wisdom of the PAC is highly valued, PSD is not obligated to follow the recommendations and advice provided.

The Lunar Exploration Analysis Group (LEAG) was established in 2004 to support NASA in providing analysis of scientific, technical, commercial, and operational issues in support of lunar exploration objectives and of their implications for lunar architecture planning and activity prioritization. Membership and participation in LEAG consists of lunar and planetary scientists, life scientists, engineers, technologists, human systems specialists, mission designers, managers, and other professionals drawn from the broad community of academia, industry, government, and the commercial sector.

However, as a matter of course, a portion of each PAC meeting is devoted to responding to the findings from the previous meeting. The PAC is not an oversight body; FACA committees cannot direct agency activity, including that of individual agency employees.

The Planetary Analysis/Assessment Groups (PAGs or AGs)

In addition to the PAC, PSD receives feedback through nine different AGs. The nine AGs are community-organized, NASA-sponsored groups. (NASA provides funding support for meeting organization and some travel.) As the name implies, they are not FACA-authorized advisory groups; they do not provide formal findings and/or recommendations to NASA. The current AGs are

- Extraterrestrial Materials Analysis Group (ExMAG)
- Lunar Exploration Analysis Group (LEAG)
- Mapping and Planetary Spatial Infrastructure Team (MAPSIT)
- Mars Exploration Analysis Group (MEPAG)
- Mercury Exploration Assessment Group (MExAG)
- Outer Planets Assessment Group (OPAG)
- Small Bodies Assessment Group (SBAG)
- Venus Exploration Analysis Group (VEXAG)
- Exoplanet Exploration Program Analysis Group (ExoPAG) [ExoPAG is formerly an AG reporting to the Astrophysics Advisory Committee (APAC), chartered by the Astrophysics Division; however, because exoplanets are a cross-divisional topic with significant involvement from planetary scientists, the ExoPAG also provides feedback to the PAC and to PSD.]

Additional information on each of the AGs can be found at www.lpi.usra.edu/analysis/; the one exception is the ExoPAG, which can be found at exoplanets.nasa.gov/exep/exopag/overview/. For the eight AGs listed on the LPI website, links lead to additional information for each AG, including the terms of reference (ToR). The ToR for each AG briefly describes the purpose of each AG, the community it serves, its planned activities, and the organization and process by which it operates. Each AG is led by a chair; the chair is selected by the community in consultation with the Director of PSD. The chair is assisted by a steering committee, and together they help plan group activities. Each AG as a whole consists of anyone who wishes to participate; there are no restrictions on participation, although each member must agree to abide by the AG Code of Conduct. The open membership of the AGs is critical for ensuring that every member of the community has a voice and a path for providing feedback to NASA.

The primary activity of the AGs is the discussion of issues relevant to their specific community. AGs meet one to two times per year (depending on the AG and the size of the relevant community) for open discussion. The agenda is typically set by the chair and the steering committee; NASA plays no part in setting the meeting agenda. Each AG has a HQ liaison — a program scientist from PSD who regularly attends the meetings and provides insight into NASA processes and policies for the group. Other HQ personnel can be invited to AG meetings to discuss specific issues relevant to the AG's community and may attend depending on availability.

AG meetings typically result in "findings" by the individual AGs. Findings from the AGs make their way to NASA through regular reporting to the PAC. The AGs give presentations at most PAC meetings and have an opportunity to highlight findings for the PAC's attention. The PAC then can determine if either a formal response from NASA or specific advice from the PAC is warranted. In general, AGs are encouraged to focus on one or two specific findings for the PAC's attention. As mentioned above, any finding/recommendation made by the PAC must be publicly discussed, and even with a small number of findings from each AG, it is not possible to publicly discuss every one of them. In addition, the HQ liaison for each AG can provide feedback on potential AG findings; this can help clarify potential issues and obviate the need for some findings to go to the PAC.

The other function of the AGs is analysis. AGs can establish, either at NASA's request or of their own volition, Specific Action Teams (SATs). SATs are used to

> “The AGs established by NASA within PSD work together with the PAC to provide invaluable feedback to NASA by articulating scientific drivers and the needs of the community.”

address specific questions of interest to NASA and/or the community. An example is the Analog Objectives for Artemis SAT established by LEAG at NASA’s request. The group was given the task of cataloging and prioritizing scientific objectives and science operations in preparation for Artemis missions that could be achieved through analog activities, and produced a report for NASA’s consumption (www.lpi.usra.edu/leag/reports/analog-objectives-report-02142022.pdf) that will help guide strategic planning for lunar science activities. While SATs are not common, they are potentially very valuable because of the specificity of their activities.

In addition to the nine AGs, the cross-AG Inclusion, Diversity, Equity, and Accessibility (IDEA) Working Group was established in 2019. This group consists of members from each of the AGs and is dedicated to addressing IDEA issues for both the community and for NASA. The cross-AG nature of the group recognizes the broad importance of such issues. The group also is given an opportunity to provide findings to the PAC (similar to the AGs).

Summary

As stated above, the AGs established by NASA within PSD work together with the PAC to provide invaluable feedback to NASA by articulating scientific drivers and the needs of the community. This feedback feeds into strategic planning and therefore serves a valuable function for the agency.

FROM THE DESK OF **LORI GLAZE**

THE SHORT AND LONG OF IT

Lori S. Glaze

Director, NASA's Planetary Science Division, July 2022

With less than three months until the September 26 Double Asteroid Redirection Test (DART) kinetic impact event, we are rapidly hurtling toward the mission's culmination. DART — humanity's first-ever demonstration of a planetary defense technique — is an anomaly in the Planetary Science Division's (PSD's) portfolio because the spacecraft is demolished at the moment its science really begins!

DART is on a direct and designed collision course with the Didymos binary asteroid system, which is the ideal target for this real-world demonstration of the kinetic impactor approach — impacting an asteroid to adjust its speed and path. Didymos (about 780 meters or 0.5 miles in diameter) poses no threat to Earth, and the fact that it is actually the larger member of a binary system makes it a perfect natural laboratory for this test. DART will aim for the smaller "moonlet" Dimorphos (about 160 meters or 525 feet in diameter) and will alter its orbit around Didymos.

When DART hits Dimorphos in a nearly head-on collision at a speed of about 22,531 kilometers per hour (14,000 miles per hour), the momentum of the spacecraft, plus the recoil from the ejecta blasted out of the impact crater, will be transferred to Dimorphos, resulting in a shortening of its orbital period. Right now, from Earth we can see (from the regular dimming of the telescopically measured light curve) that Dimorphos completes an orbit of Didymos every 11 hours and 55 minutes. We predict that the impact will cause Dimorphos' orbit to shorten by several minutes, which will mean that it will orbit slightly closer to Didymos. This binary asteroid system, and the timing of impact, were chosen so that the collision occurs when the asteroids are passing close to Earth. This means that we will be able to obtain the highest-quality telescopic observations of the system in the weeks after the impact to see precisely how much Dimorphos' orbital period has actually changed.

Although DART is accompanied by LICIACube [contributed by the Agenzia Spaziale Italiana (ASI)], which will capture images of the impact event and its effects on the surface of Dimorphos, the DART spacecraft itself carries only one scientific payload — the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO). DRACO is a high-resolution imager that will support navigation and targeting as DART approaches Dimorphos. The images it acquires before the impact will be streamed back to Earth in real time. I can't wait to see Dimorphos grow larger and larger in the pictures and see the real character of this tiny asteroid in the final moments before DART meets its purposed fate.

From launch to impact, DART's flight operations will last only 10 months — just a blink of an eye in comparison with some of our other planetary missions. It feels strange to be bidding farewell to DART almost as soon as we got to see it fly, but in recompense, I'm glad that we have recently decided to extend several of our ongoing missions after the conclusion of the 2022 Planetary Mission Senior Review (PMSR22) process.

Senior Reviews typically take place every three years and are the chance for us to examine our ongoing missions and the case for each to extend their science operations. This time around, eight missions were reviewed, including five Mars missions (MAVEN, Mars Science Laboratory, InSight, Mars Reconnaissance Orbiter, and Odyssey), as well as Lunar Reconnaissance Orbiter (LRO), OSIRIS-REx, and New Horizons. All missions submitted three-year extended mission proposals (except OSIRIS-REx, which proposed a nine-year extension to include an encounter with Apophis in 2029). These proposals were then reviewed (each independently) by a set of review panels, and we based our decisions upon their final reports.

The results of the PMSR22 are now available online, and I'm delighted to report that we elected to extend all eight missions. All of them will be extended for a further three years, with a few exceptions.

As already mentioned, OSIRIS-REx will be extended for nine years and will actually morph into a new mission with a new name — OSIRIS-APEX (APophis EXplorer). Once OSIRIS-REx, led by Principal Investigator Dante Lauretta (University of Arizona), has completed its return journey to Earth to drop off its sample capsule and precious cargo from Bennu, the spacecraft will head out on its journey toward Apophis, where it will give us a close-up look at this rubble-pile asteroid. Daniella DellaGiustina (University of Arizona) will be the new PI for OSIRIS-APEX.

New Horizons has been extended for two years, during which time it will make distant observations of Uranus and Neptune, with geometries not possible from Earth. The spacecraft's cameras will also be used to map the very faint "cosmic background" at visible and ultraviolet wavelengths. In addition, New Horizons will explore the heliosphere outward of 54 AU. Its instruments will be used to study the motion of charged particles as they interact with the solar wind and to examine the large-scale structure of the heliosphere. Indeed, New Horizons will be given the opportunity to propose to become part of NASA's Heliophysics System Observatory (HSO) at the end of this upcoming extended mission.

The shortest of all the extensions is for InSight, as we anticipate the spacecraft's expected retirement. We have extended InSight until the end of this calendar year, or until the spacecraft ceases to operate because of reduced power. Although InSight continues to monitor seismic activity on Mars, buildup of dust on its solar panels means that the amount of power available for spacecraft operations is rapidly falling, and we expect science activities to cease later this summer or fall.

I don't have space to describe the plans for all the other extended missions, but I encourage you to read the posted final report to find out more. And I want to give a special shout-out to our two particularly long-lived workhorses Odyssey (21 years old) and LRO (13 years old)!

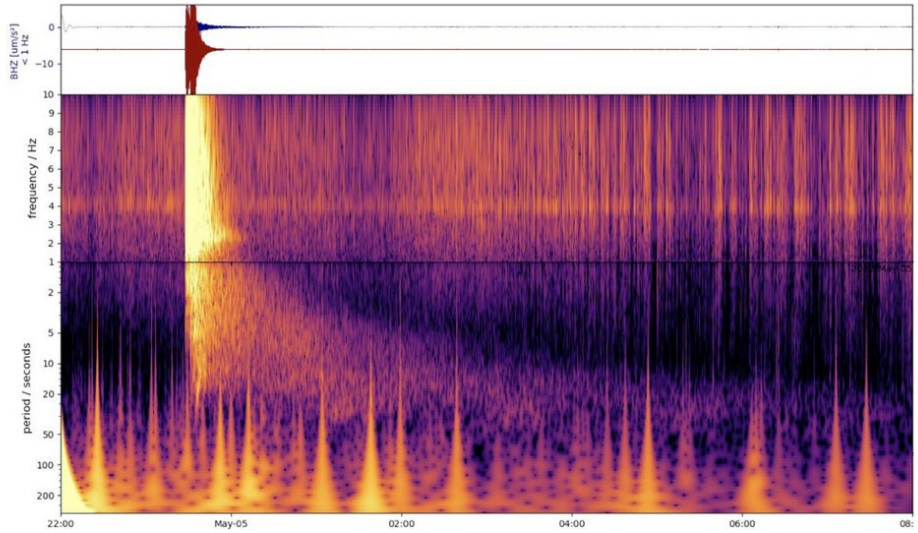
As we prepare to say goodbye to some of our beloved missions in the coming months, let's also be thankful for the prospect of many more years of fantastic science from so many of our amazing PSD missions. I'm also incredibly grateful to the PMSR22 team (led by Henry Throop and Lindsay Hays in PSD) and all the reviewers for their hard work and dedication, and especially to our mission teams, who sustain our missions and drive them forward in the pursuit of science and exploration.

NASA'S INSIGHT RECORDS MONSTER QUAKE ON MARS

NASA's InSight Mars lander has detected the largest quake ever observed on another planet: an estimated magnitude 5 temblor that occurred on May 4, 2022, the 1222nd martian day, or sol, of the mission. This adds to the catalog of more than 1313 quakes InSight has detected since landing on Mars in November 2018. The largest previously recorded quake was an estimated magnitude 4.2 detected on August 25, 2021.

InSight was sent to Mars with a highly sensitive seismometer, provided by France's Centre National d'Études Spatiales (CNES), to study the deep interior of the planet. As seismic waves pass through or reflect off material in Mars' crust, mantle, and core, they change in ways that seismologists can study to determine the depth and composition of these layers. What scientists learn about the structure of Mars can help them better understand the formation of all rocky worlds including Earth and its Moon.

A magnitude 5 quake is a medium-size quake compared to those felt on Earth, but it is close to the upper limit of what scientists hoped to see on Mars during InSight's mission. The science team will need to study this new quake further before being able to provide details such as its location, the nature of its source, and what it might tell us about the interior of Mars.



This spectrogram shows the largest quake ever detected on another planet. Estimated at magnitude 5, this quake was discovered by NASA's InSight lander on May 4, 2022, the 1222nd martian day, or sol, of the mission. Credit: NASA/JPL-Caltech/ETH Zurich.

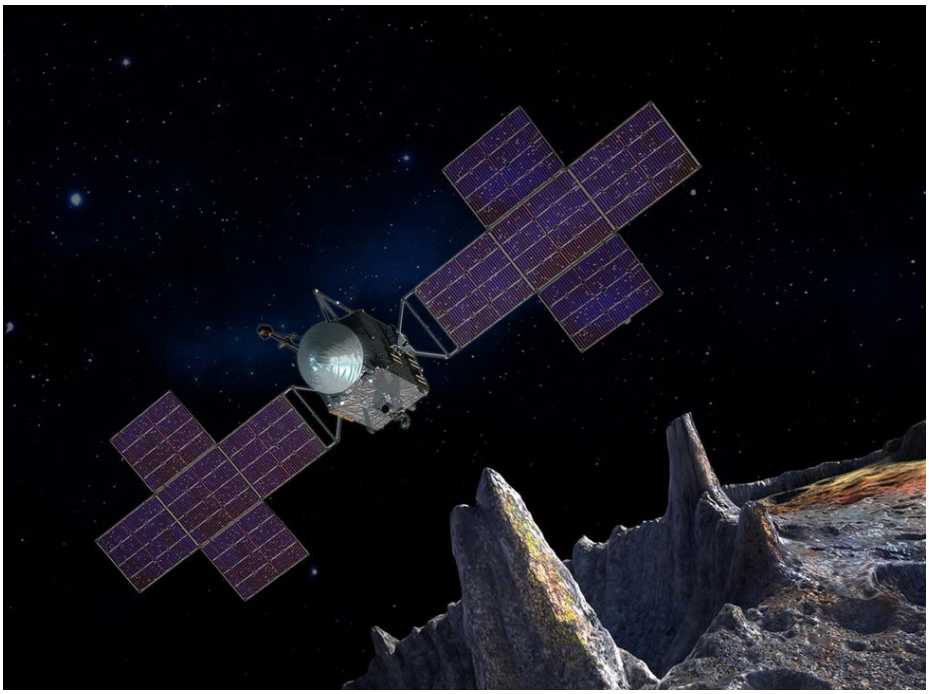
"Since we set our seismometer down in December 2018, we've been waiting for 'the big one,'" said Bruce Banerdt, InSight's principal investigator at NASA's Jet Propulsion Laboratory in Southern California, which leads the mission. "This quake is sure to provide a view into the planet like no other. Scientists will be analyzing this data to learn new things about Mars for years to come."

The large quake comes as InSight is facing new challenges with its solar panels, which power the lander. As InSight's location on Mars enters winter, there is more dust in the air, reducing available sunlight. On May 7, 2022, the lander's available energy fell just below the limit that triggers safe mode in which the spacecraft suspends all but the most essential functions. This reaction is designed to protect the lander and may occur again as available power slowly decreases.

After the lander completed its prime mission at the end of 2020 and met its original science goals, NASA extended the mission through December 2022.

"What scientists learn about the structure of Mars can help them better understand the formation of all rocky worlds including Earth and its Moon."

NASA ANNOUNCES LAUNCH DELAY FOR ITS PSYCHE ASTEROID MISSION



This illustration depicts the spacecraft of NASA's Psyche mission near the mission's target, the metal-rich asteroid Psyche. The artwork, created in May 2017, shows the spacecraft's five-panel solar arrays. Credit: NASA/JPL-Caltech/Arizona State Univ./Space Systems Loral/Peter Rubin.

NASA announced on June 24 the Psyche mission, the agency's first mission designed to study a metal-rich asteroid, will not make its planned 2022 launch attempt.

Due to the late delivery of the spacecraft's flight software and testing equipment, NASA does not have sufficient time to complete the testing needed ahead of its remaining launch period this year, which ends on October 11. The mission team needs more time to ensure that the software will function properly in flight.

NASA selected Psyche in 2017 as part of the agency's Discovery Program, a line of low-cost, competitive missions led by a single principal investigator. The agency is forming an independent assessment team to review the path forward for the project and for the Discovery Program.

"NASA takes the cost and schedule commitments of its projects and programs very seriously," said Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate in Washington, DC. "We are exploring options for the mission in the context of the Discovery Program, and a decision on the path forward will be made in the coming months."

The independent assessment team, typically made up of experts from government, academia, and industry, will review possible options for next steps, including estimated costs. Implications for the agency's Discovery Program and planetary science portfolio also will be considered.

The spacecraft's guidance, navigation, and flight software will control the orientation of the spacecraft as it flies through space and is used to point the spacecraft's antenna toward Earth so that the spacecraft can send data and receive commands. It also provides trajectory information to the spacecraft's solar electric propulsion system, which begins operations 70 days after launch.

As the mission team at NASA's Jet Propulsion Laboratory (JPL) in Southern California began testing the system, a compatibility issue was discovered with the software's testbed simulators. In May, NASA shifted the mission's targeted launch date from August 1 to no earlier than September 20 to accommodate the work needed. The issue with the testbeds has been identified and corrected; however, there is not enough time to complete a full checkout of the software for a launch this year.

> **"Flying to a distant metal-rich asteroid, using Mars for a gravity assist on the way there, takes incredible precision."**

"Flying to a distant metal-rich asteroid, using Mars for a gravity assist on the way there, takes incredible precision. We must get it right. Hundreds of people have put remarkable effort into Psyche during this pandemic, and the work will continue as the complex flight software is thoroughly tested and assessed," said JPL Director Laurie Leshin. "The decision to delay the launch wasn't easy, but it is the right one."

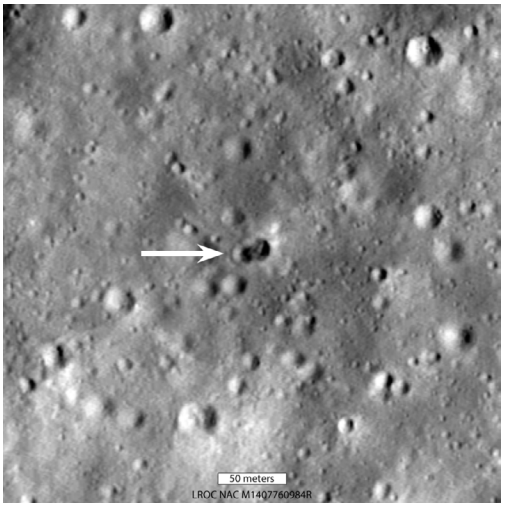
The mission's 2022 launch period, which ran from August 1 through October 11, would have allowed the spacecraft to arrive at the asteroid Psyche in 2026. There are possible launch periods in both 2023 and 2024, but the relative orbital positions of Psyche and Earth mean the spacecraft would not arrive at the asteroid until 2029 and 2030, respectively. The exact dates of these potential launch periods are yet to be determined.

"Our amazing team has overcome almost all of the incredible challenges of building a spacecraft during COVID," said Psyche Principal Investigator Lindy Elkins-Tanton of Arizona State University, who leads the mission. "We have conquered numerous hardware and software challenges, and we've been stopped in the end by this one last problem. We just need a little more time and will get this one licked too. The team is ready to move forward, and I'm so grateful for their excellence."

Total life-cycle mission costs for Psyche, including the rocket, are $985 million. Of that, $717 million has been spent to date. The estimated costs involved to support each of the full range of available mission options are currently being calculated.

Two ride-along projects were scheduled to launch on the same SpaceX Falcon Heavy rocket as Psyche, including NASA's Janus mission to study twin binary asteroid systems and the Deep Space Optical Communications technology demonstration to test high-data-rate laser communications that is integrated with the Psyche spacecraft. NASA is assessing options for both projects.

NASA'S LUNAR RECONNAISSANCE ORBITER SPOTS ROCKET IMPACT SITE ON MOON



A rocket body impacted the Moon on March 4, 2022, near Hertzsprung crater, creating a double crater roughly 28 meters (92 feet) wide in the longest dimension. LROC NAC M1407760984R; image enlarged 3×. Credit: NASA/Goddard/Arizona State University.

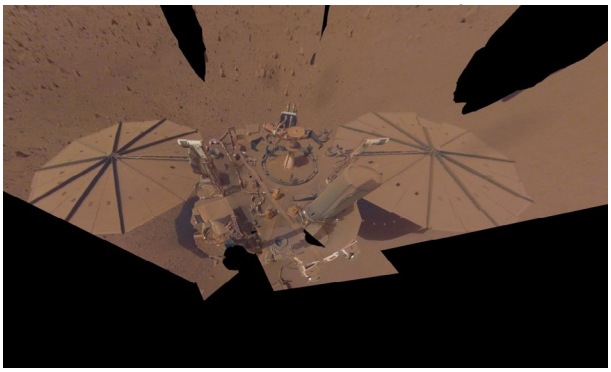
Astronomers discovered a rocket body heading toward a lunar collision late last year. The impact occurred March 4, with NASA's Lunar Reconnaissance Orbiter (LRO) later spotting the resulting crater. Surprisingly, the crater is actually two craters, an eastern crater (18 meters in diameter, or about 19.5 yards) superimposed on a western crater (16 meters in diameter, or about 17.5 yards).

The double crater was unexpected and may indicate that the rocket body had large masses at each end. Typically, a spent rocket has mass concentrated at the motor end, and the rest of the rocket stage mainly consists of an empty fuel tank. Since the origin of the rocket body remains uncertain, the double nature of the crater may indicate its identity.

No other rocket body impacts on the Moon have created double craters. The four Apollo S-IVB craters (created by Apollo 13, 14, 15, and 17) were somewhat irregular in outline and were substantially larger (greater than 35 meters, or about 38 yards) than each of the double craters. The maximum width (29 meters, or about 31.7 yards) of the double crater of the mystery rocket body was near that of the S-IVBs.

LRO is managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, for the Science Mission Directorate at NASA Headquarters in Washington, DC. Launched on June 18, 2009, LRO has collected a treasure trove of data with its seven powerful instruments, making an invaluable contribution to our knowledge about the Moon. NASA is returning to the Moon with commercial and international partners to expand human presence in space and bring back new knowledge and opportunities.

NASA'S INSIGHT GETS A FEW EXTRA WEEKS OF MARS SCIENCE



NASA's InSight Mars lander took this final selfie on April 24, 2022, the 1211th martian day, or sol, of the mission. The lander is covered with far more dust than it was in its first selfie taken in December 2018, not long after landing, or in its second selfie, composed of images taken in March and April 2019. Credit: NASA/JPL-Caltech.

As the power available to NASA's InSight Mars lander diminishes by the day, the spacecraft's team has revised the mission's timeline to maximize the science they can conduct. The lander was projected to automatically shut down the seismometer — InSight's last operational science instrument — by the end of June to conserve energy, surviving on what power its dust-laden solar panels can generate until around December.

Instead, the team now plans to program the lander so that the seismometer can operate longer, perhaps until the end of August or into early September. Doing so will discharge the lander's batteries sooner and cause the spacecraft to run out of power at that time as well, but it might enable the seismometer to detect additional marsquakes.

"InSight hasn't finished teaching us about Mars yet," said Lori Glaze, director of NASA's Planetary Science Division in Washington, DC. "We're going to get every last bit of science we can before the lander concludes operations."

InSight (short for Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is in an extended mission after achieving its science goals. The lander has detected more than 1300 marsquakes since touching down on Mars in 2018, providing information that has allowed scientists to measure the depth and composition of Mars' crust, mantle, and core. With its other instruments, InSight has recorded invaluable weather data, investigated the soil beneath the lander, and studied remnants of Mars' ancient magnetic field.

All instruments but the seismometer have already been powered down. Like other Mars spacecraft, InSight has a fault protection system that automatically triggers "safe mode" in threatening situations and shuts down all but its most essential functions, allowing engineers to assess the situation. Both low power levels and temperatures that drift outside predetermined limits can trigger safe mode.

To enable the seismometer to continue running for as long as possible, the mission team is turning off InSight's fault protection system. While this will enable the instrument to operate longer, it leaves the lander unprotected from sudden unexpected events that ground controllers wouldn't have time to respond to.

"The goal is to get scientific data all the way to the point where InSight can't operate at all, rather than conserve energy and operate the lander with no science benefit," said Chuck Scott, InSight's project manager at NASA's Jet Propulsion Laboratory in Southern California.

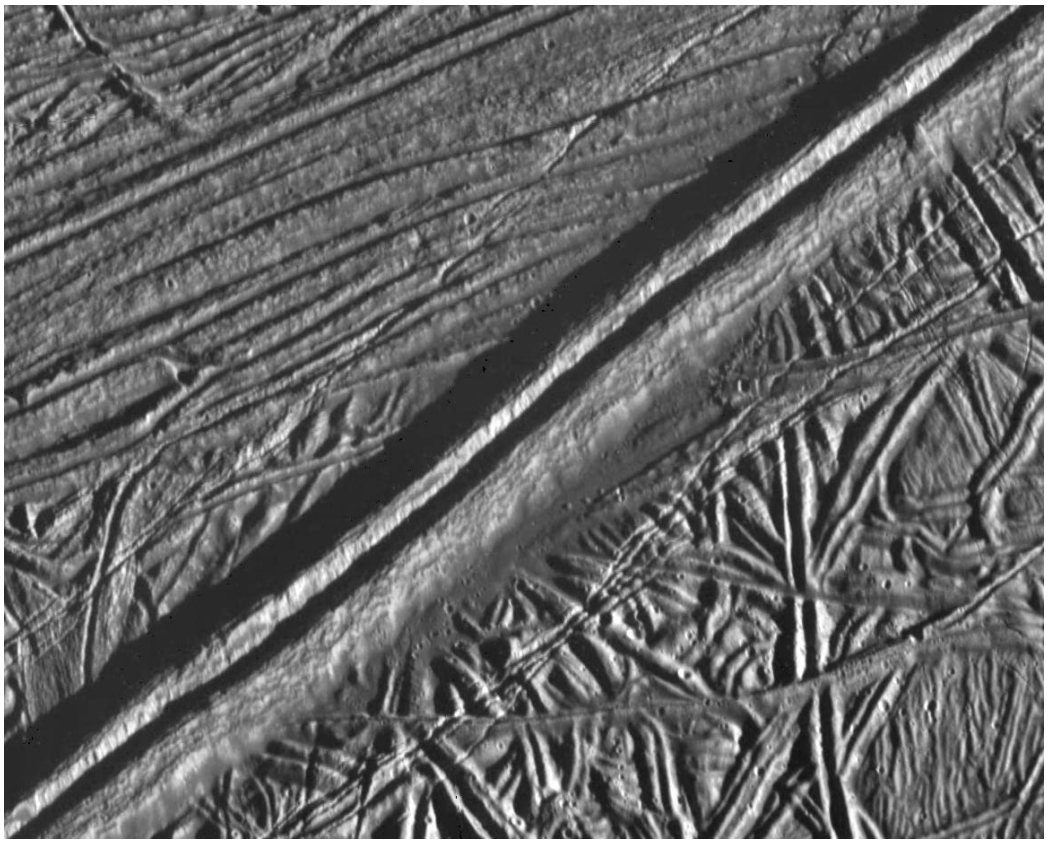
GREENLAND ICE, JUPITER MOON SHARE SIMILAR FEATURE

Parallel ice ridges in Greenland bear a striking resemblance to ridges on Jupiter's ice-encased moon Europa, suggesting the moon's icy shell could be riddled with pockets of water.

This similarity could greatly improve the odds of NASA's Europa Clipper mission detecting potentially habitable environments on the jovian moon. The spacecraft's ice-penetrating radar instrument Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) will be ideal for conducting such a search.

"If there are pockets of water under the ridges, we have the right instruments to see them," said Dustin Schroeder, a Stanford University associate professor and coauthor of a new study comparing Greenland's "double ridges" with those of Europa.

Scientists say evidence gathered so far shows that Europa harbors a deep liquid ocean hidden beneath an ice



A double ridge cutting across the surface of Europa is seen in this mosaic of two images taken by NASA's Galileo spacecraft during its close flyby on February 20, 1997. Analysis of a similar feature in Greenland suggests shallow liquid water may be ubiquitous across the jovian moon's icy shell. Credit: NASA/JPL/ASU.

shell that could be 15 to 25 kilometers (10 to 15 miles) thick. Because the ice is so substantial, a big question about the moon is whether anything from the deep ocean makes contact with the surface, or if contact goes the other way with surface material filtering down to the ocean water.

"It's exciting, what it would mean if you have plenty of water within the ice shell," said coauthor Gregor Steinbrügge, a former Stanford researcher who is now a planetary scientist at NASA's Jet Propulsion Laboratory in Southern California. "It would mean the ice shell on Europa is extremely dynamic. It could facilitate exchange processes between the surface and the subsurface ocean. It could go in both directions."

He added that potential life-sustaining nutrients on Europa's surface — perhaps deposited there by another Jupiter moon, volcanic Io — might find their way to the subsurface ocean. And chemicals or other material from the subsurface indicating a habitable ocean environment could end up on the surface.

During a presentation on Europa's ridges, the study's lead author, Stanford graduate student Riley Culberg, said he noticed similar landforms in Greenland. Ice-penetrating radar data collected from 2015 to 2017 by NASA's Operation IceBridge, an aerial observation campaign, showed not only the existence of a double ridge in northwestern Greenland, but also details of how it evolved.

The double ridges observed on the surface of the Greenland Ice Sheet formed when water from nearby surface lakes drained into a layer of impermeable ice within the ice sheet. Once there, the water pocket refroze and fractured the overlying ice, forcing peaks to rise on either side.

Something similar could be happening on Europa, but instead with water forced up toward the surface from the subsurface ocean. The ridge features on Europa, while similar to the Greenland ridges, are much larger and have taller peaks, perhaps due in part to lower gravity on Europa.

Europa Clipper's REASON instrument is designed to make the same kind of measurements at Europa that the IceBridge radar made in Greenland. Both use radio waves that can

"Europa Clipper's REASON instrument is designed to make the same kind of measurements at Europa that the IceBridge radar made in Greenland."

penetrate deeply into ice. The same waves, however, cannot penetrate liquid water and are instead reflected to the radar instrument. Water shows up as a bright patch in the radar images. These radargrams can therefore provide a vertical profile of water and ice deep below the surface.

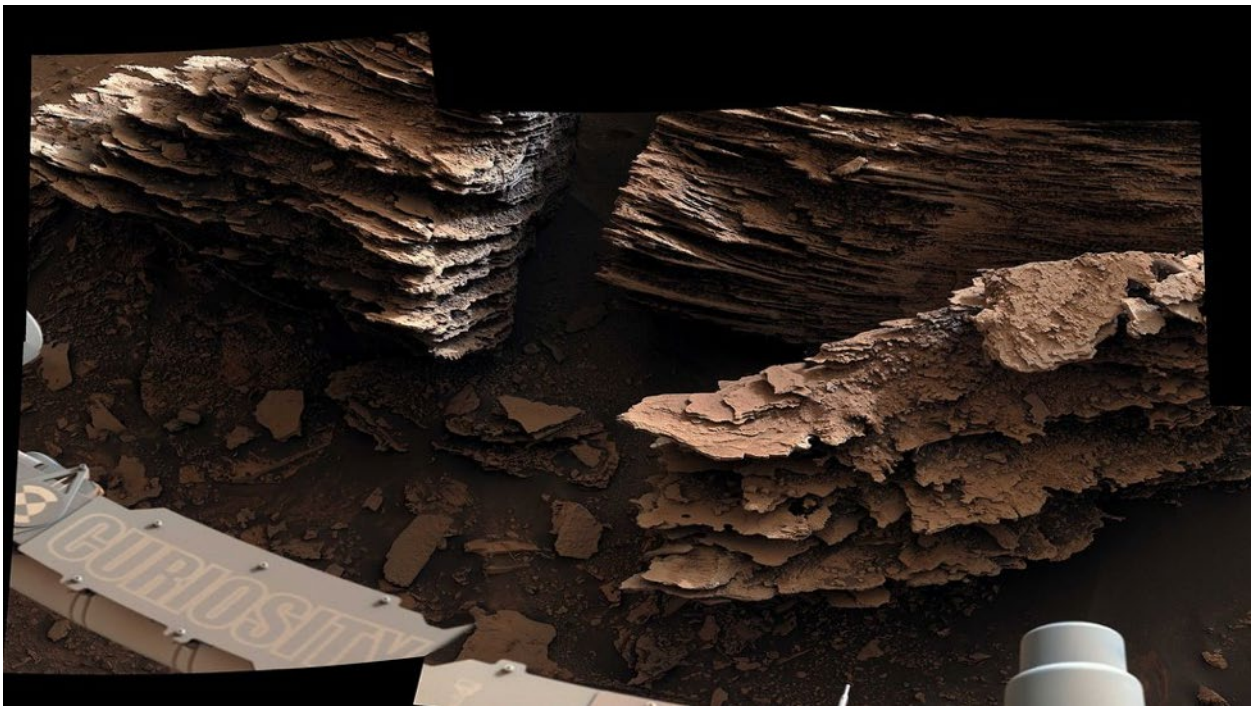
"You get reflections that are a thousand times brighter for water as opposed to ice," Schroeder said.

Schroeder, a co-investigator on REASON and part of a group that studies Europa's interior, said the new study could help the Europa Clipper team design observations to determine whether the ridges on the moon and in Greenland arose from the same underlying causes and whether water pockets are common within Europa's icy shell.

The study also highlights the growing synergy between scientists who study our planetary neighbors in the solar system and those who focus on Earth.

"This research will help us either use Earth to understand what we will see on Europa or, when we get to Europa, help us interpret what we see when we get there," Schroeder said.

NASA'S CURIOSITY CAPTURES STUNNING VIEWS OF A CHANGING MARS LANDSCAPE



NASA's Curiosity Mars rover captured this view of layered, flaky rocks believed to have formed in an ancient streambed or small pond. The six images that make up this mosaic were captured using Curiosity's Mast Camera, or Mastcam, on June 2, 2022, the 3492nd martian day, or sol, of the mission. Credit: NASA/JPL-Caltech/MSSS.

For the past year, NASA's Curiosity Mars rover has been traveling through a transition zone from a clay-rich region to one filled with a salty mineral called sulfate. While the science team targeted the clay-rich region and the sulfate-laden one for evidence each can offer about Mars' watery past, the transition zone is proving to be scientifically fascinating as well. In fact, this transition may provide the record of a major shift in Mars' climate billions of years ago that scientists are just beginning to understand.

The clay minerals formed when lakes and streams once rippled across Gale Crater, depositing sediment at what is now the base of Mount Sharp, the 5-kilometer-tall (3-mile-tall) mountain whose foothills Curiosity has been ascending since 2014. Higher on the mountain in the transition zone, Curiosity's observations show that the streams dried into trickles and sand dunes formed above the lake sediments.

"We no longer see the lake deposits that we saw for years lower on Mount Sharp," said Ashwin Vasavada, Curiosity's project scientist at NASA's Jet Propulsion Laboratory (JPL) in Southern California. "Instead, we see lots of evidence of drier climates, like dry dunes that occasionally had streams running around them. That's a big change from the lakes that persisted for perhaps millions of years before."

As the rover climbs higher through the transition zone, it is detecting less clay and more sulfate. Curiosity will soon drill the last rock sample it will take in this zone, providing a more detailed glimpse into the changing mineral composition of these rocks.

NASA's spacecraft on Mars are all affected by the winds of the Red Planet, which can produce a tiny dust devil or a global dust storm.

Unique geologic features also stand out in this zone. The hills in the area likely began in a dry environment of large, wind-swept sand dunes, hardening into rock over time. Interspersed in the remains of these dunes are other sediments carried by water, perhaps deposited in ponds or small streams that once wove among the dunes. These sediments now appear as erosion-resistant stacks of flaky layers, like one nicknamed "The Prow."

Making the story richer yet more complicated is the knowledge that there were multiple periods in which groundwater ebbed and flowed over time, leaving a jumble of puzzle pieces for Curiosity's scientists to assemble into an accurate timeline.

Curiosity will celebrate its 10th year on Mars on August 5. While the rover is showing its age after a full decade of exploring, nothing has prevented it from continuing its ascent.

On June 7, Curiosity went into safe mode after detecting a temperature reading on an instrument control box within the body of the rover that was warmer than expected. Safe mode occurs when a spacecraft senses an issue and automatically shuts down all but its most essential functions so that engineers can assess the situation.

Although Curiosity exited safe mode and returned to normal operations two days later, JPL's engineers are still analyzing the exact cause of the issue. They suspect safe mode was triggered after a temperature sensor provided an inaccurate measurement, and there is no sign it will significantly affect rover operations since backup temperature sensors can ensure the electronics within the rover body are not getting too hot.

The rover's aluminum wheels are also showing signs of wear. On June 4, the engineering team commanded Curiosity to take new pictures of its wheels, something it had been doing every 1000 meters (3281 feet) to check their overall health.

The team discovered that the left middle wheel had damaged one of its grousers, the zig-zagging treads along Curiosity's wheels. This wheel already had four broken grousers, so now five of its 19 grousers are broken.

The previously damaged grousers attracted attention online recently because some of the metal "skin" between them appears to have fallen out of the wheel in the past few months, leaving a gap.

The team has decided to increase its wheel imaging to every 500 meters (1640 feet), returning to the original cadence. A traction control algorithm had slowed wheel wear enough to justify increasing the distance between imaging.

"We have proven through ground testing that we can safely drive on the wheel rims if necessary," said Megan Lin, Curiosity's project manager at JPL. "If we ever reached the point that a single wheel had broken a majority of its grousers, we could do a controlled break to shed the pieces that are left. Due to recent trends, it seems unlikely that we would need to take such action. The wheels are holding up well, providing the traction we need to continue our climb."

U.S. SPACE FORCE RELEASES DECADES OF BOLIDE DATA TO NASA FOR PLANETARY DEFENSE STUDIES

An agreement between NASA and the U.S. Space Force recently authorized the public release of decades of data collected by U.S. government sensors on fireball events (large bright meteors also known as bolides) for the benefit of the scientific and planetary defense communities. This action results from collaboration between NASA's Planetary Defense Coordination Office (PDCO) and the U.S. Space Force to continue furthering our nation's efforts in planetary defense, which include finding, tracking, characterizing, and cataloging near-Earth objects (NEOs). The newly released data are composed of information on the changing brightness of bolides as they pass through Earth's atmosphere, called light curves, that could enhance the planetary defense community's current ability to model the effects of impacts by larger asteroids that could one day pose a threat to Earth.

Bolides, very bright meteors that can even be seen in daylight, are a regular occurrence — on the order of several

dozen times per year — that result when our planet is impacted by asteroids too small to reach the ground but large enough to explode upon impact with Earth's atmosphere. U.S. government sensors detect these atmospheric impact events, and the bolide data are reported to the Jet Propulsion Laboratory's Center for Near Earth Object Studies (CNEOS) fireballs database, which contains data going back to 1988 for nearly 1000 bolide events. Now planetary defense experts will have access to even more detailed data, specifically light-curve information that captures the optical intensity variation during the several seconds of an object's breakup in the atmosphere. This uniquely rich dataset has been greatly sought after by the scientific community, as an object's breakup in Earth's atmosphere provides scientific insight into the object's strength and composition based on the altitudes at which it breaks up and disintegrates. The approximate total radiated energy and pre-entry velocity vector (i.e., direction) can also be better derived from bolide light-curve data.

This photograph taken by an International Space Station astronaut shows a bright meteor from the Perseid meteor shower in Earth's atmosphere. The brightest meteors are known as fireballs, or bolides. Credit: NASA.

"The growing archive of bolide reports, as posted on the NASA CNEOS Fireballs website, has significantly increased scientific knowledge and contributes to the White House-approved National Near-Earth Object Preparedness Strategy and Action Plan," said Lindley Johnson, planetary defense officer at NASA Headquarters. "The release of these new bolide data demonstrates another key area of collaboration between NASA and the U.S. Space Force and helps further the pursuit of improved capabilities for understanding these objects and our preparedness to respond to the impact hazard NEOs pose to Earth."

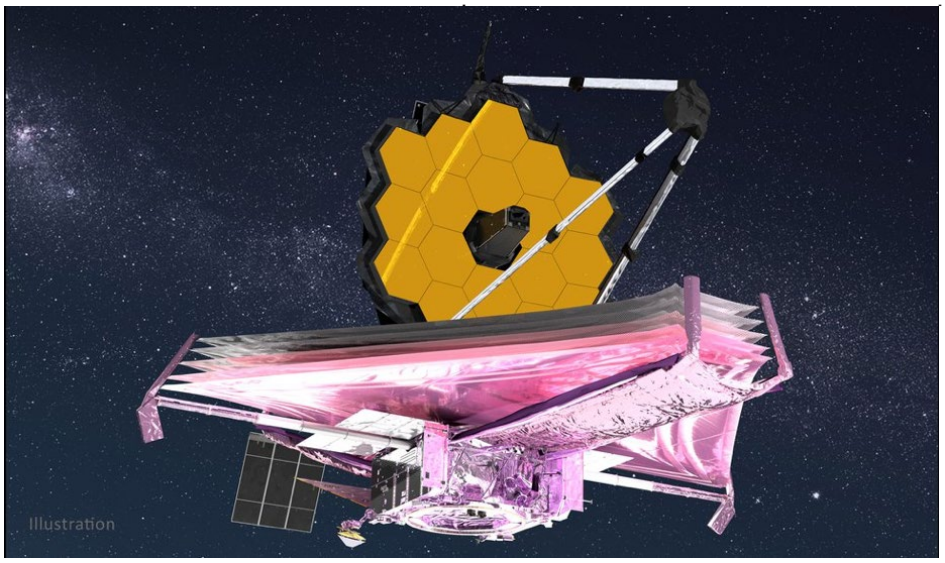
"The agency is diligently working to achieve this directive and has currently found approximately 40% of near-Earth asteroids larger than that size."

Recently a small asteroid approximately 2 meters (7 feet) in size (so small it posed no hazard to Earth) was detected in space as it approached Earth and impacted the atmosphere southwest of Jan Mayen, a Norwegian island nearly 470 kilometers (300 miles) off the eastern coast of Greenland and northeast of Iceland. While this asteroid, designated 2022 EB5, was much smaller than objects NASA is tasked to detect and warn about, CNEOS continued to update NASA's PDCO with impact location predictions as observations were collected leading up to 2022 EB5's impact. This data offered the planetary defense community a real-word scenario to test NEO tracking capabilities and give confidence that the impact prediction process and models are adequate for timely and accurate notification of the potential impact of a larger object, should one be discovered on a trajectory toward Earth. Like other bolide events, 2022 EB5's impact was detected by U.S. government sensors and reported by the U.S. Space Force units, confirming the time and location predicted by CNEOS, and was then added to NASA's archive of these events at CNEOS.

Another notable bolide event in this released dataset is of a meteor that was detected on January 8, 2014. This object gained the interest of the scientific community, as it has been posited it could have interstellar origin due to the detected event's high velocity within the atmosphere. Further analysis carried out under U.S. Space Command's purview confirmed the object's high-velocity impact, but the short duration of collected data, less than five seconds, makes it difficult to definitively determine if the object's origin was indeed interstellar.

NASA established the PDCO in 2016 to manage the agency's ongoing efforts in planetary defense. NASA has been directed to discover 90% of NEOs larger than 140 meters (459 feet) in size. The agency is diligently working to achieve this directive and has currently found approximately 40% of near-Earth asteroids larger than that size.

WEBB TELESCOPE'S COLDEST INSTRUMENT REACHES OPERATING TEMPERATURE



In this illustration, the multilayered sunshield on NASA's James Webb Space Telescope stretches out beneath the observatory's honeycomb mirror. The sunshield is the first step in cooling down Webb's infrared instruments, but the Mid-Infrared Instrument (MIRI) requires additional help to reach its operating temperature. Credit: NASA GSFC/CIL/Adriana Manrique Gutierrez.

NASA's James Webb Space Telescope will see the first galaxies to form after the big bang, but to do that its instruments first need to get cold, really cold. On April 7, Webb's Mid-Infrared Instrument (MIRI) — a joint development by NASA and the European Space Agency (ESA) — reached its final operating temperature below 7 kelvins (–266°C, or –447°F).

Along with Webb's three other instruments, MIRI initially cooled off in the shade of Webb's tennis-court-sized sunshield, dropping to about 90 kelvins (–183°C, or –298°F). But dropping to less than 7 kelvins required an electrically powered cryocooler. Last week, the team passed a particularly challenging milestone called the "pinch point" when the instrument goes from 15 kelvins (–258°C, or –433°F) to 6.4 kelvins (–267°C, or –448°F).

"The MIRI cooler team has poured a lot of hard work into developing the procedure for the pinch point," said Analyn Schneider, project manager for MIRI at NASA's Jet Propulsion Laboratory (JPL) in Southern California. "The team was both excited and nervous going into the critical activity. In the end it was a textbook execution of the procedure, and the cooler performance is even better than expected."

The low temperature is necessary because all four of Webb's instruments detect infrared light that has wavelengths slightly longer than those that human eyes can see. Distant galaxies, stars hidden in cocoons of dust, and planets outside our solar system all emit infrared light. But so do other warm objects, including Webb's own electronics and optics hardware. Cooling down the four instruments' detectors and the surrounding hardware suppresses those infrared emissions. MIRI detects longer infrared wavelengths than the other three instruments, which means it needs to be even colder.

Another reason Webb's detectors need to be cold is to suppress something called dark current, electric current created by the vibration of atoms in the detectors themselves. Dark current mimics a true signal in the detectors, giving the false impression that they have been hit by light from an external source. Those false signals can drown out the real signals that astronomers want to find. Since temperature is a measurement of how fast the atoms in the detector are vibrating, reducing the temperature means less vibration, which in turn means less dark current.

MIRI's ability to detect longer infrared wavelengths also makes it more sensitive to dark current, so it needs to be colder than the other instruments to fully remove that effect. For every degree the instrument temperature increases, the dark current goes up by a factor of about 10.

Once MIRI reached a frigid 6.4 kelvins (–209°C, or –344°F), scientists began a series of checks to make sure the detectors were operating as expected. Like a doctor searching for any sign of illness, the MIRI team looks at data describing the instrument's health, then gives the instrument a series of commands to see if it can execute tasks correctly. This milestone is the culmination of work by scientists and engineers at multiple institutions in addition to JPL, including Northrop Grumman, which built the cryocooler, and NASA's Goddard Space Flight Center, which oversaw the integration of MIRI and the cooler to the rest of the observatory.

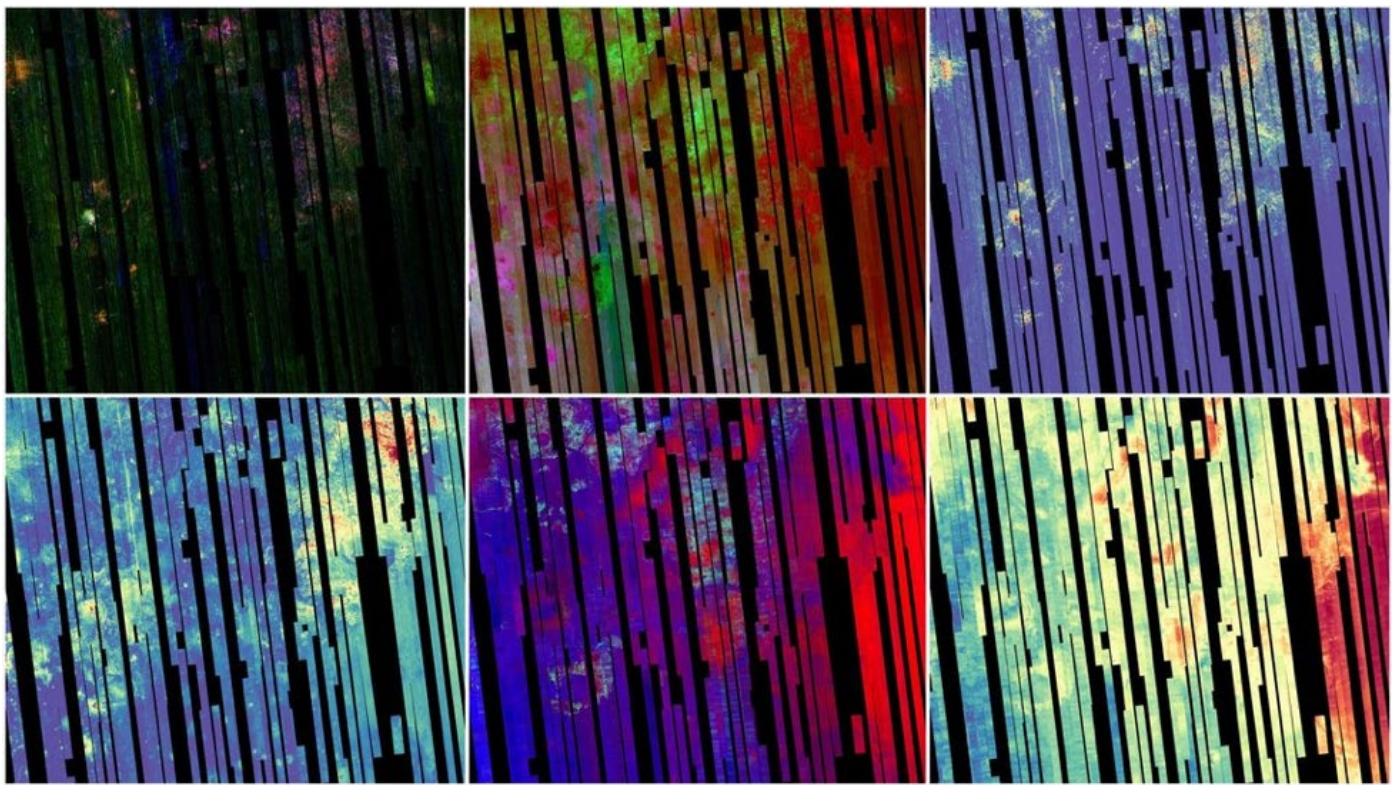
"We spent years practicing for that moment, running through the commands and the checks that we did on MIRI," said Mike Ressler, project scientist for MIRI at JPL. "It was kind of like a movie script:

Everything we were supposed to do was written down and rehearsed. When the test data rolled in, I was ecstatic to see it looked exactly as expected and that we have a healthy instrument."

There are still more challenges that the team will have to face before MIRI can start its scientific mission. Now that the instrument is at operating temperature, team members will take test images of stars and other known objects that can be used for calibration and to check the instrument's operations and functionality. The team will conduct these preparations alongside calibration of the other three instruments, delivering Webb's first science images this summer.

"I am immensely proud to be part of this group of highly motivated, enthusiastic scientists and engineers drawn from across Europe and the U.S.," said Alistair Glasse, MIRI instrument scientist at the UK Astronomy Technology Centre in Edinburgh, Scotland. "This period is our 'trial by fire,' but it is already clear to me that the personal bonds and mutual respect that we have built up over the past years is what will get us through the next few months to deliver a fantastic instrument to the worldwide astronomy community."

NASA MARS ORBITER RELEASING ONE OF ITS LAST RAINBOW-COLORED MAPS



These are six views of the Nili Fossae region of Mars captured by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), one of the instruments onboard NASA's Mars Reconnaissance Orbiter. Credit: NASA/JPL-Caltech/JHU-APL.

Scientists are about to get a new look at Mars, thanks to a multicolored 5.6-gigapixel map. Covering 86% of the Red Planet's surface, the map reveals the distribution of dozens of key minerals. By looking at mineral distribution, scientists can better understand Mars' watery past and can prioritize which regions need to be studied in more depth.

The first portions of this map were released by NASA's Planetary Data System. Over the next six months, more will be released, completing one of the most detailed surveys of the martian surface ever made.

NASA's Mars Reconnaissance Orbiter (MRO) has been mapping minerals on the Red Planet for 16 years with its Compact Reconnaissance Imaging Spectrometer for Mars (CRISM).

Using detectors that see visible and infrared wavelengths, the CRISM team has previously produced high-resolution mineral maps that provide a record of the formation of the martian crust and

where and how it was altered by water. These maps have been crucial to helping scientists understand how lakes, streams, and groundwater shaped the planet billions of years ago. NASA has also used CRISM's maps to select landing sites for other spacecraft, as with Jezero Crater where NASA's Perseverance rover is exploring an ancient river delta.

The first piece of this new map includes 51,000 images, each of which represents a "strip" 540 kilometers (336 miles) long by 10 kilometers (6 miles) wide that was captured as MRO passed overhead. The resolution is lower than CRISM maps made from targeted observations because the data were acquired with the instrument looking straight down, a different imaging strategy designed to cover much more of the planet.

To acquire its data, CRISM used two spectrometers, one of which was designed with three cryocoolers to keep temperatures low so that it could more clearly detect the longest wavelengths of reflected solar infrared light. Used in succession, the last of these cryocoolers completed its lifecycle in 2017, limiting the instrument's capabilities to view visible wavelengths. So, this will be CRISM's last map covering the instrument's full wavelength range. The instrument is now in a standby mode and may record data a few more times in the coming months before being decommissioned.

One last map will be released within the year, covering visible wavelengths and focusing only on iron-bearing minerals; this will have twice the spatial resolution of the latest map.

"The CRISM investigation has been one of the crown jewels of NASA's MRO mission," said Richard Zurek, the mission's project scientist at NASA's Jet Propulsion Laboratory in Southern California. "Analyses based on these final maps will provide new insights into the history of Mars for many years to come."

NASA'S PERSEVERANCE ROVER ARRIVES AT DELTA FOR NEW SCIENCE CAMPAIGN

This image of the parachute that helped deliver NASA's Perseverance Mars rover to the martian surface was taken by the rover's Mastcam-Z instrument on April 6, 2022. Credit: NASA/JPL-Caltech/ASU/MSSS.

After collecting eight rock core samples from its first science campaign and completing a record-breaking 31-martian-day (or sol) dash across about 5 kilometers (3 miles) of Mars, NASA's Perseverance rover arrived at the doorstep of Jezero Crater's ancient river delta on April 13. Dubbed "Three Forks" by the Perseverance team (a reference to the spot where three route options to the delta merge), the location serves as the staging area for the rover's second science expedition, the "Delta Front Campaign."

"The delta at Jezero Crater promises to be a veritable geologic feast and one of the best locations on Mars to look for signs of past microscopic life," said Thomas Zurbuchen, the associate administrator of NASA's Science Mission Directorate in Washington, DC. "The answers are out there — and Team Perseverance is ready to find them."

The delta, a massive fan-shaped collection of rocks and sediment at the western edge of Jezero Crater, formed at the convergence of a martian river and a crater lake billions of years ago. Its exploration tops the Perseverance science team's wish list because all the fine-grained sediment deposited at its base long ago is the mission's best bet for finding the preserved remnants of ancient microbial life.

Using a drill on the end of its robotic arm and a complex sample collection

system, Perseverance is gathering rock cores for return to Earth — the first part of the Mars Sample Return campaign.

"We've been eyeing the delta from a distance for more than a year while we explored the crater floor," said Ken Farley, Perseverance project scientist at Caltech in Pasadena. "At the end of our fast traverse, we are finally able to get close to it, obtaining images of ever-greater detail revealing where we can best explore these important rocks."

The Delta Front Campaign kicked off on April 18 with about a week's worth of driving to the southwest and then west. One goal of this excursion is to scope out the best route to ascend the delta, which rises about 40 meters (130 feet) above the crater floor. Two options, called "Cape Nukshak" and "Hawksbill Gap," look traversable. The science team is leaning toward Hawksbill Gap because of the shorter drive time needed to reach the top of the delta, but that may change as the rover acquires additional information on the two options. Whichever route Perseverance takes to the plateau atop the delta, the team will perform detailed science investigations, including taking rock core samples on the way up, then turning around to do the same thing on the way down. The rover is expected to collect around eight samples over about half an Earth year during the Delta Front Campaign.

After completing the descent, Perseverance will, according to current plans, again ascend the delta (perhaps via the other, untraveled route) to begin the "Delta Top Campaign" which will last about half an Earth year as well.

"The delta is why Perseverance was sent to Jezero Crater: It has so many interesting features," said Farley. "We will look for signs of ancient life in the rocks at the base of the delta, rocks that we think were once mud on the bottom of 'Lake Jezero.' Higher up the delta, we can look at sand and rock fragments that came from upstream, perhaps from miles away. These are locations the rover will never visit. We can take advantage of an ancient martian river that brought the planet's geological secrets to us."

Perseverance is kicking off its second science campaign more than a month earlier than planned due to the rover's ability to autonomously negotiate Jezero Crater's sandpits, craters, boulders, and fields of sharp rocks. The rover's six flight-grade aluminum wheels completed 3116.25 revolutions during the 5065-meter (16,617-foot) journey to Three Forks. Averaging 211 meters (692 feet) per drive (no driving occurred on six sols), the rover's artificial-intelligence-assisted auto-navigation capability, or AutoNav, assessed 10,744 navigation camera images during the road trip and commanded the rover to halt and turn in place to negotiate surface hazards 55 times.

NASA'S CURIOSITY ROVER MEASURES INTRIGUING CARBON SIGNATURE ON MARS

After analyzing powdered rock samples collected from the surface of Mars by NASA's Curiosity rover, scientists have announced that several of the samples are rich in a type of carbon that on Earth is associated with biological processes.

While the finding is intriguing, it does not necessarily point to ancient life on Mars, as scientists have not yet found conclusive supporting evidence of ancient or current biology there, such as sedimentary rock formations produced by ancient bacteria or a diversity of complex organic molecules formed by life.

"We're finding things on Mars that are tantalizingly interesting, but we would really need more evidence to say we've identified life," said Paul Mahaffy, who served as the principal investigator of the Sample Analysis at Mars (SAM) chemistry lab onboard Curiosity until retiring from NASA's Goddard Space Flight Center in Greenbelt, Maryland, in December 2021. "So we're looking at what else could have caused the carbon signature we're seeing, if not life."

In a report of their findings published in the journal *Proceedings of the National Academy of Sciences* in January, Curiosity scientists offer several explanations for the unusual carbon signals they detected. Their hypotheses are drawn partly from carbon signatures on Earth, but scientists warn the two planets are so different they can't make definitive conclusions based on Earth examples.

"The hardest thing is letting go of Earth and letting go of that bias that we have and really trying to get into the fundamentals of the chemistry, physics, and environmental processes on Mars," said Goddard astrobiologist Jennifer Eigenbrode, who participated in the carbon study. Previously, Eigenbrode

NASA's Curiosity Mars rover captured these clouds just after sunset on March 19, 2021, the 3063rd martian day, or sol, of the rover's mission. The image is made up of 21 individual images stitched together and color-corrected so that the scene appears as it would to the human eye. Credit: NASA/JPL-Caltech/MSSS.

led an international team of Curiosity scientists in the detection of myriad organic molecules — ones that contain carbon — on the martian surface.

"We need to open our minds and think outside the box, and that's what this paper does," said Eigenbrode.

The biological explanation Curiosity scientists present in their paper is inspired by Earth life. It involves ancient bacteria in the surface that would have produced a unique carbon signature as they released methane into the atmosphere where ultraviolet light would have converted that gas into larger, more complex molecules. These new molecules would have rained down to the surface and could be preserved with their distinct carbon signature in martian rocks.

Two other hypotheses offer nonbiological explanations. One suggests the carbon signature could have resulted from the interaction of ultraviolet light with carbon dioxide gas in the martian atmosphere, producing new carbon-containing molecules that would have settled to the surface. The other hypothesis speculates that the carbon could have been left behind from a rare event hundreds of millions of years ago when the solar system passed through a giant molecular cloud rich in the type of carbon detected.

"All three explanations fit the data," said Christopher House, a Curiosity scientist based at Pennsylvania State University who led the carbon study. "We simply need more data to rule them in or out."

> **"On Earth, processes that would produce the carbon signal we're detecting on Mars are biological."**

To analyze carbon in the martian surface, House's team used the Tunable Laser Spectrometer (TLS) instrument inside the SAM lab. SAM heated 24 samples from geologically diverse locations in the planet's Gale Crater to about 850°C (or 1500°F) to release the gases inside. Then the TLS measured the isotopes from some of the reduced carbon that was set free in the heating process. Isotopes are atoms of an element with different masses due to their distinct number of neutrons, and they are instrumental in understanding the chemical and biological evolution of planets.

Carbon is particularly important since this element is found in all life on Earth; it flows continuously through the air, water, and ground in a cycle that is well understood thanks to isotope measurements.

For instance, living creatures on Earth use the smaller, lighter carbon-12 atom to metabolize food and for photosynthesis versus the heavier carbon-13 atom. Thus, significantly more carbon-12 than carbon-13 in ancient rocks, along with other evidence, suggests to scientists they are looking at signatures of life-related chemistry. Looking at the ratio of these two carbon isotopes helps Earth scientists tell what type of life they are looking at and the environment it lived in.

On Mars, Curiosity researchers found that nearly half their samples had surprisingly large amounts of carbon-12 compared to what scientists have measured in the martian atmosphere and meteorites. These samples came from five distinct locations in Gale Crater, the researchers report, which may be related in that all the locations have well-preserved ancient surfaces.

"On Earth, processes that would produce the carbon signal we're detecting on Mars are biological," House said. "We have to understand whether the same explanation works for Mars, or if there are other explanations because Mars is very different."

Mars is unique because it may have started off with a different mix of carbon isotopes than Earth 4.5 billion years ago. Mars is smaller, cooler, has weaker gravity, and has different gases in its atmosphere. In addition, the carbon on Mars could be cycling without any life involved.

"There's a huge chunk of the carbon cycle on Earth that involves life, and because of life, there is a chunk of the carbon cycle on Earth we can't understand, because everywhere we look there is

life," said Andrew Steele, a Curiosity scientist based at the Carnegie Institution for Science in Washington, DC.

Steele noted that scientists are in the early stages of understanding how carbon cycles on Mars and how to interpret isotopic ratios and the nonbiological activities that could lead to those ratios. Curiosity, which arrived on the Red Planet in 2012, is the first rover with tools to study carbon isotopes in the surface. Other missions have collected information about isotopic signatures in the atmosphere, and scientists have measured ratios of martian meteorites that have been collected on Earth.

"Defining the carbon cycle on Mars is absolutely key to trying to understand how life could fit into that cycle," Steele said. "We have done that really successfully on Earth, but we are just beginning to define that cycle for Mars."

Curiosity scientists will continue to measure carbon isotopes to see if they get a similar signature when the rover visits other sites suspected to have well-preserved ancient surfaces. To further test the biological hypothesis involving methane-producing microorganisms, the Curiosity team would like to analyze the carbon content of a methane plume released from the surface. The rover unexpectedly encountered such a plume in 2019, but there is no way to predict whether that will happen again. Otherwise, researchers point out that this study provides guidance to the team behind NASA's Perseverance rover on the best types of samples to collect to confirm the carbon signature and determine definitively whether it is coming from life or not. Perseverance is collecting samples from the martian surface for possible future return to Earth.

NEW MAPS OF ASTEROID PSYCHE REVEAL AN ANCIENT WORLD OF METAL AND ROCK

Later this year, NASA is set to launch a probe the size of a tennis court to the asteroid belt, a region between the orbits of Mars and Jupiter where remnants of the early solar system circle the Sun. Once inside the asteroid belt, the spacecraft will zero in on Psyche, a large, metal-rich asteroid that is thought to be the ancient core of an early planet. The probe, named after its asteroid target, will then spend close to two years orbiting and analyzing Psyche's surface for clues to how early planetary bodies evolved.

Ahead of the mission led by principal investigator Lindy Elkins-Tanton, planetary scientists at the Massachusetts Institute of Technology (MIT) and elsewhere have now provided a sneak peak of what the Psyche spacecraft might see when it reaches its destination.

In a paper that appeared in June in the *Journal of Geophysical Research: Planets*, the team presents the most detailed maps of the asteroid's surface properties to date based on observations taken by a large array of ground telescopes in northern Chile. The maps reveal vast metal-rich regions sweeping across the asteroid's surface, along with a large depression that appears to have a different surface texture between the interior and its rim; this difference could reflect a crater filled with finer sand and rimmed with rockier materials. Overall, Psyche's surface was found to be surprisingly varied in its properties.

The new maps hint at the asteroid's history. Its rocky regions could be vestiges of an ancient mantle — similar in composition to the rocky outermost layer of Earth, Mars, and the asteroid Vesta — or the imprint of past impacts by space rocks. Finally, craters that contain metallic material support the idea proposed by previous studies that the asteroid may have experienced early eruptions of metallic lava as its ancient core cooled.

> **" It's an evolved surface, and these maps confirm that metal-rich asteroids are interesting, enigmatic worlds."**

"Psyche's surface is very heterogeneous," says lead author Saverio Cambioni, the Crosby Distinguished Postdoctoral Fellow in MIT's Department of Earth, Atmospheric, and Planetary Sciences (EAPS). "It's an evolved surface, and these maps confirm that metal-rich asteroids are interesting, enigmatic worlds. It's another reason to look forward to the Psyche mission going to the asteroid."

Cambioni's co-authors are Katherine de Kleer, assistant professor of

Astronomers at MIT and elsewhere have mapped the composition of asteroid Psyche, revealing a surface of metal, sand, and rock. Credit: NASA.

planetary science and astronomy at Caltech, and Michael Shepard, professor of environmental, geographical, and geological sciences at Bloomsburg University.

The surface of Psyche has been a focus of numerous previous mapping efforts. Researchers have observed the asteroid using various telescopes to measure light emitted from the asteroid at infrared wavelengths that carry information about Psyche's surface composition. However, these studies could not spatially resolve variations in composition over the surface.

Instead, Cambioni and his colleagues were able to see Psyche in finer detail, at a resolution of about 32 kilometers (20 miles) per pixel, using the combined power of the 66 radio antennas of the Atacama Large Millimeter/submillimeter Array (ALMA) in northern Chile. Each antenna of ALMA measures light emitted from an object at millimeter wavelengths within a range that is sensitive to temperature and certain electrical properties of surface materials.

"The signals of the ALMA antennas can be combined into a synthetic signal that's equivalent to a telescope with a diameter of 16 kilometers (10 miles)," de Kleer said. "The larger the telescope, the higher the resolution."

On June 19, 2019, ALMA focused its entire array on Psyche as it orbited and rotated within the asteroid belt. De Kleer collected data during this period and converted it into a map of thermal emissions across the asteroid's surface, which the team reported in a 2021 study. Those same data were used by Shepard to produce the most recent high-resolution three-dimensional shape model of Psyche, also published in 2021.

In the new study, Cambioni ran simulations of Psyche to see which surface properties might match best and explain the measured thermal emissions. In each of hundreds of simulated scenarios, he set the asteroid's surface with different combinations of materials, such as areas of different metal abundances. He modeled the asteroid's rotation and measured how simulated materials on the asteroid would give off thermal emissions. Cambioni then looked for the simulated emissions that best matched the actual emissions measured by ALMA. That scenario, he reasoned, would reveal the likeliest map of the asteroid's surface materials.

"We ran these simulations area by area so we could catch differences in surface properties," Cambioni said.

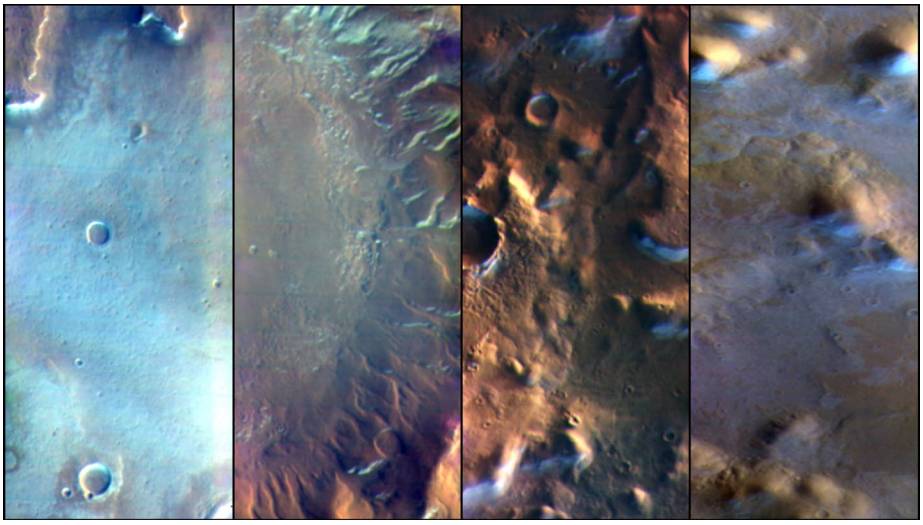
The study produced detailed maps of Psyche's surface properties, showing that the asteroid's façade is likely covered in a large diversity of materials. The researchers confirmed that, overall, Psyche's surface is rich in metals, but the abundance of metals and silicates varies across its surface. This may be a further hint that early in its formation, the asteroid may have had a silicate-rich mantle that has since disappeared.

They also found that, as the asteroid rotates, the material at the bottom of a large depression — likely a crater — changes temperature much faster than material along the rim. This suggests that the crater bottom is covered in "ponds" of fine-grained material like sand on Earth, which heats up quickly, whereas the crater rims are composed of rockier, slower-to-warm materials.

"Ponds of fine-grained materials have been seen on small asteroids, whose gravity is low enough for impacts to shake the surface and cause finer materials to pool," Cambioni said. "But Psyche is a large body, so if fine-grained materials accumulated on the bottom of the depression, this is interesting and somewhat mysterious."

"These data show that Psyche's surface is heterogeneous, with possible remarkable variations in composition," said Simone Marchi, staff scientist at the Southwest Research Institute and a co-investigator on NASA's Psyche mission, who was not involved in the current study. "One of the primary goals of the Psyche mission is to study the composition of the asteroid surface using its gamma rays and neutron spectrometer and a color imager. So, the possible presence of compositional heterogeneities is something that the Psyche science team is eager to study more."

SCIENCE AT SUNRISE: SOLVING THE MYSTERY OF FROST HIDING ON MARS



Martian surface frost, made up largely of carbon dioxide, appears blueish-white in these images from the Thermal Emission Imaging System (THEMIS) camera onboard NASA's 2001 Odyssey orbiter. THEMIS takes images in both visible light perceptible to the human eye and heat-sensitive infrared. Credit: NASA/JPL-Caltech/ASU.

Scientists were baffled last year while studying images of the martian surface taken at dawn by NASA's Mars Odyssey orbiter. When they looked at the surface using visible light — the kind that the human eye perceives — they could see ghostly, blueish-white morning frost illuminated by the rising Sun. But using the orbiter's heat-sensitive camera, the frost appeared more widely, including in areas where none was visible.

The scientists knew they were looking at frost that forms overnight and is made mostly of carbon dioxide — essentially, dry ice, which often appears as frost on the Red Planet rather than as water ice. But why was this dry-ice frost visible in some places and not others?

In a paper published in the *Journal of Geophysical Research: Planets*, these scientists proposed a surprising answer that may also explain how dust avalanches, which are reshaping the planet, are triggered after sunrise.

Launched in 2001, Odyssey is NASA's longest-lived Mars mission and carries the Thermal Emission Imaging System (THEMIS), an infrared, or temperature-sensitive, camera that provides a one-of-a-kind view of the martian surface. Odyssey's current orbit provides a unique look at the planet at 7:00 a.m. local Mars time.

"Odyssey's morning orbit produces spectacular pictures," said Sylvain Piqueux of NASA's Jet Propulsion Laboratory (JPL) in Southern California and primary author of the paper. "We can see the long shadows of sunrise as they stretch across the surface."

Because Mars has so little atmosphere (just 1% the density of Earth's), the Sun quickly warms frost that builds up overnight. Instead of melting, dry ice vaporizes into the atmosphere within minutes.

Lucas Lange, a JPL intern working with Piqueux, first noticed the cold-temperature signature of frost in many places where it couldn't be seen on the surface. These temperatures were appearing just tens of micrometers underground — less than the width of a human hair "below" the surface.

"Our first thought was ice could be buried there," Lange said. "Dry ice is plentiful near Mars' poles, but we were looking closer to the equator of the planet, where it's generally too warm for dry-ice frost to form."

In their paper, the authors propose they were seeing "dirty frost" — dry-ice frost mixed with fine grains of dust that obscured it in visible light but not in infrared images.

The phenomenon led the scientists to suspect dirty frost might also explain some of the dark streaks that can stretch 1000 meters (3300 feet) or more down martian slopes. They knew the streaks resulted from dust avalanches that slowly reshape mountainsides across the planet. Scientists think these dust avalanches probably look something like a ground-hugging river of dust releasing a trail of fluffy material behind. As the dust travels downhill over several hours, it exposes streaks of darker material underneath.

These dark streaks are not the same as a better-documented variety called recurring slope lineae, which recur in the same places season after season for weeks (instead of hours) at a time. Once thought to result from briny water slowly seeping from mountainsides, recurring slope lineae are now generally believed to result from flows of dry sand or dust.

Mapping the slope streaks for their recent study, the authors found they tend to appear in places with morning frost. The researchers propose the streaks resulted from the vaporizing frost creating just enough pressure to loosen the dust grains, causing an avalanche.

The hypotheses are further evidence of just how surprising the Red Planet can be.

"Every time we send a mission to Mars, we discover exotic new processes," said Chris Edwards, a paper co-author at Northern Arizona University in Flagstaff. "We don't have anything exactly like a slope streak on Earth. You have to think beyond your experiences on Earth to understand Mars."

THE IMPORTANCE OF IDEA IN PLANETARY SCIENCE

By Edgard G. Rivera-Valentín

As you read this, think about who is in your organization, your department, and those who you closely collaborate with. Then ask yourself who is missing from the conversation and who are you listening to? Are you thinking about and acknowledging the hardships faced by different people in your group, and are you working with them to include them in your work?

For decades, sociologists have advised businesses that diverse and inclusive teams lead to innovative work and increased creativity. Studies have shown that a randomly selected group of problem-solvers often outperforms groups only composed of those identified as the "best" in the field. For these reasons, to advance planetary science and astrobiology, the community should embrace the principles of inclusion, diversity, equity, and accessibility (IDEA). But more importantly, beyond wanting to drive scientific progress, IDEA principles are a social imperative. The fair, just, and impartial treatment of all people is a hallmark of an ethical community.

Over the past few years, several resources have been made available that we can leverage to make progress towards a more inclusive, diverse, equitable, and accessible community. For the first time, the Planetary Science and Astrobiology Decadal Survey requested white papers on the state of the profession from the community and included those findings and recommendations in the survey report. Beyond the decadal survey, the National Academies of Sciences, Engineering, and Medicine released a report providing guidance on "Advancing Diversity, Equity, Inclusion, and Accessibility in the Leadership of Competed Space Missions." Recently, the LPI hosted the Advancing IDEA in Planetary Science conference, which facilitated discussions on ongoing and needed initiatives in the community and provided tangible recommendations in the conference Consensus Report. NASA has also released an Equity Action Plan and a policy statement on Diversity, Equity, Inclusion, and Accessibility. Acknowledging the severe underrepresentation of Black and Latinx researchers in planetary science, the LPI's Planetary ReaCH program, funded by the NASA Science Activation Program, is hosting workshops on Culturally Inclusive Planetary Engagement to provide actionable strategies so that scientists can build authentic partnerships with Black and Latinx audiences.

IDEA IN ACTION

Learning from these resources can help us all be better allies. We can also take another step by advocating for the recommendations in some of these reports and supporting, participating, and learning from IDEA groups. For example, the Cross-AG IDEA Working Group develops and disseminates resources, findings, and other recommendations associated with IDEA matters for the NASA Assessment/Analysis Groups (AGs). There are also several advocacy groups centering on historically excluded people, such as the Planetary Scientists of Color (PSoC), Women in Planetary Science (WiPS), Queers in Planetary Science (QuiPS), and Disabled for Accessibility in Space (DAIS). A simple, daily task we can all do is to ask ourselves questions, such as those posed at the beginning of this article, to reflect on our actions and improve how we interact with others.

Planetary science and astrobiology are inspirational endeavors that bring awe and wonder to many. As the people leading the discoveries in the field, we are its representatives, which carries with it a responsibility to demonstrate principled work. To quote directly from the Planetary Science and Astrobiology Decadal Survey, "NASA's aspirational nature, built on the idea of limitless exploration, provides a fitting backdrop to develop initiatives that will seek solutions to the issues that concern the state of the profession." Advancing an entire field can seem daunting, but we are the community that launched missions to explore the outermost edges of the solar system and learned to overcome extreme environments just for a glimpse of what lies beyond Earth. If each of us takes a step forward, we can take giant leaps together!

ENGAGING DIVERSE COMMUNITIES IN PLANETARY SCIENCE

A 2021 survey of planetary scientists conducted by the Planetary Resources and Content Heroes (ReaCH) team revealed a desire to engage more effectively with diverse communities and a need for help in learning where and how to begin.

The Planetary ReaCH team, led by Andy Shaner, principal investigator and senior education specialist at the Lunar and Planetary Institute, is developing workshops for planetary science and exploration subject matter experts (SMEs; including graduate students, post-doctoral researchers, engineers, and technicians) to learn how to effectively engage diverse audiences, specifically Black and Latinx youth and their families, in planetary science and exploration.

In April 2022, the Planetary ReaCH team held a three-day pilot workshop at Arizona State University (ASU) to begin to address this need. Workshop participants — planetary scientists and informal educators — explored strategies and resources for engaging diverse audiences in the excitement of NASA's planetary science and exploration. Following the workshop, participants conducted a public engagement event at Riverside Elementary School in Phoenix, Arizona, with students and their families, many of whom identify as Latinx. This event enabled participants to practice activities and engagement strategies from the workshop.

Participants indicated the workshop helped them prepare to engage diverse audiences, noting that the post-workshop public event was a beneficial exercise. Lessons learned from evaluation data and the experience will inform future ReaCH workshops. The next Planetary ReaCH workshop will be in Houston, Texas, on August 4–6, 2022. Join the Planetary ReaCH mailing list and receive information about upcoming events at mailchi.mp/lpi.usra.edu/planetary-reach.

Ms. Corinne Rojas of Arizona State University, planetary science subject matter expert and Mastcam Operations Engineer on the Perseverance rover, speaks with children about exploring Mars with rovers.

The Planetary ReaCH team is part of a cooperative network from across the nation that works with NASA to connect NASA science experts and content to engage with learners of all ages to activate minds and promote a deeper understanding of our world and beyond.

Planetary ReaCH is supported by NASA under cooperative agreement award number 80NSSC21M0003 and is part of NASA's Science Activation Portfolio.

NASA RELEASES EQUITY ACTION PLAN TO MAKE SPACE MORE ACCESSIBLE TO ALL

In support of the Biden-Harris Administration's efforts to advance racial equity in the federal government, NASA has released its first-ever Equity Action Plan. The plan establishes key focus areas that will allow the agency to track progress toward improved diversity, equity, inclusion, and accessibility both internally and externally to NASA.

"At NASA, all of our missions depend on our steadfast commitment to equal opportunity," said NASA Administrator Bill Nelson. "The Equity Action plan deepens our commitment to further identify and remove the barriers that limit opportunity in underserved and underrepresented communities. This framework anchors fairness as a core component in every NASA mission to make the work we do in space and beyond more accessible to all."

The four focus areas the plan addresses are:

- Increasing integration and utilization of contractors and businesses from underserved communities and expanding equity in NASA's procurement process
- Enhancing grants and cooperative agreements to advance opportunities, access, and representation for underserved communities
- Leveraging Earth science and socioeconomic data to help mitigate environmental challenges in underserved communities
- Advancing external civil rights compliance and expanding access to limited English proficient populations within underserved communities

NASA will lean into the focus areas by further analyzing and assessing feedback received from an initial request for information. The initial request solicited insight from the public on whether, and to what extent, NASA programs and policies perpetuate barriers and limit benefits for people of color and other underserved communities. The agency also will work to implement enhancements to policies and programs that bridge gaps and provide more opportunities within NASA, the aerospace industry, and STEM fields.

This action plan is the latest step in the agency's Mission Equity initiative announced last year in response to White House Executive Order 13985, "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government."

For more information about the Equity Action Plan and NASA's Mission Equity initiative, visit nasa.gov/mission-equity.

THE COLOR OF SPACE: A NASA DOCUMENTARY SHOWCASING THE STORIES OF BLACK ASTRONAUTS

Credit: NASA.

The Color of Space captures the personal stories of seven current and former Black astronauts, each selected to become part of NASA's astronaut corps and train for space missions. Current NASA astronauts Stephanie Wilson, Victor Glover, Jeanette Epps, as well as retired astronauts Leland Melvin, Bernard Harris, Robert Curbeam, and Bobby Satcher, speak about their journeys and their motivations in a panel hosted by NASA Johnson Space Center Director Vanessa Wyche, the first Black woman to lead a NASA center.

They took the step to achieve the impossible, overcoming barriers and making space for others to follow. In this new documentary, be empowered by the remarkable stories of tenacity, courage, and motivation from the agency's most decorated heroes. Learn about their path to NASA, their sources of inspiration, experiences in space, the importance of representation, the meaning of Juneteenth, and much more.

Originally held at Space Center Houston on March 25, the panel discussion marks the first time the seven astronauts have been assembled for an official NASA event. For more details, visit go.nasa.gov/3Oktwxa.

JESSICA WATKINS MAKES HISTORY AS FIRST BLACK WOMAN ON ISS CREW

NASA has assigned astronaut Jessica Watkins to serve as a mission specialist on the agency's SpaceX Crew-4 mission, the fourth crew rotation flight of the Crew Dragon spacecraft to the International Space Station, which docked on April 27, 2022.

This is Watkins' first trip to space following her selection as an astronaut in 2017. Watkins joins NASA astronauts Kjell Lindgren and Robert Hines, as well as European Space Agency (ESA) astronaut Samantha Cristoforetti, as a crew member for the Crew-4 mission.

Watkins was born in Gaithersburg, Maryland, and considers Lafayette, Colorado, her hometown. She earned a bachelor's degree in geological and environmental sciences from Stanford University and a doctorate in geology from the University of California, Los

Credit: NASA/Bill Ingalls.

Angeles. Dr. Watkins conducted her graduate research on the emplacement mechanisms of large landslides on Mars and Earth. She began her career at NASA as an intern and has worked at the agency's Ames Research Center in California and NASA's Jet Propulsion Laboratory in Southern California. At the time of her astronaut selection, Watkins was a postdoctoral fellow in the Division of Geological and Planetary Sciences at the California Institute of Technology, where she collaborated as a member of the Science Team for the Mars Science Laboratory rover, Curiosity.

Follow Watkins on Instagram throughout her mission and get the latest space station crew news, images and features on Instagram, Facebook, and Twitter.

AGU BRIDGE PARTNER PROPOSALS DUE OCTOBER 1

AGU BRIDGE PROGRAM

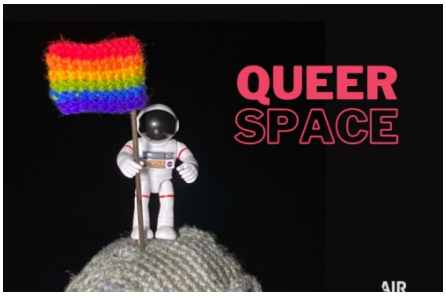
The Bridge Program increases opportunities for students from historically marginalized populations to obtain graduate degrees and create a network of peers, mentors, and advisers to support and serve them before, during, and after grad school. The program is open to those who have not applied to graduate school or those who applied and were not accepted.

As part of the Inclusive Graduate Education Network (IGEN), the Bridge Program defined standards for recruiting, admitting, and retaining students to develop, adopt and share the best inclusive practices. AGU works as a community with this national network to provide opportunities for students and participating institutions. Download the flyer and learn more.

The AGU Bridge Program is an asset to institutions seeking to increase diversity in their departments and the larger geosciences community. By working together, we can create a more welcoming environment in the Earth and space sciences for everyone. With the addition of the 2021 partner cohort, the AGU Bridge Program now has a total of 46 partner departments.

To learn more, visit www.agu.org/bridge-program.

QUEERSPACE PODCAST FROM THE SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM



QueerSpace is a limited series from the creators of AirSpace, featuring stories and people at the intersection of aviation, space, and LGBTQ+ history and culture. This podcast series highlights the scope and diversity of queer experiences found across human flight and space science.

- Episode 1: Fly the Friendly Skies — The community built by male flight attendants in the 1970s
- Episode 2: We're All Stories in the End — Queer worldbuilding in science fiction
- Episode 3: Becoming Light — The Air Force and Space Force's LGBTQ+ Initiative Team
- Episode 4: Saxophones on the Moon — Space, queerness, and futurism in art
- Episode 5: Fight for Your Right — The first precedent ruling that the federal government can't fire an employee for being gay

Listen to QueerSpace: Apple Podcasts | Spotify | RadioPublic | Stitcher

THE 41ST ANNUAL TECHNICAL CONFERENCE OF THE NATIONAL ASSOCIATION OF BLACK GEOSCIENTISTS

"Reimagining the Geosciences"
September 7–10, 2022
Houston, Texas

Come join us as we work towards developing strategies for the geoscience future. Let's move to understand the realities associated with generating reliable and affordable energy while working towards a low-carbon existence. Register now to ensure that you are an effective part of the movement toward progress and evolution in the ever-changing geosciences.

The National Association of Black Geoscientists (NABG) was organized to:

- Inform students of career opportunities that exist in the field of Geosciences.
- Encourage them to take advantage of scholarship programs, grant, loans, etc., that are established for minority students.
- Give financial support to students pursuing degrees in Geology and Geophysics.
- Follow the educational careers of the scholarship recipients.
- Aid minority students in the search for summer employment and aid corporate members interested in obtaining summer employees for positions that will enhance the students' background and marketability.
- Allow minority geologists and geophysicists to establish professional and inter-company relationships.
- Assist in the development of professional standards and practices of members within their geoscience careers and entrepreneurial pursuits.

GEM RECEIVES 2022 PRESIDENTIAL AWARD FOR EXCELLENCE IN SCIENCE, MATHEMATICS, AND ENGINEERING MENTORING

The National GEM Consortium, a nonprofit organization working collaboratively across education and industry sectors to advance the next generation of STEM professionals, has received a Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring (PAESMEM) announced earlier this year by President Joe Biden. The PAESMEM award is the nation's highest award of its kind. The prestigious recognition honors the exceptional efforts of mentors in encouraging the next generation of innovators and developing a science and engineering workforce that reflects the diverse talent of America.

Founded at the University of Notre Dame, GEM has been instrumental in its mission to enhance the value of the nation's human capital by increasing the participation of underrepresented groups (African Americans, American Indians, and Hispanic Americans) at the master's and doctoral levels in engineering and science. To date, the organization has graduated over 4,000 GEM fellowships including researchers, professors, entrepreneurs, inventors, and business leaders.

"For the past 45 years, GEM has been supporting the best and brightest talent in STEM, who are also members of underrepresented communities. These individuals not only achieve their fullest potential, but also give back to help those coming up behind them," said GEM CEO, Brennon Marcano.

PAESMEM recognizes the critical roles mentors play outside the traditional classroom in the academic and professional development of the future STEM workforce, now at a critical shortage of qualified professionals. Between 2005 and 2015, STEM employment in the United States grew by nearly 25% — over five times more than non-STEM employment over the same period. Throughout the 2020s, the U.S. Bureau of Labor Statistics projects more than 1,000,000 STEM jobs will have been added, representing nearly 11% growth and at a median annual wage of $89,780.

For more information about the National GEM Consortium, visit www.gemfellowship.org/.

SACNAS RECEIVES FUNDING FROM GENERAL MOTORS (GM) TO DEEPEN INVOLVEMENT AT TRIBAL COLLEGES AND UNIVERSITIES

SACNAS (Society for Advancement of Chicanos/Hispanics & Native Americans in Science) is honored to receive funding from General Motors (GM) to support their initiative to work with tribal colleges and universities (TCU) and their students and faculty in STEM.

"We look forward to working closely with TCU students, faculty, and administrators to build meaningful relationships and deliver empowering programming to our communities at these campuses," said Dr. Darryl Monteau, SACNAS Associate Director, Mission Programs and Native Initiatives. "We are very appreciative of this support from GM and the chance to make a difference for our Native American and Indigenous students in STEM. Through their support, we'll also work intimately with campuses interested in starting their own SACNAS chapter."

There are currently 35 TCUs across the United States serving over 16,000 college students, and all of them are diverse and unique in the students they serve and the programs they offer.

About SACNAS

For 49 years, SACNAS has served as an inclusive organization dedicated to fostering the success of Chicano/Hispanics & Native Americans, from college students to professionals, in attaining advanced degrees, careers, and positions of leadership within STEM. Today, the organization serves a growing community of over 28,000 supporters, including nearly 8,000 members and 133 student and professional chapters throughout the United States, including Guam and Puerto Rico. SACNAS influences the STEM diversity movement through STEM outreach and advocacy, the promotion of STEM leaders, and The SACNAS National Diversity in STEM Conference. Learn more about SACNAS at sacnas.org, Facebook, or Twitter.

TOOLS FOR ENGAGING COMMUNITIES AND INCORPORATING DIVERSITY, EQUITY, ACCESSIBILITY, AND INCLUSION (DEAI) PRACTICES

The National Informal STEM Education (NISE) Network offered an online workshop on July 19 that explored the Diversity, Equity, Accessibility, and Inclusion (DEAI) tools and resources that the NISE Network and other organizations have to offer, alongside examples from the Making Earth & Space Relevant and Inclusive Professional Learning Community. Whether you are new to DEAI work or are just looking for additional resources and examples, this recording offers an opportunity to reflect on how you can make your own programming more relevant and inclusive to your audiences.

The NISE Network is a community of informal educators and scientists dedicated to supporting learning about science, technology, engineering, and math (STEM) across the United States.

MEETING HIGHLIGHTS

ADVANCING IDEA IN PLANETARY SCIENCE

The Advancing IDEA in Planetary Science Conference was held virtually on April 25–29, 2022. The conference was motivated by the recent transformation of thought in the planetary and astrobiological sciences regarding the principles of inclusion, diversity, equity, and accessibility (IDEA).

Over the past decade, NASA and other planetary science stakeholders have committed to fostering IDEA principles throughout their agencies and funded programs. NASA has added language to standard Announcements of Opportunity, requested information and feedback from the community on agency practices, and added inclusion as a core value. Additionally, for the first time, the Planetary Science and Astrobiology Decadal Survey "Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032" (OWL) requested white papers on the state of the profession from the community and included those findings and recommendations in the survey report. The Decadal Survey on Astronomy and Astrophysics "Pathways to Discovery in Astronomy and Astrophysics for the 2020s", which partially covered planetary science, also included IDEA-related recommendations to advance the field.

In the wake of these activities, the Advancing IDEA in Planetary Science Conference aimed to leverage this momentum to ensure that the planetary science and astrobiology community can make the necessary improvements toward advancing IDEA principles in the workforce over the next decade. The goal of the conference was to bring together the planetary, astrobiological, and social science communities to (1) lean into lessons learned to date, (2) identify opportunities for improvement by listening to those most impacted in the community, and (3) make recommendations for actionable and tangible measures for advancing IDEA principles within planetary science.

The conference received 70 abstract submissions and 427 registrants from across the planetary, astrobiological, and social sciences. Besides presentations based on contributed abstracts, the conference included talks from four keynote speakers. These presentations were intended to provide important context and set the tone for the discussion. Janet Vertesi (Department of Sociology, Princeton University) and co-speaker Stephanie Beth Jordan (Department of Communication Arts and Science, Michigan State University) presented "Science in/as White Space: Ethnographic Observations from the Planetary, Earth, and Ocean Science Communities." Adia Harvey Wingfield (Department of Sociology, Washington University in St. Louis) presented "Behind the Myth of Meritocracy: How STEM Fields Perpetuate Racial and Gender Disparities." Orlando Figueroa (Orlando Leadership Enterprise, LLC) presented "Conclusions from the Planetary and Astrobiology Decadal Survey on the State of the Profession and Personal Observations." Phoebe Cohen (Department of Geosciences, Williams College) presented on "Finding and Strengthening My Voice as an IDEA Advocate in Earth and Planetary Science." All presentations at the conference for which authors provided consent were recorded and are available in the online program.

The conference also included three workshops to practice and delve deeper into some topics. The "Designing and Sustaining Authentic Partnerships" workshop explored the definition and characteristics of authentic partnerships and shared insights and implementation strategies on designing and sustaining such partnerships. The "Listening Session" workshop facilitated discussions with people from underrepresented communities to better understand their needs and the challenges they face. One of the potential pitfalls of an IDEA

conference held within the physical sciences is that the discussion can become data-centric. The goal of this session was to mitigate such a mentality by centralizing lived experiences, providing the space for perspectives directly from those most affected — in particular, leaders and advocates from different communities within the planetary sciences. The third workshop was a proposal-writing workshop entitled "Tips to Writing Proposals and Building Resiliency Within Your Career," which focused on key points to communicating science through successful proposal writing and learning to understand one's values and maintaining those through the process. This workshop helped to bridge some opportunity gaps faced by early career and new researchers in the planetary sciences in their understanding of the NASA proposal culture and system.

A key outcome of this conference was to identify community-led actionable and tangible recommendations to advance IDEA principles within the planetary science and astrobiology community. To do this, the conference organized discussions throughout the week into seven working groups: (1) recommendations for funding agencies, (2) recommendations for universities, (3) recommendations for research groups, (4) recommendations for professional organizations, (5) recommendations for employers and about employment, (6) recommendations about safety and accessibility, and (7) recommendations about public engagement and outreach. The working groups were led by co-facilitators who led asynchronous conversations via Slack and two focused discussion sessions during the conference. After the conference, the working groups organized their recommendations into a summary report. The final consensus report, which collates and summarizes the recommendations from the seven working groups, is available online (DOI: 10.5281/zenodo.6656887).

— Summary provided by Edgard Rivera-Valentín

APOPHIS T–7 YEARS: KNOWLEDGE OPPORTUNITIES FOR THE SCIENCE OF PLANETARY DEFENSE

The Apophis T-7 Years Workshop was held virtually May 11–12, 2022. Participation at the workshop, which was organized by the Lunar and Planetary Institute, was broadly international, with 150 registrants representing more than 20 countries delivering 40 presentations. Particularly noteworthy was the participation and valuable contributions of students and new postdocs exploring the topic for the first time. Online participants spanned 18 time zones. The workshop theme centered on the knowledge opportunities for the science of planetary defense that might be gained through observations of the asteroid 99942 Apophis, which will make a close flyby of Earth on April 13, 2029. (Coincidentally, that will be Friday the 13th...) At the flyby distance of 5.8 Earth radii, Apophis will reach a distance that is nearer than geosynchronous satellites, yet outside the classic Roche limit. Yet even outside the Roche limit, gravitational torques by Earth on Apophis are likely to alter its spin state and may induce seismic effects on Apophis sufficient to mobilize its regolith.

The workshop provided the opportunity for the international planetary science community to come together and share current data for the known physical and orbital characteristics of Apophis, as well as current best models for measurable effects on Apophis that may be induced by Earth. As an overview, it was noted that an object as large as Apophis (340 meters, or 1115 feet) makes such

a close approach to Earth about once every 1000 years. Measurements of this "natural experiment" therefore provide an extremely rare opportunity to deduce the internal structure properties of a potentially hazardous asteroid (PHA).

Workshop presentations and findings noted and endorsed the concurrent activity of a NASA Specific Action Team (SAT) that is preparing a report quantifying the best estimates for measurable effects, including prioritization and methods (groundbased and *in situ*) to achieve them. Also noted were the specific findings and recommendations of the *2022 Planetary Decadal Survey* report supporting the detailed study of Apophis during its encounter. The approved extended mission for OSIRIS-REx, to be renamed OSIRIS-APEX (Apophis Explorer) was described, bringing outstanding capabilities to study Apophis.

Orbital dynamics do not allow OSIRIS-APEX to arrive until after the date of Apophis' Earth encounter. Workshop participants noted that pre-encounter measurements remain an open challenge to be solved. Four mission concepts were presented to address the pre-encounter measurement challenge. A workshop finding noted that time is of the essence for identifying a funding pathway for bringing these concepts to maturity and possible flight. Also identified was a need for international collaboration on an Apophis campaign, so that multi-wavelength experiments (radar, radio) and possible spacecraft operations at the time of close approach do not create mutual interference. An additional goal of an Apophis campaign would be to be at the forefront of public information on the Apophis 2029 flyby being a science opportunity and not a hazard. Apophis will miss Earth, but we will be watching to learn the most that we can.

For more information about the Apophis T-7 workshop , including links to the program and abstracts, visit the meeting website at www.hou.usra.edu/meetings/apophis2022/.

— *Summary provided by Richard Binzel*

OPPORTUNITIES FOR STUDENTS

INTERNSHIPS AND PROGRAMS

POSTDOCTORAL PROFESSIONAL DEVELOPMENT PROGRAM — FOUNDATIONS OF LEADERSHIP: CORE CONCEPTS FOR BUILDING YOUR LEADERSHIP STYLE

This premier leadership development program, organized by Sanford Burnham Prebys Medical Discovery Institute, is open to postdoctoral scholars at all institutions. The unique, 11-module, year-long program gives postdocs insight into how their innate preferences and associated behaviors can affect their leadership styles, impact their teams, and ultimately affect their career satisfaction and success. The 2022–2023 program cohort will include 30 postdoctoral scholars who will attend online, monthly modules and engage in discussions and coursework. Certificates will be awarded to participants who complete all program requirements. Click here to learn more and apply.

FUTURE LEADERS OF OCEAN WORLDS NETWORK

Future Leaders of Ocean Worlds (FLOW) is a multidisciplinary group of early-career scientists and engineers (undergrads, grad students, postdocs, research scientists, and others <10 years post terminal degree) interested in ocean worlds and actively engaged in research relating to planetary science, origins of life, astrobiology, cryospheres, and/or oceanography. The group seeks to foster collaboration, develop community, and advance the interests of early-career ocean world researchers. Click here to learn more and join.

CONTRIBUTE YOUR STORY TO THE NPA'S "WHAT'S A POSTDOC?" AWARENESS CAMPAIGN

The National Postdoctoral Association (NPA) is collecting information for the What's A Postdoc? awareness campaign. The NPA and its partners believe that more Americans, including members of academia, policymakers, and the general public need to know more about who postdocs are and the contributions they provide to our society and economy. Visit the What's A Postdoc? page to provide information about you and your postdoc career with a quote, a picture, or a short video. You're also encouraged to submit articles or news coverage about your work. Help paint a compelling picture of what it means to be a postdoc! Click here to share your story.

INTERNSHIPS AT JOHNS HOPKINS UNIVERSITY (JHU) APPLIED PHYSICS LABORATORY (APL)

As a JHU APL intern, undergraduate students have the opportunity to use the skills they've gained at school to push the boundaries of science and technology. Interns join a strong support system of dedicated coworkers and have opportunities to work on meaningful projects. APL strives to give interns the tools and resources that allow them to shape the career of their dreams. Applications for college internships open on September 1, 2022. Click here to learn more and apply.

NASA'S ASTROPHOTO CHALLENGES

Learners of all ages are invited to join NASA for an exciting opportunity to use real astronomical data and tools to create images of the eruptive Eta Carinae star system and the nebula in which it resides — the Carina Nebula. NASA's Astrophoto Challenges include two challenges: the MicroObservatory Challenge and the NASA Data Challenge. The Challenges provide authentic experiences using real astrophysics data, including those from NASA spacebased missions. The deadline to submit entries is July 31, 2022. Click here to learn more.

SCIENCE UNDERGRADUATE LABORATORY INTERNSHIPS (SULI)

Online applications for the Spring 2023 Science Undergraduate Laboratory Internship (SULI) term close on October 5, 2022. The SULI program encourages undergraduate students and recent graduates to pursue science, technology, engineering, and mathematics (STEM) careers by providing research experiences at the Department of Energy (DOE) laboratories. Selected students perform research, under the guidance of laboratory staff scientists or engineers, on projects supporting the DOE mission during 10- to 16-week appointments. Click here to learn more and apply.

COMMUNITY COLLEGE INTERNSHIPS (CCI)

The Community College Internships (CCI) program seeks to encourage community college students to enter technical careers relevant to the DOE mission by providing technical training experiences at the DOE laboratories. Selected students work on technologies or instrumentation projects or major research facilities supporting DOE's mission under the guidance of laboratory staff scientists or engineers during 10-week appointments. Applications for the Spring 2023 term close on October 5, 2022. Click here to learn more and apply.

SCHOLARSHIPS AND FELLOWSHIPS

USRA DISTINGUISHED UNDERGRADUATE AWARDS

The Universities Space Research Association (USRA) Distinguished Undergraduate Awards provide college scholarship awards to students who have shown a career interest in science or engineering with an emphasis on space research or space science education and aeronautics-related sciences. USRA presents up to four scholarship awards to undergraduate students each fall. Applications are due on August 10, 2022. Click here to learn more and apply.

EUGENE AND CAROLYN SHOEMAKER IMPACT CRATERING AWARD

The Eugene and Carolyn Shoemaker Impact Cratering Award is for undergraduate or graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. The award, which will include $3000, is to be applied to the study of impact craters, either on Earth or on the other solid bodies in the solar system. Areas of study may include but are not limited to impact cratering processes; the bodies (asteroidal or cometary) that make the impacts; or the geological, chemical, or biological results of impact cratering. Applications are due on August 26, 2022. Click here to learn more and apply.

NATIONAL SCIENCE FOUNDATION (NSF) GRADUATE RESEARCH FELLOWSHIP PROGRAM (GRFP)

The NSF GRFP recognizes and supports outstanding graduate students in NSF-supported STEM disciplines who are pursuing research-based master's and doctoral degrees at accredited U.S. institutions. The five-year fellowship includes three years of financial support and a cost of education allowance to the institution. The fellowship is competitive, and those planning to apply should devote a sincere effort to their application. The 2023 GRFP application will open in late July 2022. Informational webinars for applicants will be held on August 31 and September 21; these webinars will provide an overview of the GRFP and the application process. Click here to learn more and apply.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) EDUCATIONAL PARTNERSHIP PROGRAM WITH MINORITY-SERVING INSTITUTIONS UNDERGRADUATE SCHOLARSHIP

The NOAA Educational Partnership Program (EPP) with Minority-Serving Institutions (MSI) Undergraduate Scholarship provides an opportunity for undergraduate students to study a wide range of science, engineering, mathematical, computer, technology, and social science disciplines related to the National Oceanic and Atmospheric Administration's (NOAA's) mission and objectives. During the internships portion of the award, the scholar is provided opportunities for hands-on research at participating NOAA facilities. Scholars receive financial assistance for two academic years, a bi-weekly stipend, and a housing allowance during summer internships. Applications for the 2023 program open on September 1, 2022. Click here to learn more and apply.

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 project by providing access to the expertise, resources, and capabilities available at the DOE laboratories/facilities. Applications will open in August 2022. Click here to learn more and apply.

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

Southwest Research Institute Postdoctoral Positions

U.S. National Labs — Postdoctoral Positions

AGU Job Board — Postdoctoral Positions

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.

WEBB TELESCOPE'S FIRST IMAGES

After years of development and anticipation, NASA, in partnership with the European Space Agency (ESA) and Canadian Space Agency (CSA), released the James Webb Space Telescope's first full-color images and spectroscopic data during a televised broadcast on July 12. These first images from the world's largest and most powerful space telescope demonstrate Webb at its full power, ready to begin its mission to unfold the infrared universe. To learn more, visit www.nasa.gov/webbfirstimages.

INCOMING! DART'S IMMINENT IMPACT

Credit: NASA/Vi Nguyen.

The Double Asteroid Redirection Test (DART) is NASA's first planetary defense test mission. DART is dedicated to investigating and demonstrating one method of asteroid deflection: changing an asteroid's motion in space through kinetic impact. Launched in November 2021, the DART spacecraft is roughly the size of a small car and will strike its target at about 6 kilometers (4 miles) per second on September 26, 2022. Find out more about planetary defense and stay up to date on the DART mission here.

INTERNATIONAL OBSERVE THE MOON NIGHT

International Observe the Moon Night will be observed on October 1, 2022, and is a time to come together with fellow Moon enthusiasts and curious people worldwide. Everyone on Earth is invited to learn about lunar science and exploration, take part in celestial observations, and honor cultural and personal connections to the Moon by hosting or attending an event or observing from home. Click here for more information about International Observe the Moon Night and how to get involved.

OPPORTUNITIES AND RESOURCES FOR STEM ENGAGEMENT

ONLINE COURSE: CONFIDENCE AND CURIOSITY

Students track water with NASA satellite data. Credit: LoriAnn Pawlik.

The Confidence and Curiosity: Engaging Girls in Informal Science course runs from July 25 to August 12, 2022. Sign up today for a three-week, online course from the Astronomical Society of the Pacific (ASP) that will explore public engagement techniques and strategies you can use at your next science event to inspire public engagement, including how to encourage growth mindset, utilize diverse storytelling and representation, address misconceptions, ask and answer questions, and investigate bias and micromessaging. To learn more, visit astrosociety.org/education-outreach/learn-asp/confidence-curiosity-engaging-girls-in-informal-science.html.

PROFESSIONAL DEVELOPMENT OPPORTUNITY — INCLUSIVE STEM TEACHING PROJECT

The Inclusive STEM Teaching Project, a NSF Improving Undergraduate STEM Education program, is hosting a free, six-week Massive Open Online Course (MOOC) from October 3 to November 22, 2022, via the edX platform. Register for the online course this fall to join a community of nearly 6000 faculty, postdocs, graduate students, and staff. Topics will focus on cultivating inclusive STEM learning environments for all students and developing skills as reflective, inclusive practitioners. To learn more, visit www.edx.org/course/the-inclusive-stem-teaching-project.

ADVOCATE FOR SCIENCE — JOIN AAAS'S LOCAL SCIENCE ENGAGEMENT NETWORK (LSEN)

In 2021, the American Association for the Advancement of Science (AAAS) launched the Local Science Engagement Network (LSEN), a program dedicated to elevating the role of science in evidence-based public policy by building, energizing, and channeling the commitment of AAAS members and the science community. The LSEN connects science advocates to local conversations about energy, sustainability, climate change, and other pressing issues. To learn more, visit lsen.quorum.us/.

TOOLKIT FOR SCIENTISTS — COMMUNICATING WITH THE PUBLIC

Successful public engagement with science depends on clear, concise communication. The AAAS has created a Communication Toolkit that provides guidance for scientists to build skills and develop strategies to communicate and engage with public audiences more effectively. Sections of the Toolkit focus on various modes of communication, including online and face-to-face communication, and a section about engaging with journalists. To learn more, visit www.aaas.org/resources/communication-toolkit.

COMMUNICATING WITH THE MEDIA

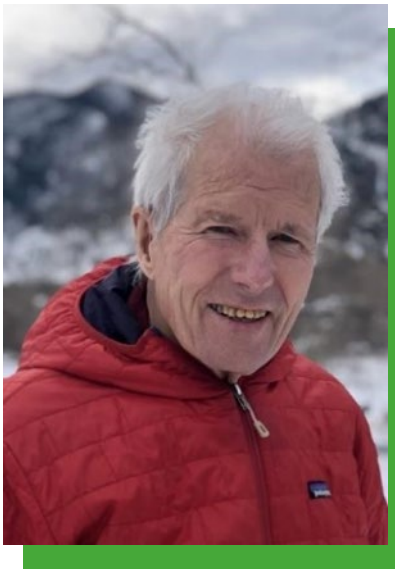
As a scientist, you have the topical expertise and insights that can help journalists understand the latest evidence and put it into context. SciLine, a free service for journalists and scientists, is based at the American Association for the Advancement of Science (AAAS). SciLine's mission is to advance the amount and quality of scientific evidence in news stories. Join SciLine to interact with and support journalists covering science-related topics and improve your media-communication skills. To learn more, visit www.sciline.org/scientists/.

SHARING SCIENCE THROUGH ARTWORK — AGU'S VIRTUAL GALLERY

AGU's Science and Society Art and Science Track welcomes submissions of creative pieces for inclusion in a virtual art exhibit to be shown during AGU's 2022 Fall Meeting. Pieces need to embody art and science and can be submitted by an artist, a project team or collaboration. Pieces can be existing or newly created and must be able to be shown in a digital space. Please note you must indicate your intent to submit by August 5. We encourage submissions that speak to AGU'S 2022 Fall Meeting theme: Science Leads the Future. To learn more, visit the 2022 American Geophysical Union Fall Meeting Art and Science Virtual Exhibit.

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

IN MEMORIAM



PETER W. BIRKELAND

1934–2022

Geologist Peter Wessel Birkeland died of natural causes in Boulder, Colorado, on January 25, 2022.

Birkeland was born in Seattle, Washington, on September 19, 1934, to Norwegian immigrant Ivar Wessel Birkeland and Marguerite Ellen O'Conner Birkeland of Rochester, Minnesota, and grew up in the Seattle area. He served in the U.S. Army from 1953 to 1955, ending his service as a ski trooper in the Mountain and Cold Weather Training Command at Camp Hale in Colorado. In 1958, he graduated from the University of Washington in Geology, and in 1961 he completed a Ph.D. in Geology from Stanford University, studying under Art Howard and J. Hoover Mackin.

Birkeland's professional career began in 1962 as an instructor and assistant professor at the University of California, Berkeley. In 1967, he took a position in the Department of Geological Sciences at the University of Colorado–Boulder, where he taught and conducted research in soils and Quaternary geology until his retirement in 1997.

Birkeland was a prolific researcher for more than four decades. His work was geographically broad and generated a steady stream of publications, commonly with his students. His main area of research was soil geomorphology — the application of pedology to address landform and landscape evolution. This work had tremendous importance to Quaternary stratigraphic, neotectonic, and paleoclimatic problems.

Birkeland's remarkable accomplishments in research resulted in Distinguished Career Awards from both the Quaternary Geology and Geomorphology Division of the Geological Society of America (2000) and the American Quaternary Association (2009), but his proudest professional accomplishment was his mentoring and training of many successful students in this field, all of whom became his colleagues and cherished friends.

— Portions of text courtesy of the Geological Society of America and the Daily Camera (Boulder)

BRAD BLAIR

1965–2022

Brad Blair, a prominent member of the lunar in situ resource utilization (ISRU) community, passed away unexpectedly on June 25, 2022. Blair was a professional consultant on advanced mining technology and the economic use of space mineral resources, as well as a visionary entrepreneur with the ability to network and bring together experts in diverse fields of research to collaborate on projects related to economic resources in space.

Blair held degrees in Engineering Geology (B.Sc. 1989), Mining Engineering (M.E., 1993), and Mineral Economics (M.Sc., 2004) from the Colorado School of Mines (CSM). He began researching lunar ISRU technology in 1989 under NASA Space Exploration Initiative funding as a graduate student at CSM. During the summer of 1999, as a visiting professional in the Exploration Office at NASA Johnson Space Center under the mentorship of Douglas Cooke,

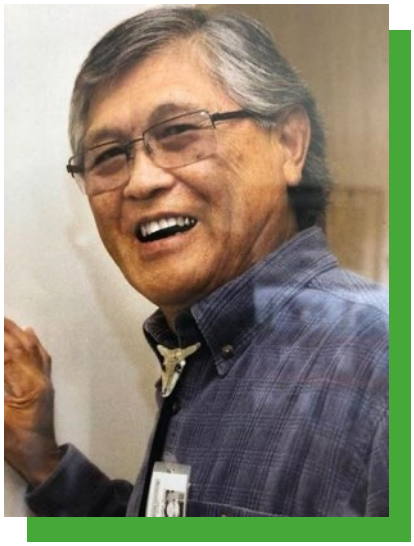
he learned and practiced the art of cost estimation in support of a design reference mission for human Mars exploration. From 2001 to 2005, he and a small team at CSM conducted research for NASA on topics related to ISRU technology, cost estimation, and space resource economic analysis.

Blair worked under numerous U.S. and Canadian government research contracts and consulted for aerospace and mining industry clients on ISRU systems development and economic analysis. He participated in two NASA Centennial Challenges and was an advisor and participant in several startup companies.

Blair was founder and general partner of NewSpace Analytics LLC in Idaho Springs, Colorado; senior consultant to Xtraordinary Innovative Space Partnerships, Inc. (XISP-Inc); part owner of Orbchem LLC; and was in the early stages of a new startup venture called Moonrise Mining Inc., working on a revolutionary new concept for conducting mining on the Moon. Blair was also the primary inventor named on several preliminary patents that were filed with the U.S. Patent Office.

Blair served in a number of nonprofit service roles, including member of the Board of Directors of United Societies in Space (USIS) since 2006, Chairman of the Board of the International Space Development Authority Corporation (ISDAC) since 2011, and Advocate of the Space Frontier Foundation (SFF) since 2011. He also served as a regional board member for the National Space Society and was a longtime contributor to their vision and mission. A devoted father, husband, and colleague, Blair's integrity, visionary ideas, and intellect will be greatly missed by all who had the privilege of knowing him. A GoFundMe page has been established in Blair's honor: https://gofund.me/5060ea7b.

— Portions of text provided by the National Space Society



SHERWOOD CHANG

1940–2022

Sherwood Chang, an organic chemist, died in Tacoma, Washington, on June 6, 2022, at the age of 81.

During his 30 years at NASA as a physical organic chemist, Chang was a leader in the evolution of the application of chemistry in the field of space science. His innovative and collaborative approach to science — uniting cosmochemistry, origin of life research, and molecular biology — helped create the then-new field of astrobiology. In recognition of his contributions, NASA dedicated an Exobiology Conference room in his honor in 2009.

Among many other honors, as a Principal Investigator for the Apollo program, Chang was awarded NASA's Exceptional Scientific Achievement Medal (1976) for his contributions to geochemistry, cosmochemistry, and lunar and planetary science. While at NASA he served as Assistant Chief for Science and Technology Extraterrestrial Research (1983) and Chief of Exobiology (1985–1998). In 1999 he was elected a fellow by the International Society for the Study of the Origins of Life (ISSOL).

Following his retirement from NASA, Chang became a farmer on a small ranch in the foothills of the Trinity Alps of northern California where he raised Certified Organic grass-fed beef, hay, and produce. On the ranch, he combined nineteenth-century infrastructure (hand-dug irrigation ditches and hand-crafted seasonal dams and flumes) with twenty-first-century technology (power from solar panels and inverters, communication via small-aperture satellites). After 16 years of farming, he took a second retirement, moving north to Tacoma, Washington.

Chang was unfailingly kind to strangers and friends alike, keeping strong many bonds of friendship lasting half a century. His dedicated encouragement, support, and inspiration nurtured and empowered the next generation of skilled and curious scientists, and he meaningfully enriched the lives of all who knew him.

— Portions of text courtesy of the San Jose Mercury News

CHARLES T. PREWITT

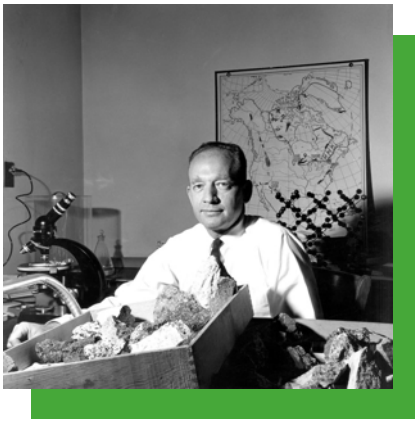
1933–2022

Mineralogist Charles (Charlie) Prewitt peacefully passed away at home on April 28, 2022, at the age of 89.

Prewitt's distinguished career reflects the diversity and impact of the mineral sciences. Following a bachelor's degree in geology from the Massachusetts Institute of Technology, Prewitt remained in Cambridge to pursue advanced degrees under Martin Buerger. His Ph.D. thesis on the crystal structures of wollastonite and pectolite was completed in 1962. Immediately following his doctorate, Prewitt joined DuPont as a research scientist. There, in collaboration with Bob Shannon, he developed the crystal chemical systematics that led to the much-cited revised values of effective ionic radii. From 1969 to 1986 Prewitt was professor of crystallography at the Stony Brook campus of the State University of New York, where he began one of the country's preeminent programs in crystal chemistry and high-pressure research and nurtured the careers of many outstanding graduate students.

Prewitt's tenure was distinguished by extensive service to the science community, including membership on U.S. National Committees on Geology and on Crystallography, and serving in several different offices in the Mineralogical Society of America, including president in 1983–1984. It was also during this period that he forged important international ties through visiting professorships in Japan, Australia, and the United Kingdom. In the process, he was instrumental in establishing the new field of mineral physics. He was also one of the founding editors of the journal *Physics and Chemistry of Minerals*.

— Portions of text courtesy of the Geological Society of America



LEON T. "LEE" SILVER

1925–2022

Leon Theodore "Lee" Silver, an American geologist who was an emeritus professor at the California Institute of Technology (Caltech), passed away on January 31, 2022. He was 96 years old.

Silver was an instructor to the Apollo 13, 15, 16, and 17 astronaut crews. Working with NASA, he taught astronauts how to perform field geology, essentially creating lunar field geology as a new discipline. His training is credited with a significant improvement in the J-Mission Apollo flights' scientific returns. After the Apollo program, he became a member of the U.S. National Academy of Sciences in 1974. He retired as the W. M. Keck Foundation Professor for Resource Geology, emeritus, at Caltech.

Silver was born in Monticello, New York, on April 9, 1925. His father and mother emigrated from Russia and Poland, respectively, and met in Brooklyn. Silver graduated from high school in 1942, just months after the U.S. entered World War II. He joined the Navy Reserve while studying at the Colorado School of Mines and was called up to active service in 1943, having turned 18 only three months earlier.

Through the V-12 Navy College Training Program, which paid the college tuition of engineering students who were expected to become officers at the end of their studies, Silver earned a bachelor's degree from the University of Colorado in 1945. He served in the Navy until 1946, then earned a master's degree from the University of New Mexico in 1948 and a doctorate in geology and geochemistry from Caltech in 1955. During this time, he also worked at the U.S. Geological Survey (USGS).

After completing his doctoral degree, Silver began teaching at Caltech as an assistant professor of geology in 1955. He was promoted to associate professor in 1962 and earned tenure in 1965. He was named the W. M. Keck Foundation Professor for Resource Geology in 1983 and became emeritus in 1996.

Silver's main research interests were petrology, tectonics, and applications of geology and isotope geochemistry to geochronology, crustal evolution, ore deposits, and comparative planetology. He is perhaps most famous for his contributions to the Apollo program during the 1970s. He instructed Apollo astronauts on geology and lunar sample selection — including Apollo 17 astronaut and Caltech alumnus Harrison "Jack" Schmitt — and developed approaches for using isotope ratios for geochronology, the study of the age and history of rocks and sediments. In addition to his instruction of the astronauts, Silver served on the Lunar Surface Geology Experiment Team (Apollo 13–17), the Lunar Sample Preliminary Examination Team (Apollo 15–17), the Lunar Surface Traverse Planning Team (Apollo 15–17), the Lunar Science Working Panel (Apollo 15–17), and the Lunar Sample Analysis Planning Team (1972–1974).

Silver's work with the Apollo program has been recounted in Andrew Chaikin's *A Man on the Moon* (1994). The book became a TV mini-series in 1998, with David Clennon portraying Professor Silver in the HBO docudrama series *From The Earth To The Moon*. In 2006, Apollo 15 Commander Dave Scott devoted a section of his co-authored book *Two Sides of the Moon* to the training and instruction that Scott and other Apollo astronauts received from Silver.

Silver also served on several federal advisory committees, including as chair of the Advisory Committee to the Office of Basic Energy Sciences of the Department of Energy from 1990 to 1992. Throughout his career, he received numerous honors and awards, including a NASA Exceptional Scientific Achievement Medal both for his training of the Apollo astronauts in geologic science and for his individual research. He was also selected to receive a Guggenheim Fellowship, an American Institute of Professional Geologists Award for Professional Excellence, and numerous NASA Group Achievement Awards. He was named a member of the National Academy of Sciences and a senior fellow of the Mineralogical Society of America and served as president of the Geological Society of America in 1979.

In 2002, Silver was the subject of an interview with the NASA Johnson Space Center Oral History Project. To read the transcript of that interview, visit tinyurl.com/bjydzsru.

WILLIAM STONEY

1925–2022

William Edmund Stoney Jr., an aeronautical engineer who was one of the developers of rockets during the early days of the space program and a lead engineer during the Apollo program, died May 28, 2022. He was 96 years old.

Stoney was born in 1925 in Terre Haute, Indiana, and developed an interest in flight at an early age. After serving in the Air Force during World War II, Stoney enrolled at the Massachusetts Institute of Technology (MIT), where he received a bachelor's degree in aeronautical engineering in 1949. He later completed a master's degree in aeronautical engineering from the University of Virginia in 1951 and a second master's degree in industrial management from MIT in 1962.

Stoney joined the staff at the National Advisory Committee for Aeronautics, the agency that was the predecessor to NASA, in 1949. Working at Langley Research Center in Hampton, Virginia, he had the opportunity to work with a group of engineers who were known for their work on rocket technology, so he was in an ideal position when the space race began in the 1950s. After the Soviet Union's successful launch of Sputnik 1 in 1957, Stoney realized that the work they were doing would benefit from the public and governmental support they would have as the U.S. fought to catch up to their rival superpower.

Stoney was named to the position of program manager overseeing the development of Scout, a solid-propellant rocket booster that NASA describes as one of the most successful rocket boosters in the history of the space agency. Stoney was then appointed chief of advanced space vehicle concepts at NASA Headquarters in Washington, DC and led the advanced spacecraft technology division in Houston. During the Apollo program, he served in numerous top engineering roles and received the NASA Exceptional Service Medal in 1969, the year that Apollo 11 landed on the Moon.

Stoney went on to become the director of NASA's Earth observations program in 1973 and played a key role in leading the development of satellites that monitored pollution in the atmosphere and other Earth resources as well as other meteorological uses. After retiring from NASA in 1978, Stoney worked in the private sector for companies such as RCA Corp. and Noblis.

— Portions of text courtesy of NASA and the Washington Post

ALLAN TREIMAN RECEIVES PRESTIGIOUS G. K. GILBERT AWARD

USRA's Allan Treiman, at the Lunar and Planetary Institute (LPI), was selected to receive the 2022 Geological Society of America G. K. Gilbert Award from the Planetary Geology Division for his outstanding contributions to the field of planetary geology.

"As Principal Scientist at the LPI, Allan is richly deserving of this award not only for his extensive body of work on the geologic histories of a wide variety of planetary materials, but also for the breadth of his many research collaborations that have reached across the U.S. and around the world," said Lisa Gaddis, Director of the LPI. "Allan has had a strong positive influence on many in the international planetary science community."

The award is named for G. K. Gilbert, who 100 years ago clearly recognized the importance of a planetary perspective in solving terrestrial geologic problems. The G. K. Gilbert Award is presented annually for outstanding contributions to the solution of fundamental problems in planetary geology in the broadest sense, which includes geochemistry, mineralogy, petrology, geophysics, geologic mapping, and remote sensing.

Treiman studies planetary materials and geology, emphasizing Mars. His current work is closely tied to the Mars Science Laboratory (MSL) and Mars 2020 (M2020) rover spacecraft. Treiman is a co-investigator for the CheMin (MSL) and PIXL (M2020) instruments and has taken on mission-level roles like long-term planner and return sample scientist. This mission work builds on Treiman's extensive studies of martian meteorites, and related investigations of lunar rocks and asteroidal samples. Treiman has a long-standing interest in Venus' rocks and their chemical interactions with its atmosphere; he happily anticipates results from the upcoming flotilla of Venus spacecraft.

Credit: USRA/Lunar and Planetary Institute.

Treiman has made outstanding contributions to fundamental problems in planetary geology in the broadest possible sense. He has an international track record in studies of the petrology and geochemistry of Venus, Mars, meteorites, and the Moon. He has an unusually broad set of interests, investigating not only small-scale processes such as tiny melt inclusions in meteorites, but also large-scale planetary processes such as vast volcanic flows on Venus. The impact of his work is demonstrated by his publication of no fewer than 141 papers, and the fact that he routinely receives over 700 citations a year.

Presentation of the G. K. Gilbert Award is made during the annual business meeting of the Division held in association with the Annual Meeting of the Society to be held on October 9–12, 2022, in Denver, CO. For more information, visit www.geosociety.org/GSA/Awards/about_Division_Awards.aspx#gilbert.

NASA ANNOUNCES RETIREMENT OF ARMSTRONG FLIGHT RESEARCH CENTER DIRECTOR

David McBride, director of NASA's Armstrong Flight Research Center in California, announced plans to retired on June 30 after 35 years of service to the agency. He began his career at NASA as an intern.

During McBride's tenure as director, the center completed the flight evaluation of the X-48B/C hybrid wing body experimental aircraft and demonstrated the Orion spacecraft's launch abort system.

David D. McBride, director of NASA's Armstrong Flight Research Center in Edwards, California. Credit: NASA.

"David's contributions in aviation, science, and exploration have strengthened our agency's missions and improved the lives of people throughout our country — and will for generations to come," said NASA Administrator Bill Nelson. "Individuals at the beginning of their career at NASA – and members of the Artemis Generation who dream of one day working here – will be inspired by David, knowing their work can also lead to a lifetime of service to this storied agency. I wish him and his family all the best in his retirement."

While studying electrical engineering at the University of New Mexico, McBride joined the NASA family as a cooperative education student, specializing in digital flight control systems analysis. His technical assignments included serving as chief engineer for the X-33 Extended Test Range and as lead flight systems engineer for the X-29.

Before his appointment as director in 2010, McBride served as acting center director, deputy center director, and associate director for programs and projects, where he oversaw Armstrong Flight Research Center's portfolio supporting exploration, science, and aeronautics.

Upon McBride's retirement, Deputy Center Director Brad Flick will serve as acting center director. Flick began his career at the Dryden Flight Research Center, now Armstrong Flight Research Center, in 1986 as a flight systems engineer on the F/A-18 High Alpha Research Vehicle project. The agency also will soon start the formal process to identify a successor and will announce a selection later.

NASA'S GLENN RESEARCH CENTER DIRECTOR RETIRES

Dr. Marla Pérez-Davis, director of NASA's Glenn Research Center in Cleveland, retired on June 17, after nearly four decades of service at the agency.

"Marla's four decades of service to NASA have made a remarkable impact on critical agency goals and missions in aeronautics, human exploration and, of course, on Glenn Research Center. Her trailblazing legacy is the members of the Artemis Generation she has inspired to believe they, too, can work for, and lead at, NASA. I wish her well in her future endeavors," said NASA Administrator Bill Nelson.

Pérez-Davis' career with the agency will conclude where it began: at Glenn. Over her 38-year career at Glenn, Pérez-Davis held several positions, including deputy center director from 2016 to 2020, and deputy director of the Research and Engineering Directorate from 2014 to 2016. In this role, she was responsible for leading, planning, and coordinating all phases of Glenn's research and engineering activities to accomplish NASA missions.

Earlier in her career, Pérez-Davis' leadership as the chief of the Electrochemistry Branch resulted in new energy storage and power capabilities critical to advancing aeronautics and spaceflight, as well as the formation of new partnerships to support NASA missions. She also is the recipient of numerous accolades, including the NASA Outstanding Leadership Medal, Presidential Rank Award for Meritorious Executives, and 2021 Hispanic Engineer National Achievement Awards Corporation Engineer of the Year.

Dr. Marla Pérez-Davis, director of NASA's Glenn Research Center in Cleveland. Credit: NASA.

Her tenure as Glenn's director began in January 2020. She effectively and compassionately guided the center workforce through the global COVID-19 pandemic, engaging regularly and frequently with them to ensure the mission continued safely. Major milestones and activities completed at Glenn during this time include the construction of the new Research Support Building, testing on the Orion spacecraft for the Artemis I Moon mission, and testing for the X-59 QueSST quiet supersonic aircraft.

For more information about Pérez-Davis and NASA's Glenn Research Center, visit www.nasa.gov/glenn.

2022 NASA EXPLORATION SCIENCE AWARDS

NASA's Solar System Exploration Research Virtual Institute (SSERVI) Awards recognize outstanding achievements in exploration science. Recipients have each made unique contributions to NASA's human exploration efforts. SSERVI Award winners are nominated by their academic peers and are selected by a committee based at SSERVI's central office. The awards were presented along with invited lectures from the recipients at the 2022 NASA Exploration Science Forum (NESF) on July 19–21.

"Please join me in congratulating all of the 2022 Award winners," said Greg Schmidt, Director of SSERVI. "We look forward to future scientific discoveries from these individuals, as their outstanding research efforts have furthered NASA's goals for human and robotic exploration of the Moon and other destinations in the solar system."

SUSAN MAHAN NIEBUR EARLY CAREER AWARD

The 2022 Susan Mahan Niebur Early Career Award is an annual award given to early-career scientists who have made significant contributions to the science or exploration communities. Recipients of the Susan M. Niebur Early Career Award are researchers who are no more than ten years from receiving their Ph.D., who have shown excellence in their field and demonstrated meaningful contributions to the science or exploration communities. This year the award is presented to Drs. Kelsey Young and Orenthal James "O.J." Tucker.

Kelsey Young is a Research Space Scientist at NASA Goddard Space Flight Center focused on the integration of science into human exploration and addressing major strategic knowledge gaps in preparing for human science on the Moon.

Dr. Young is a leader in developing Concepts of Operation for crews on the Moon and has participated in several operational field tests run by NASA, including as a crewmember and Science Team member for NASA's Desert RATS, as the Science Operation Co-Lead for NEEMO, as a submersible pilot for NXT, and other analog missions that are maturing ways our astronauts will explore the lunar surface during ARTEMIS missions.

Dr. Young is a Theme Lead for two SSERVI teams, RISE2 and GEODES, where she is involved in testing handheld and field portable instruments and using geophysical instrumentation in

human exploration-relevant analog environments. In addition, Dr. Young serves as one of the lead trainers for Earth and Planetary Science training for NASA Astronauts. She served on the 2020 Artemis III Science Definition Team, as part of the Organizing Committee for NASA's Lunar Surface Science Workshops, as Human Exploration Chair of the LEAG Executive Committee, and as Session Chair at numerous scientific meetings (AGU, LPSC, GSA, NESF, etc.). She received her PhD and MS in Geological Sciences, from Arizona State University's School of Earth and Space Exploration, and a BS in Geological Sciences from the Department of Civil Engineering and Environmental Geosciences at the University of Notre Dame.

Within the first two years post-PhD, she won two awards as a PI with NASA's competitive Planetary Science and Technology Through Analog Research (PSTAR) Program, and has received numerous others, including the 2020 NASA Early Career Achievement Medal, the Wiley-Blackwell Award, the LPI Career Development Award, the 2011 School of Earth and Space Exploration Merit Award, and a NASA Group Achievement Award for her work on Desert-RATS. As an early-career researcher she has an extensive list of publications. Dr. Young has focused her career on a single objective– enabling crewed science on the lunar surface– and the science and exploration communities have each benefitted from this. Young represents the very nexus of lunar science and exploration and is highly deserving of the 2022 Susan Niebur Award.

Orenthal James "O.J." Tucker is a Research Scientist at NASA GSFC and NASA Postdoctoral Fellow. He earned his Ph.D. and his bachelor's degree in Mathematics and Physics from Hampden-Sydney College, where he was on both the football team and honor court for math and physics and was active in the minority student union.

As a plasma physicist, Dr. Tucker develops and carries out molecular-level simulations to model gas flows on planetary bodies and to describe radiation effect in solids. His research interests are aimed at understanding how dynamics at the molecular level affects planets and planetary materials. Dr. Tucker is a leading expert on rarefied atmospheres and exospheres across the solar system. He has made significant contributions to exploration science– particularly through his work on the lunar hydrogen cycle and its response to

magnetospheric shielding, and on transient atmospheres produced by lunar volcanism. His work has been critical to advancing scientific understanding of the lunar volatile system and provides testable hypotheses for several upcoming orbital and landed lunar missions. The breadth of Dr. Tucker's work is unparalleled; he has simulated rarefied atmospheres on bodies ranging from Mercury and the Moon, to the moons of Jupiter and Saturn, Pluto and beyond!

In addition, Dr. Tucker has mentored many undergraduate and graduate students and is held in the highest esteem by a wide, international network of colleagues and collaborators. He is currently a Co-Investigator on the SSERVI LEADER team and a Co-Investigator for the PITMS mass spectrometer, a NASA-provided lunar payload. Dr. Tucker has also served in critical leadership and service roles; he is a member of the White House Scientific Integrity Task Force, served as a SOC member for the AAS-DPS, is one of the co-founders of the Planetary Scientists of Color group, and a mentor and role model for the dynamic Black in Astro community.

Dr. Tucker makes an effort above and beyond his own role as a civil servant to bring minority students into the field and these efforts have been inspirational to this community. Because of both his own unique scientific contributions and his constant work to incorporate minority students into his field, Dr. Tucker's efforts exactly reflect Dr. Susan Niebur's "untiring work at bringing people together and finding ways to help everyone live up to their potential." Dr. O.J. Tucker is an exceptional scientist and incredible person and could not be more deserving of recognition.

ANGIOLETTA CORADINI MID-CAREER AWARD

The SSERVI Angioletta Coradini Mid-Career Award is given annually to a mid-career scientist for broad, lasting accomplishments related to SSERVI fields of interest. Angioletta Coradini (1946-2011) was an Italian planetary scientist who inspired astronomers and planetary scientists around the world. The 2022 Angioletta Coradini Mid-Career Award is given to Dr. Carolyn van der Bogert.

Carolyn H. van der Bogert has been a Research Scientist in the Institute for Planetology at the University of Münster, Germany since 2006, and prior to that, she was a Research Scientist with the Gemological Institute of America. She is a Science Team Associate on the Lunar Reconnaissance Orbiter Camera, where she provides Mission support, scientific investigations of geological studies of the lunar surface, and is preparing for future lunar missions. She has been involved with PLANMAP, an EU Planetary Mapping project, and is preparing for a commercial ISRU demonstration mission.

Dr. van der Bogert grew up on a small farm in the mountains of North Carolina, where she was inspired to study space science after attending a public talk with her father about the Voyager 2 mission and its impressive images of Uranus's moon Miranda.

She earned both Doctor of Philosophy and Master of Science at Brown University's Department of Geological Sciences and a Bachelor of Arts in Geology from Boston University's Planetary & Space Sciences program. She was a NASA Graduate Student Research Program Fellow, a NASA-Rhode Island Space Grant Graduate Student Fellow, and received the Brown University Charles Wilson Brown Dissertation Fellowship and Amelia Earhart Fellowship. She has extensively published over her career and received numerous poster awards, the Stephen E. Dwornik Planetary Geoscience Student Paper Award, and the Boston University Collegiate Excellence Award in Earth Sciences.

MICHAEL J. WARGO EXPLORATION SCIENCE AWARD

The Michael J. Wargo Exploration Science Award is an annual award given to a scientist or engineer who has significantly contributed to the integration of exploration and planetary science throughout their career. The 2022 Michael J. Wargo Exploration Science Award is given to Dr. Ben Bussey.

Ben Bussey is a physicist and planetary scientist researching the Moon's lunar poles for the space science and exploration communities. He has led national and international research teams, including two successful NASA virtual institute teams, one with the Lunar Science Institute and one with SSERVI. He was an initial member of the Exploration Science Strategy and Integration Office (ESSIO) within NASA's Science Mission Directorate which coordinates SMD's lunar activities; the Deputy Associate Administrator for Exploration (DAAX), running ESSIO; and the Chief Exploration Scientist for NASA's Human Exploration and Operations Mission Directorate (HEOMD).

Dr. Bussey was the principal investigator (PI) of the Mini-RF radar orbiting the Moon on NASA's Lunar Reconnaissance Orbiter and deputy PI for the sister instrument that flew on India's Chandrayaan-1 lunar orbiter. He has an extensive variety of mission experience, including LCROSS, AlHAT, RLEP 2, NEAR, Mars Express, Smart-1, and the Mercury and Venus sample return missions. He is currently a Co-investigator on the ShadowCam instrument, scheduled to fly to the Moon next year on Korea's KPLO spacecraft, and the lead of APL's Lunar Surface Innovation Initiative activities for NASA's STMD.

He has been a key member of several NASA strategy groups and workshops, including the Lunar Exploration Analysis Group, and has served on several NASA review panels (both

research and mission-related). He has conducted geologic fieldwork in volcanic terrains and was selected twice for NSF/NASA Antarctic Search for Meteorites expeditions. Ben has worked in a variety of roles training and developing Ph.D. scientists conducting planetary surface and atmospheric research, and can be credited with hiring several young-career scientists who have become leaders in their fields.

Dr. Bussey earned his B.A. in Physics from Wadham College, Oxford University, and his Ph.D. in Astronomy from the University College London. His training as a scientist, coupled with his mission experience, has given him an admirable understanding of the engineering associated with space missions. He has won several NASA Group Achievement Awards: LRO (2011); Mini-RF (2008); Near Earth Asteroid Rendezvous Shoemaker Mission (2002); the JHU/APL publication award for an outstanding professional book (2004).

EUGENE SHOEMAKER DISTINGUISHED SCIENTIST MEDAL

The Eugene Shoemaker Distinguished Scientist Medal, named after American geologist and one of the founders of planetary science, Eugene Shoemaker (1928-1997), is a lifetime achievement award given to a scientist who has significantly contributed to our understanding the Moon and other small bodies in our solar system. The 2022 Eugene Shoemaker Distinguished Scientist Medal is awarded to Lisa Gaddis for her significant scientific contributions throughout the course of her career.

As director of the Lunar and Planetary Institute (LPI), Dr. Lisa Gaddis is providing scientific leadership and management of the research and operations of LPI in support of NASA's strategic goals in planetary science and solar system exploration. Prior to her appointment to USRA/LPI, Dr. Gaddis was at the U.S. Geological Survey (USGS) Astrogeology Science Center in Flagstaff, Arizona, where she worked since 1990 as a scientist, administrator, and supervisor.

Dr. Gaddis holds a BA from Vassar College, an MS from Brown University, and a Ph.D. from the University of Hawaii. She brings broad scientific expertise spanning geology and geophysics, remote sensing, planetary science, space mission planning and operations, cartography, and data archiving. Her research interests include analyzing the composition, physical properties, and geologic history of planetary surfaces in our solar system, using remote sensing data at a variety of wavelengths. She has served as PI on more than 35 NASA projects, including the NASA Planetary Data System Cartography and Imaging Sciences Node from 2004 to 2020. Lisa also served as Chief Scientist for the USGS Astrogeology Program, serving as PI of the NASA Planetary Cartography Research Program from 2003 to 2007. Her NASA flight mission experience includes science and operations roles on the Mars Exploration Rovers (MER) and a Lunar Reconnaissance Orbiter (LRO) Participating Scientist.

A prolific author, she has published numerous papers in various scientific journals, several book chapters, and has served on several committees and advisory groups for NASA on national and international space science and exploration plans. She is a Fellow of the Geological Society of America and a recipient of the U.S. Department of the Interior Honor Award for Meritorious Service.

NASA ADMINISTRATOR ANNOUNCES NEXT NAC MEETING, NEW MEMBERS

NASA Administrator Bill Nelson announced the NASA Advisory Council (NAC) will convene its next meeting on August 9–10. Nelson also appointed new members to the NAC, who will provide leadership counsel and advice on agency programs and priorities.

"NASA remains a global leader in exploration as a result of having a world-class workforce, and the NASA Advisory Council is no different," said Nelson. "I am incredibly proud of the accomplishments and progress we've made to date, and these new additions to the NAC will bring new ideas and solutions to complex problems we face. We are in the midst of another banner year at the agency, and I look forward to hearing from and working with an exceptional NAC."

The new council members are:

Dr. John-Paul Clarke (Chair, NAC Aeronautics Committee) – Clarke is a professor of aerospace engineering and engineering mechanics at The University of Texas at Austin, where he holds the Ernest Cockrell Jr. memorial chair in engineering. He is also a former researcher at NASA's Jet Propulsion Laboratory in Southern California.

Hon. Kay Bailey Hutchison (Member at Large) – Hutchison most recently served as the U.S. permanent representative to NATO and served in the U.S. Senate prior to that. While in the Senate, she served as chair of the Commerce Science and Space Subcommittee, supporting funding for the NASA investment in research and education in STEM. In 2005, she sponsored and passed the National Aeronautics and Space Administration Authorization Act.

Dr. Ellen Williams (Chair, NAC Science Committee) – Williams is the director of the Earth System Science Interdisciplinary Center and a distinguished university professor at the University of Maryland, where she works at the interface of energy technology and policy in the context of mitigating climate change. She is also the former director of the Advanced Research Projects Agency-Energy (ARPA-E).

Ms. Jacklyn Wynn (Member at Large) – Wynn is vice president of strategic programs for the federal health sector at General Dynamics Information Technology, where she oversees multi-year, technology-enabled strategic engagements that provide high-quality health care enterprise solutions and resources across the federal health agencies.

Retired Gen. Lester Lyles will continue to chair the NAC and its 60 members appointed across the council and five committees supporting aeronautics, human spaceflight, science, and STEM, as well as technology, innovation, and engineering.

The NAC typically meets three times per year, and the second virtual meeting of 2022 is slated for August 9–10, 2022. This year, in addition to its reviews of NASA's mission areas, the NAC will also align its work to focus on the following agency priorities:

- Climate Change
- Commercial and Industry Partnerships
- Diversity, Inclusion, Equity, and Accessibility
- International Collaboration
- Program Management and Acquisition

For the latest on the NASA Advisory Council events, activities, and news, visit www.nasa.gov/offices/nac.

NASA INTRODUCES 2022 CLASS OF FLIGHT DIRECTORS

NASA has selected seven new additions to the team of flight directors to oversee operations of the International Space Station, commercial crew, and Artemis missions to the Moon. The inductees in the class of 2022 include Heidi Brewer, Ronak Dave, Chris Dobbins, Garrett Hehn, Nicole McElroy, Elias Myrmo, and Diana Trujillo.

After completing a comprehensive training program that includes operational leadership and risk management, as well as the technical aspects of flight control and spacecraft systems, these future flight directors will lead human spaceflight missions from the Mission Control Center at NASA's Johnson Space Center in Houston.

In this role, these individuals will lead teams of flight controllers, research and engineering experts, and support personnel around the world, making the real-time decisions critical to keeping NASA astronauts safe in space.

"These highly qualified individuals will be responsible for keeping astronauts safe and executing human spaceflight missions," said NASA Director of Flight Operations Norm Knight. "There were many outstanding candidates, both from within the agency and across the spaceflight industry, which is a great indication of the tremendous talent we have here at NASA and within the growing spaceflight community."

NASA's flight directors lead missions to the space station and are preparing for lunar missions for NASA's Artemis program. The total number of agency flight directors is now 108 since the namesake of the Mission Control Center, Christopher C. Kraft Jr., became the agency's first flight director in 1958. The new class will be at the forefront of everything humans do in space, following in the footsteps of Apollo-era flight directors, including Glynn Lunney, Gene Kranz, and Kraft.

Becoming a NASA flight director requires years of study and dedication, as well as a background of professional experience in a high-stress environment, requiring fast-paced decision-making.

Meet NASA's newest class of flight directors:

Heidi Brewer

Heidi Brewer started her career at NASA in 2006 in the Space Shuttle Instrumentation and Communications Officer group. In that role, she supported 19 shuttle missions and was a lead

NASA's 2022 class of flight directors. The inductees from left to right: Heidi Brewer, Ronak Dave, Garrett Hehn, Diana Trujillo, Elias Myrmo, Chris Dobbins, and Nicole McElroy. Credit: NASA.

for the final shuttle flight, STS-135. At the conclusion of the shuttle program in 2011, Brewer transitioned to the Space Station Integration and Systems Engineer group, where she worked as a specialist in integrating operations and training with SpaceX. She supported more than 20 Dragon missions for NASA's Commercial Resupply Services and Commercial Crew Programs, serving as a lead for multiple SpaceX resupply missions to the station for NASA, and Axiom Mission 1, the first private astronaut mission to the space station. Brewer also served as a lead operations integrator for the Bigelow Expandable Activity Module, the Common Communication for Visiting Vehicles ship-to-ship radio system, and most recently, the Artemis human landing system.

Brewer was raised in Marietta, Georgia, graduated from Georgia Tech in Atlanta with a Bachelor of Science degree in aerospace engineering in 2005, and holds a Master of Science degree in aeronautical science from Embry-Riddle Aeronautical University in Daytona Beach, Florida.

Ronak Dave

Ronak Dave started his career at NASA in 2011 in the Pathways Intern Program. Upon becoming a full-time NASA engineer, he started work in the International Space Station Motion Control Systems Group as an attitude determination and control officer. In that role, he logged more than 1,000 hours in mission control and supported a SpaceX commercial resupply mission to the space station for NASA. He then transitioned to the propulsion systems group to support Orion, Space Launch System, and Boeing Starliner development and operations. He supported the Boeing Starliner Orbital Flight Test-1 mission as a propulsion officer. Most recently, he served as the ascent propulsion officer for the Boeing Starliner Orbit Flight Test-2 mission, supported astronaut training for the Boeing Starliner Crewed Flight Test, and served as the main propulsion systems officer for SLS and propulsion officer for Orion for the Artemis I mission, while leading rocket operations as a booster systems engineer for Artemis II.

Dave was raised in Secaucus, New Jersey, and graduated from Purdue University in West Lafayette, Indiana, with a Bachelor of Science degree in aeronautical and astronautical engineering.

Chris Dobbins

Chris Dobbins also began his NASA career in 2011 in the Pathways Intern Program. He started his full-time NASA career as a space station Environmental and Thermal Operating Systems flight controller in 2014, logging more than 2,500 hours of console time and serving as a lead for the International Space Station Expedition 56 and several spacewalks. He later began supporting the Boeing Starliner spacecraft as an Emergency, Environmental, and Consumables Manager flight controller, working in Mission Control for the company's uncrewed flight test for NASA. He most recently served as the ascent and entry lead for Boeing's Orbital Flight Test-2, while helping develop operational strategies and conduct astronaut training for the company's crewed flight test mission, including crewed vehicle emergency response procedures.

Dobbins is originally from Crystal Lake, Illinois, and graduated from the University of Michigan, Ann Arbor, with a Bachelor of Science degree in aerospace engineering.

Garrett Hehn

Garrett Hehn began his career at NASA in 2014 in the International Space Station Trajectory Operations group and became certified as a Trajectory Operations Officer in 2016. In that role, he served as lead for Expedition 50, a SpaceX commercial resupply mission to the space station for NASA, Sierra Space Dream Chaser development, and Boeing's Crew Flight Test. Hehn led an overhaul of an agency training flow and has been an instructor for other trainees since achieving certification as a trajectory operations officer. In 2018, he expanded his scope to become the lead Artemis II Flight Dynamics Officer while maintaining his previous roles. Earlier this year, he obtained his flight dynamics officer certification for Artemis I.

Hehn was raised in Pittsburgh and graduated from Virginia Tech in Blacksburg, Virginia, with a Bachelor of Science degree in aerospace engineering and minors in mathematics and Spanish.

Nicole (Lewis) McElroy

Nicole McElroy joins the NASA flight director team from Virgin Orbit in Long Beach, California, where she worked as the launch director. McElroy first started her work at Virgin Orbit as an intern and then returned full-time as a propulsion systems engineer designing the propellant and pressurant management systems. She later qualified those systems for flight, leading the first stage and second stage test campaigns. McElroy ultimately joined the launch operations team as the

rocket systems operator for LauncherOne's first two flights. She served as launch director for the third and fourth flights, where she was responsible for the entire launch operation timeline.

McElroy was born in England and raised in Highlands Ranch, Colorado. She graduated valedictorian from the Columbia University School of Engineering and Applied Science in New York, earning a Bachelor of Science degree in mechanical engineering in 2015.

Elias Myrmo

Elias Myrmo joined NASA in 2008 in the Flight Operations Directorate's Mission Systems Division, working on Mission Control Center systems and information technology infrastructure. Myrmo became a communication radio frequency onboard network utilization specialist in 2010, logging more than 2,000 hours at console in support of International Space Station Expeditions 32 through 50. Since 2016, he has served as lead of the Exploration Flight Dynamics and Operations Group, responsible for the training and certification of flight dynamics officers for Artemis missions. The group also is responsible for the protection of the public on launch day through range safety, as well as day-of-launch update operations for the agency's Space Launch System rocket during Artemis missions.

Myrmo was raised in Naples, Florida, and graduated from the University of Central Florida in Orlando with a Bachelor of Science degree in computer science.

Diana Trujillo

Diana Trujillo most recently served as the Integrated Planning and Sequencing for Surface Missions Group Supervisor at NASA's Jet Propulsion Laboratory in California. In that role, she supported mission operations for NASA's ongoing exploration missions on the surface of Mars as well as the planned Mars Sample Return mission. She previously served as a mission lead for the Mars Perseverance rover, where she was responsible for the rover's tactical command team and the team that analyzed the rover's telemetry to determine its health and state. She served as a surface flight director during the early surface operations of the Mars Perseverance rover, including rover commissioning and the deployment of Ingenuity, the first helicopter to operate on another planet. Previously, she served as a mission lead and the engineering operations deputy team chief for the Mars Curiosity mission.

Trujillo was born and raised in Cali, Colombia, and earned a Bachelor of Science degree in aerospace engineering from the University of Maryland in College Park, with additional studies at the University of Florida in Gainesville. She also is a graduate of Miami-Dade College in Florida and the NASA Academy at NASA's Langley Research Center in Virginia. In 2021, she received the Cruz de Boyacá, the highest honor that the government of Colombia bestows upon civilians.

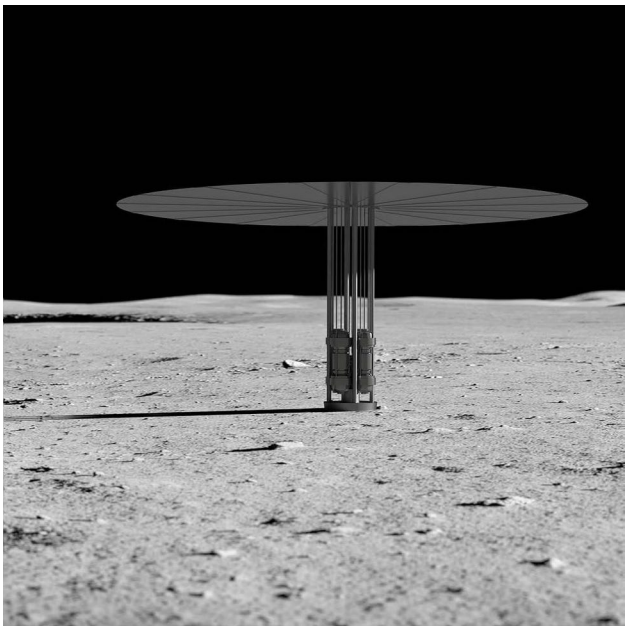
NASA ANNOUNCES ARTEMIS CONCEPT AWARDS FOR NUCLEAR POWER ON MOON

NASA and the U.S. Department of Energy (DOE) are working together to advance space nuclear technologies. The agencies have selected three design concept proposals for a fission surface power system design that could be ready to launch by the end of the decade for a demonstration on the Moon. This technology would benefit future exploration under the Artemis umbrella.

The contracts, to be awarded through the DOE's Idaho National Laboratory, are each valued at approximately $5 million. The contracts fund the development of initial design concepts for a 40-kilowatt class fission power system planned to last at least 10 years in the lunar environment.

Relatively small and lightweight compared to other power systems, fission systems are reliable and could enable continuous power regardless of location, available sunlight, and other natural environmental conditions. A demonstration of such systems on the Moon would pave the way for long-duration missions on the Moon and Mars.

Battelle Energy Alliance, the managing and operating contractor for Idaho National Laboratory, led the Request for Proposal development, evaluation, and procurement sponsored by NASA. Idaho National Laboratory will award 12-month contracts to the following companies to each develop preliminary designs:



Fission surface power systems — depicted in this conceptual illustration — could provide reliable power for human exploration of the Moon under Artemis. Credits: NASA.

- **Lockheed Martin of Bethesda, Maryland** – The company will partner with BWXT and Creare.
- **Westinghouse of Cranberry Township, Pennsylvania** – The company will partner with Aerojet Rocketdyne.
- **IX of Houston, Texas, a joint venture of Intuitive Machines and X-Energy** – The company will partner with Maxar and Boeing.

"The Fission Surface Power project is a very achievable first step toward the United States establishing nuclear power on the Moon," said Idaho National Laboratory Director John Wagner. "I look forward to seeing what each of these teams will accomplish."

The Phase 1 awards will provide NASA critical information from industry that can lead to a joint development of a full flight-certified fission power system. Fission surface power technologies also will help NASA mature nuclear propulsion systems that rely on reactors to generate power. These systems could be used for deep space exploration missions.

NASA's fission surface power project is managed by the agency's Glenn Research Center in Cleveland. The power system development is funded by the Space Technology Mission Directorate's Technology Demonstration Missions program, which is located at Marshall Space Flight Center in Huntsville, Alabama.

For more information about NASA's investments in space technology, visit www.nasa.gov/spacetech.

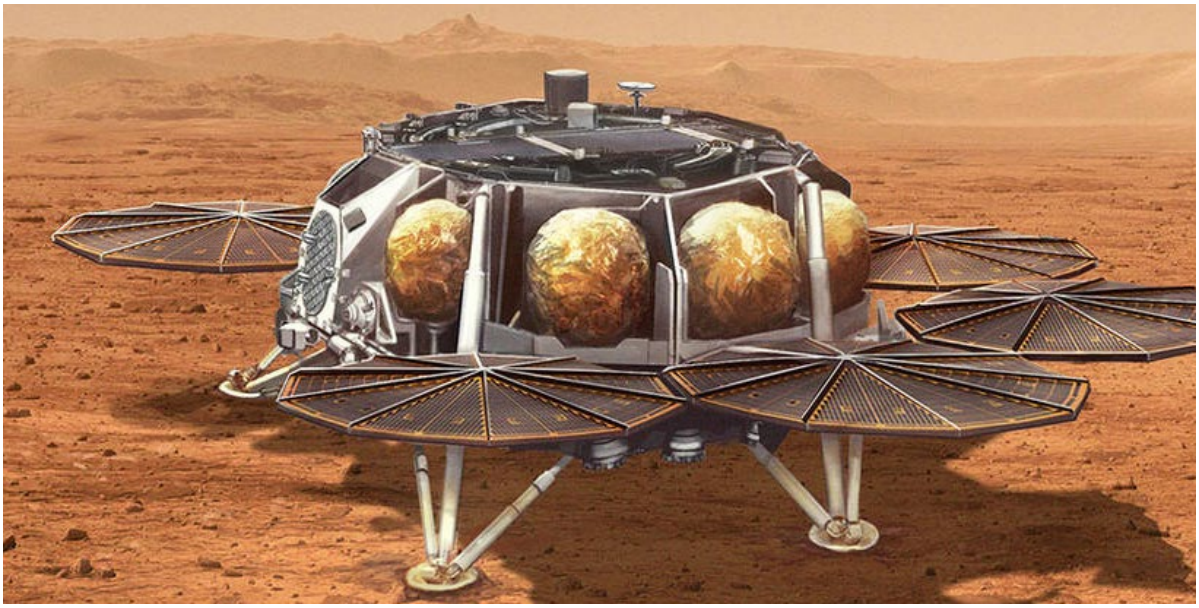
NASA, PARTNER ESTABLISH NEW RESEARCH GROUP FOR MARS SAMPLE RETURN PROGRAM

Sixteen scientists from the U.S., Europe, Canada, and Japan have been chosen to help future samples from the Red Planet achieve their full potential.

NASA and ESA (European Space Agency), its partner in the Mars Sample Return Program, have established a new group of researchers to maximize the scientific potential of Mars rock and sediment samples that would be returned to Earth for in-depth analysis. Called the Mars Sample Return Campaign Science Group, the 16 researchers will function as a science resource for the campaign's project teams as well as for related Earth-based ground projects, such as sample recovery and curation.

"These 16 individuals will be the standard-bearers for Mars Sample Return science," said Michael Meyer, Mars Exploration Program lead scientist at NASA Headquarters in Washington. "They will build the roadmap by which science for this historic endeavor is accomplished – including establishing the processes for sample-related decision-making and designing the procedures that will allow the worldwide scientific community to become involved with these first samples from another world."

The members of the Mars Sample Return Campaign Science Group are:



This illustration shows a concept for a proposed NASA Sample Retrieval Lander that would carry a small rocket (about 10 feet, or 3 meters, tall) called the Mars Ascent Vehicle to the martian surface. Credit: NASA/JPL-Caltech.

- Laura Rodriguez – NASA's Jet Propulsion Laboratory, Southern California
- Michael Thorpe – Johnson Space Center Engineering, Technology and Science at NASA's Johnson Space Center, Houston; Texas State University, San Marcos
- Audrey Bouvier – Bayerisches Geoinstitut, Universität Bayreuth, Germany
- Andy Czaja – Department of Geology, University of Cincinnati
- Nicolas Dauphas – Origins Laboratory, the University of Chicago
- Katherine French – Central Energy Resources Science Center, U.S. Geological Survey, Denver
- Lydia Hallis – School of Geographical and Earth Sciences, University of Glasgow, UK
- Rachel Harris – Department of Organismic and Evolutionary Biology, Harvard University, Boston
- Ernst Hauber – Institute of Planetary Research, German Aerospace Center, Germany
- Suzanne Schwenzer – School of Earth, Environment and Ecosystem Sciences, the Open University, UK
- Andrew Steele – Earth and Planetary Laboratory, Carnegie Institution of Washington
- Kimberly Tait – Department of Natural History, Royal Ontario Museum, Canada
- Tomohiro Usui – Japan Aerospace Exploration Agency
- Jessica Vanhomwegen – Laboratory for Urgent Response to Biological Threats, Institut Pasteur, France
- Michael Velbel – Department of Earth and Environmental Sciences, Michigan State University
- Maria-Paz Zorzano Mier – Astrobiology Center, National Institute for Aerospace Technology, Spain

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

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

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

LPI ANNOUNCES THE 2022 BARRINGER AWARD RECIPIENTS

The Lunar and Planetary Institute is pleased to announce the 2022 awardees of the Barringer Family Fund for Meteorite Impact Research.

- Paige Cincio
  University of Western Ontario, Canada
- Juliette Faucher
  Vrije Universiteit Brussel, Belgium
- Shania James
  University of Kerala, India
- Liseloane Malelu
  University of the Witwatersrand, South Africa
- Fernando Pereira
  State University of Campinas, Brazil
- Daniel Sheikh
  Portland State University, USA

The Barringer Family Fund for Meteorite Impact Research has been established as a memorial to recognize the contributions of Brandon, Moreau, Paul, and Richard Barringer to the field of meteoritics and the Barringer family's strong interest and support over many years in research and student education. In addition to its memorial nature, the Fund also reflects the family's long-standing commitment to responsible stewardship of the Barringer Meteorite Crater and the family's steadfast resolve in maintaining the crater as a unique scientific research and education site.

Credit: NASA Earth Observatory.

For more information, visit The Barringer Family Fund for Meteorite Impact Research.

SEASON FIVE OF "THE INVISIBLE NETWORK" EXPLORES THE DEEP SPACE NETWORK

Credit: NASA.

NASA's "The Invisible Network" podcast returned on June 9 for a six-episode season about NASA's Deep Space Network. Managed by the Jet Propulsion Laboratory in Southern California, the Deep Space Network provides critical communications links to flagship NASA missions on Mars, the outer planets, and even in interstellar space.

Podcast episodes debuted on Thursdays throughout June and July. Check out the season trailer here.

"The Invisible Network" first debuted in 2018 with a six-episode season covering a variety of topics related to NASA's Space Communications and Navigation (SCaN) program office. Since then, the podcast's 22 episodes have covered burgeoning commercialization efforts, laser communications technologies, NASA's Artemis Moon missions, and so much more.

You can find episodes of the podcast on Apple Podcasts, Google Podcasts, Soundcloud, and at 'The Invisible Network' Podcast.

From long-form interviews with astronauts and engineers to stories that take you on a tour of the galaxy, NASA's audio offerings let you experience the thrill of space exploration without ever leaving Earth. Discover all of NASA's podcasts at nasa.gov/podcasts.

NASA'S EUROPA CLIPPER MISSION COMPLETES MAIN BODY OF THE SPACECRAFT

The main body of NASA's Europa Clipper spacecraft has been delivered to the agency's Jet Propulsion Laboratory (JPL) in Southern California. Over the next two years there, engineers and technicians will finish assembling the craft by hand before testing it to make sure it can withstand the journey to Jupiter's icy moon Europa.

The spacecraft body is the mission's workhorse. Standing 10 feet (3 meters) tall and 5 feet (1.5 meters) wide, it's an aluminum cylinder integrated with electronics, radios, thermal loop tubing, cabling, and the propulsion system. With its solar arrays and other deployable equipment stowed for launch, Europa Clipper will be as large as an SUV; when extended, the solar arrays make the craft the size of a basketball court. It is the largest NASA spacecraft ever developed for a planetary mission.

"It's an exciting time for the whole project team and a huge milestone," said Jordan Evans, the mission's project manager at JPL. "This delivery brings us one step closer to launch and the Europa Clipper science investigation."

Set to launch in October 2024, Europa Clipper will conduct nearly 50 flybys of Europa, which scientists are confident harbors an internal ocean containing twice as much water as Earth's oceans combined. And the ocean may currently have conditions suitable for supporting life. The spacecraft's nine science instruments will gather data on Europa's atmosphere, surface, and interior – information that scientists will use to gauge the depth and salinity of the ocean, the thickness of the ice crust, and potential plumes that may be venting subsurface water into space.

Those instruments already have begun arriving at JPL, where the phase known as assembly, test, and launch operations has been underway since March. The ultraviolet spectrograph, called Europa-UVS, arrived in March. Next came the spacecraft's thermal emission imaging instrument, E-THEMIS, delivered by the scientists and engineers leading its development at Arizona State University. E-THEMIS is a sophisticated infrared camera designed to map Europa's temperatures and help scientists find clues about the moon's geological activity – including regions where liquid water may be near the surface.

By the end of 2022, most of the flight hardware and the remainder of the science instruments are expected to be complete.

The Whole Package

The Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland, designed Europa Clipper's body in collaboration with JPL and NASA's Goddard Space Flight Center in Greenbelt, Maryland.

NASA's Europa Clipper spacecraft is visible in a main clean room at JPL, as engineers and technicians inspect it after delivery in early June 2022. Credit: NASA/JPL-Caltech/Johns Hopkins APL/Ed Whitman.

"The flight system designed, built, and tested by APL – using a team of hundreds of engineers and technicians – was the physically largest system ever built by APL," said APL's Tom Magner, the mission's assistant project manager.

The work on the main module continues now at JPL.

"What arrived at JPL represents essentially an assembly phase unto itself. Under APL's leadership, this delivery includes work by that institution and two NASA centers. Now the team will take the system to an even higher level of integration," said Evans.

The main structure is two stacked aluminum cylinders dotted with threaded holes for bolting on the spacecraft's cargo: the radio frequency module, radiation monitors, propulsion electronics, power converters, and wiring. The radio frequency subsystem will power eight antennas, including an enormous high-gain antenna that measures 10 feet (3 meters) wide. The structure's web of electrical wires and connectors, called the harness, weighs 150 pounds (68 kilograms) by itself; if stretched out, it would run almost 2,100 feet (640 meters) – twice the perimeter of a football field.

The heavy-duty electronics vault, built to withstand the intense radiation of the Jupiter system, will be integrated with the main spacecraft structure along with the science instruments.

Inside the main body of the spacecraft are two tanks – one to hold fuel, one for oxidizer – and the tubing that will carry their

contents to an array of 24 engines, where they will combine to create a controlled chemical reaction that produces thrust.

"Our engines are dual-purpose," said JPL's Tim Larson, the deputy project manager. "We use them for big maneuvers, including when we approach Jupiter and need a large burn to be captured in Jupiter's orbit. But they're also designed for smaller maneuvers to manage the attitude of the spacecraft and to fine-tune the precision flybys of Europa and other solar system bodies along the way."

Those big and small maneuvers will come into play a lot during the six-year, 1.8-billion-mile (2.9-billion-kilometer) journey to this ocean world, which Europa Clipper will begin investigating in earnest in 2031.

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

NASA SELECTS NEW INSTRUMENTS FOR PRIORITY ARTEMIS SCIENCE ON MOON

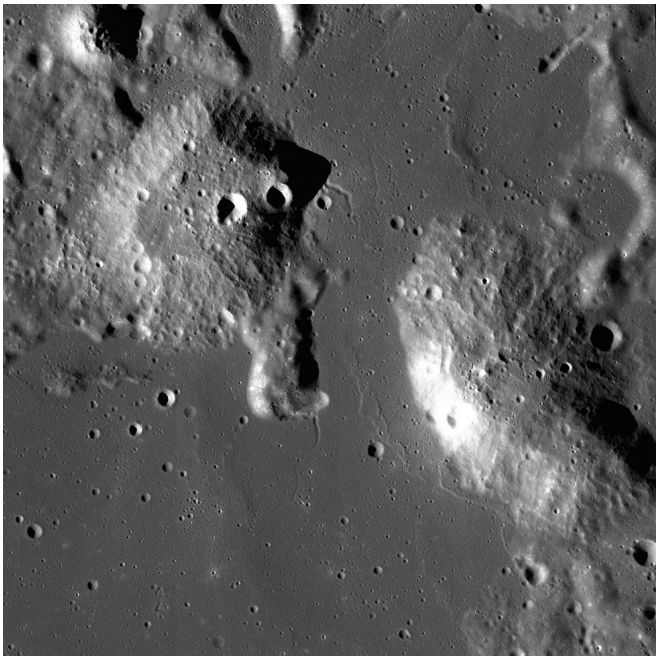
Adding to the growing list of commercial deliveries slated to explore more of the Moon than ever before under Artemis, NASA has selected two new science instrument suites, including one that will study the mysterious Gruithuisen Domes for the first time.

These payload suites mark the second selection through the agency's Payloads and Research Investigations on the Surface of the Moon (PRISM) call for proposals. Both payloads will be delivered to the lunar surface on future flights through NASA's Commercial Lunar Payload Services (CLPS) initiative, which is one part of the agency's larger lunar exploration architecture planned for this decade.

"The two selected studies will address important scientific questions related to the Moon," said Joel Kearns, deputy associate administrator for exploration in NASA's Science Mission Directorate. "The first will study geologic processes of early planetary bodies that are preserved on the Moon, by investigating a rare form of lunar volcanism. The second will study the effects of the Moon's low gravity and radiation environment on yeast, a model organism used to understand DNA damage response and repair."

The Lunar Vulkan Imaging and Spectroscopy Explorer (Lunar-VISE) investigation consists of a suite of five instruments, two of which will be mounted on a stationary lander and three mounted on a mobile rover to be provided as a service by the CLPS vendor.

Over the course of 10 Earth days (one lunar day), Lunar-VISE will explore the summit of one of the Gruithuisen Domes. These domes are suspected to have been formed by a sticky magma rich in silica, similar in composition to granite. On Earth, formations like these need oceans of liquid water and plate tectonics to form, but without these key ingredients on the Moon, lunar scientists have been left to wonder how these domes formed and evolved over time.



NASA is planning to send a lander and rover to the Gruithuisen Domes, as seen in this controlled mosaic, and LROC images will help guide the way. The domes are located at 36.3° N, 319.8° E. Credit: NASA/GSFC/Arizona State University.

By analyzing the lunar regolith at the top of one of these domes, the data collected and returned by Lunar-VISE's instruments will help scientists answer fundamental open questions regarding how these formations came to be. The data also will help inform future robotic and human missions to the Moon. Dr. Kerri Donaldson Hanna of the University of Central Florida will lead this payload suite.

The second selected investigation, the Lunar Explorer Instrument for space biology Applications (LEIA) science suite, is a small CubeSat-based device. LEIA will provide biological research on the Moon – which cannot be simulated or replicated with

high fidelity on the Earth or International Space Station – by delivering the yeast Saccharomyces cerevisiae to the lunar surface and studying its response to radiation and lunar gravity. S. cerevisiae is an important model of human biology, especially in the areas of genetics, cellular and molecular replication and division processes, and DNA damage response to environmental factors such as radiation. The data returned by LEIA, in conjunction with previously existing data from other biological studies, could help scientists answer a decades-old question of how partial gravity and actual deep space radiation in combination influence biological processes. Dr. Andrew Settles of NASA's Ames Research Center in Silicon Valley, California, will lead the LEIA payload suite.

With these selections in place, NASA will work with the CLPS office at the agency's Johnson Space Center in Houston to issue task orders to deliver these payload suites to the Moon in the 2026 timeframe.

For these payload suites, the agency also has selected two project scientists to coordinate science activities for the selected instrument suites, including working with the payloads on landing site selection, developing concepts of operations, and archiving science data acquired during surface operations. Dr. John Karcz of NASA Ames Research Center in California will coordinate the Lunar-VISE investigation suite for delivery to the Gruithuisen Domes, and Dr. Cindy Young of NASA's Langley Research Center in Hampton, Virginia, will coordinate the LEIA investigation suite for delivery.

CLPS is a key part of NASA's Artemis lunar exploration plans. The science and technology payloads sent to the Moon's surface will help lay the foundation for human missions on and around the Moon. The agency has made seven task order awards to CLPS providers for lunar deliveries between in the early 2020s with more delivery awards expected through 2028.

For more information, visit www.nasa.gov/clps.

NASA PARTNERS WITH INDUSTRY FOR NEW SPACEWALKING, MOONWALKING SERVICES

An artist's illustration of two suited crew members working on the lunar surface. The one in the foreground lifts a rock to examine it while the other photographs the collection site in the background. Credit: NASA.

NASA has selected Axiom Space and Collins Aerospace to advance spacewalking capabilities in low-Earth orbit and at the Moon, by buying services that provide astronauts with next-generation spacesuit and spacewalk systems to work outside the International Space Station, explore the lunar surface on Artemis missions, and prepare for human missions to Mars.

The awards leverage NASA's expertise with commercial innovation to support continued science at the orbiting laboratory and long-term human exploration at the Moon under Artemis, including landing the first woman and first person of color on the lunar surface.

"With these awards, NASA and our partners will develop advanced, reliable spacesuits that allow humans to explore the cosmos unlike ever before," said Vanessa Wyche, director of NASA's Johnson Space Center in Houston. "By partnering with industry, we are efficiently advancing the necessary technology to keep Americans on a path of successful discovery on the International Space Station and as we set our sights on exploring the lunar surface."

Each partner has invested a significant amount of its own money into development. Partners will own the spacesuits and are encouraged to explore other non-NASA commercial applications for data and technologies they co-develop with NASA. This new approach to spacewalk services encourages an emerging commercial market for a range of customers and grants NASA the right to use the same data and technologies within the agency and on future exploration program procurements.

NASA experts defined the technical and safety standards by which the spacesuits will be built, and the chosen companies agreed to meet these key agency requirements. The commercial partners will be responsible for the design, development,

qualification, certification, and production of spacesuits and support equipment to enable space station and Artemis missions.

The agency will continue to make flight- and ground-based test data from NASA-led space station spacewalks and NASA's Exploration Extravehicular Mobility Unit (xEMU) development project available to companies through the EVA Technical Library. This will encourage an accelerated transition to industry while reducing risks and providing access to previous NASA investments in advanced exploration spacesuit development.

NASA designed the contract to endure and evolve with the needs of the agency and space industry. The contract also provides the agency with an optional mechanism to add additional vendors that were not selected in the original award announcement as the commercial space services market evolves.

Learn more about spacewalking at nasa.gov/suitup.

NASA SUPPORTS SMALL BUSINESS RESEARCH TO POWER FUTURE EXPLORATION

A project funded by NASA's Small Business Technology Transfer program could help improve the efficiency of solar cells for space missions and use on Earth. Here, a team member installs solar panels onto the CAPSTONE spacecraft — short for Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment — before its launch to the Moon. Credit: NASA/Dominic Hart.

NASA has selected hundreds of small businesses and dozens of research institutions to develop technology to help drive the future of space exploration, ranging from novel sensors and electronics to new types of software and cutting-edge materials. The newly awarded projects under the agency's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program also include a high-power electric rocket and a coating to make solar panels more efficient that could be used both in space and on Earth.

The awards total nearly $50 million, with investments spread out over 39 states and Washington. Under the selection, 333 proposals from 257 small businesses and 41 research institutions – including 10 Minority Serving Institutions — will be awarded first-round funding for technology development. View the full lists of SBIR awardees and STTR awardees online.

"NASA is working on ambitious, groundbreaking missions that require innovative solutions from a variety of sources — especially our small businesses," said NASA Deputy Administrator Pam Melroy. "Small businesses have the creative edge and expertise needed to help our agency solve our common and complex challenges, and they are crucial to maintaining NASA's leadership in space. The SBIR program is one of the key ways we do that as well as creating jobs in a growing, sustainable space economy."

NASA investments in American small businesses and research institutions help provide the innovations needed for the exciting and ambitious missions on the agency's horizon and foster robust commercial space and technology sectors.

Each proposal team will receive $150,000 — a 20% increase over previous years' funding — to establish the merit and feasibility of their innovations. Phase I SBIR contracts are awarded to small businesses and last for six months, while Phase I STTR contracts are awarded to small businesses in partnership with a research institution and last for 13 months.

About 30% of the awards will go to first-time NASA SBIR/STTR recipients. This includes Ad Astra Rocket Company based in Webster, Texas. With its Phase I award, the company will develop a new way of manufacturing part of its Variable Specific Impulse Magnetoplasma Rocket, or VASIMR, engine — a high-power electric rocket engine the company has been working on with NASA for 25 years. In the engine, powerful radiofrequency waves are launched by special antennas called couplers. The waves ionize gas into plasma, which is then accelerated to provide rocket thrust. Phase I funding will be used to manufacture couplers in a

way that increases the engine's power limit. This innovation will help move the entire engine closer to commercialization, where it could be used for high-maneuverability satellites, lunar settlement cargo delivery, and more.

Nearly 25% of the selected companies are women-owned, veteran-owned, disadvantaged, and/or HUBzone small businesses. For example, D2K Technologies, a woman- and minority-owned small business based in Oceanside, California, will create a monitoring and advisory system for the health management of solenoid-operated valves (SOV) used in industrial applications with its Phase I award. This technology could find use in many of NASA's research centers, testing centers, and launch sites since SOVs are basic components of most fluid systems. With the widespread use of SOVs in industrial applications, the system could be useful to oil and gas, nuclear, manufacturing, power generation, chemical, food, and pharmaceutical companies. This company is also a first-time NASA SBIR awardee.

M-STTR awardee Oakwood University, a historically Black university based in Huntsville, Alabama, will continue working alongside SSS Optical Technologies, a small business also based in Huntsville, using their Phase I award to develop a new type of coating for photovoltaic (PV) cells embedded in solar sails. The coating could generate extra electricity and improve the overall PV conversion efficiency, which could advance solar sailing and other power and energy conversion needs for space exploration. This technology could improve the efficiency of commercial solar panels.

NASA selected Phase I proposals to receive funding by judging their technical merit and commercial potential. Based on their progress during Phase I, companies may submit proposals for $850,000 in Phase II funding to develop a prototype, as well as subsequent SBIR/STTR Post Phase II opportunities. The NASA SBIR/STTR program is part of the Space Technology Mission Directorate and is managed by NASA's Ames Research Center in California's Silicon Valley.

To learn more about NASA's SBIR/STTR program and apply to future opportunities, visit sbir.nasa.gov/.

NASA AWARDS CONTRACT TO NATIONAL ACADEMY OF SCIENCES

NASA has awarded a sole-source contract to the National Academy of Sciences of Washington to conduct studies on questions of national importance within the domain of NASA science and technology programs relating to space science, Earth science, and biological and physical science in space.

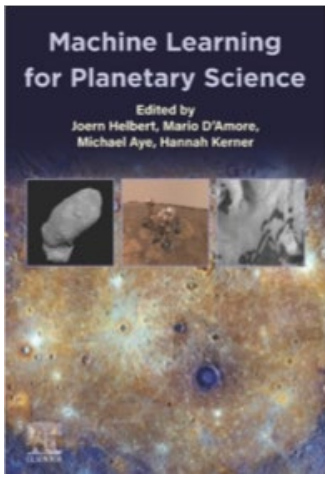
The Strategic Advice Supporting NASA Science and Technology Programs in Space Science, Earth Science, Biological and Physical Science in Space (SASNSTP) contract is a cost-reimbursement, no-fee, indefinite-delivery/indefinite-quantity contract, with a maximum ordering value of $32 million. The five-year period of performance began June 1.

With this contract, NASA can obtain access to an independent, authoritative forum for information, dialogue and advice on all aspects of space science and applications, and serve as the focal point within the academies for activities on space research. The scope includes scientific, technical, and programmatic aspects of investigations to include decadal surveys.

The work will be performed at the contractor's facility in Washington.

For information about NASA and agency programs, visit www.nasa.gov.

NEW AND NOTEWORTHY

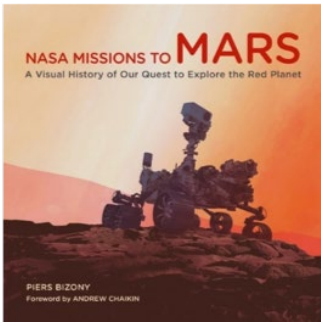


MACHINE LEARNING FOR PLANETARY SCIENCE

Edited by Joern Helbert, Mario D'Amore, Michael Aye, and Hannah Kerner

Elsevier, 2022, 232 pp., Paperback. $170.00. www.elsevier.com

Machine Learning for Planetary Science presents planetary scientists with a way to introduce machine learning into the research workflow as increasingly large nonlinear datasets are acquired from planetary exploration missions. The book explores research that leverages machine-learning methods to enhance our scientific understanding of planetary data and serves as a guide for selecting the right methods and tools for solving a variety of everyday problems in planetary science using machine learning. Illustrating ways to employ machine learning in practice with case studies, the book is clearly organized into four parts to provide thorough context and easy navigation. The book covers a range of issues, from data analysis on the ground to data analysis onboard a spacecraft, and from prioritization of novel or interesting observations to enhanced missions planning. This book is therefore a key resource for planetary scientists working in data analysis, missions planning, and scientific observation.



NASA MISSIONS TO MARS: A Visual History of Our Quest to Explore the Red Planet

By Piers Bizony

Motorbooks, 2022, 198 pp., Hardcover. $50.00. www.quarto.com

Gorgeously illustrated with NASA photography, the large-format *NASA Missions to Mars* examines everything from the first tentative steps toward the fourth planet to the 2021 landing of the Perseverance rover and beyond. Space exploration has always been about pushing boundaries, but perhaps the achievement that has most piqued a sense of possibility has been the exploration of Mars. Beginning with Soviet and American flybys in the early 1960s that were part and parcel of the Space Race, acclaimed space historian Piers Bizony continues through complete coverage of the Viking 1 and 2 missions of 1975–1976. Bizony also traces NASA's acclaimed rover program, describing the development, technologies, mission histories, and achievements of the rovers Sojourner, Opportunity, Spirit, and Curiosity — all on the 25th anniversary of their first landing.

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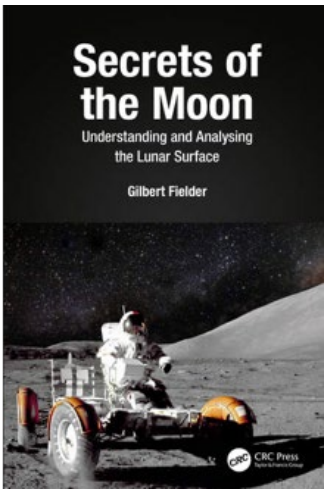
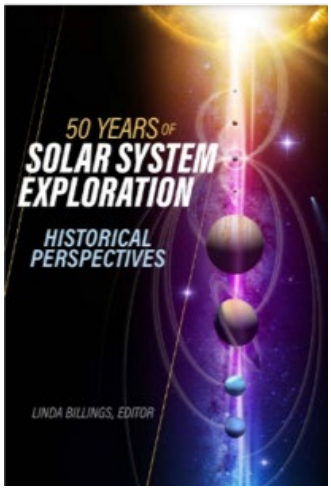


SECRETS OF THE MOON: Understanding and Analysing the Lunar Surface

By Gilbert Fielder

CRC Press, 2022, 244 pp., Hardcover. $144.00. www.routledge.com

Secrets of the Moon provides a unique account of the origin of key features on the lunar surface. Containing historical accounts and the latest observations from the field, in addition to exciting data from the Apollo manned missions, this book describes the development of our current understanding of the Moon. It also explores the fracturing of the Moon, a topic not explored in other literature in the area, and contains a statistical treatment of the smaller craters of the Moon as well as a geological treatment of the larger craters. This moderately technical account is designed to clarify and update the general thinking on the nature and origin of the most important lunar surface features for both undergraduate and research students. It may also be read by the professional scientist, especially the astronomer and the geologist who has found little time to study the Moon's topography, in addition to the lunar amateur astronomer and even the dedicated layman with a keen interest in lunar science. The book excludes nearly all mathematical symbols to remain accessible to those without a formal education in the area.

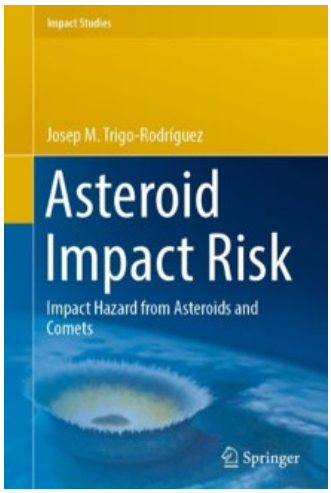


50 YEARS OF SOLAR SYSTEM EXPLORATION: Historical Perspectives

Edited by Linda Billings

NASA History Division, 2021, 364 pp., E-book. Free to read online and download. www.nasa.gov/sites/default/files/atoms/files/50-years-of-solar-system-exploration_tagged.pdf

NASA's first successful mission to another planet, Mariner 2 to Venus in 1962, marked the beginning of what NASA Chief Scientist Jim Green describes in this volume as "a spectacular era" of solar system exploration. In its first 50 years of planetary exploration, NASA sent spacecraft to fly by, orbit, land on, or rove on every planet in our solar system, as well as Earth's Moon and several moons of other planets. Pluto, reclassified as a dwarf planet in 2006, was visited by the New Horizons spacecraft in 2015. What began as an endeavor of two nations — the United States and the former Soviet Union — has become a multinational enterprise, with a growing number of space agencies worldwide building and launching planetary exploration missions, sometimes alone, sometimes together. In this NASA Special Publication, a diverse array of scholars address the science, technology, policy, and politics of planetary exploration. This volume offers a collection of in-depth studies of important projects, decisions, and milestones of this era.

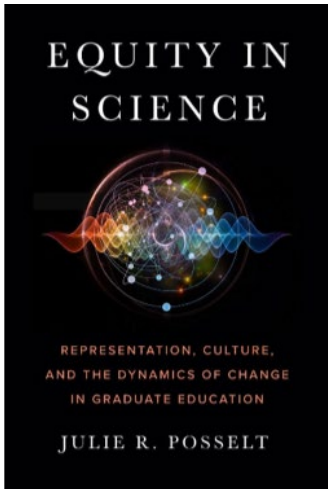


ASTEROID IMPACT RISK: Impact Hazard from Asteroids and Comets

By Josep M. Trigo-Rodriguez

Springer, 2022, 126 pp., Hardcover. $149.99. www.springer.com

This book describes the complexity of impact hazards associated with asteroids and comets. The challenge in this regard lies in the heterogeneous nature of these bodies that endanger our planet, which is why we are conducting new experiments to better understand their unique physicochemical properties. Impact hazards represent one of the greatest threats to the survival of human beings in the medium term. Geological studies show that the stratigraphic record holds clear geological evidence of these rare but transcendental encounters in the history of life on our planet. The study and quantification of past catastrophes can give us clues to face future challenges in the form of potential impacts. The goal of this book is to underscore the need for society-wide awareness of the dangers associated with asteroid and comet impacts, on the basis of scientific evidence and with no intention of sparking alarmism. The book also emphasizes the role of space missions to gain insights on these bodies, particularly describing the relevance of the DART (NASA) and Hera (ESA) missions to deflect and study Dimorphos, respectively, the small satellite of the Didymos binary asteroid.

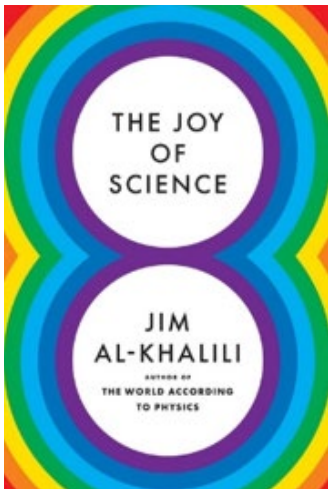


EQUITY IN SCIENCE: Representation, Culture, and the Dynamics of Change in Graduate Education

By Julie R. Posselt

Stanford University Press, 2020, 240 pp., Paperback. $28.00. www.sup.org

STEM disciplines are believed to be founded on the idea of meritocracy – recognition earned by the value of the data, which is objective. Such disciplinary cultures resist concerns about implicit or structural biases, and yet year after year, scientists observe persistent gender and racial inequalities in their labs, departments, and programs. In *Equity in Science*, the author makes the case that understanding how field-specific cultures develop is a crucial step for bringing about real change. She does this by examining existing equity, diversity, and inclusion efforts across astronomy, physics, chemistry, geology, and psychology. These ethnographic case studies reveal the subtle ways that exclusion and power operate in scientific organizations and sometimes within change efforts themselves. Posselt argues that accelerating the movement for inclusion in science requires more effective collaboration across boundaries that typically separate people and scholars – across the social and natural sciences; across the faculty-student-administrator roles; and across race, gender, and other social identities. Ultimately this book is a call for academia to place equal value on expertise and on those who do the work of cultural translation. Posselt closes with targeted recommendations for individuals, departments, and disciplinary societies for creating systemic, sustainable change.



THE JOY OF SCIENCE

By Jim Al-Khalili

Princeton University Press, 2022, 224 pp., Hardcover. $16.95. www.press.princeton.edu

The Joy of Science presents eight short lessons on how to unlock the clarity, empowerment, and joy of thinking and living a little more scientifically. In this brief guide to leading a more rational life, acclaimed physicist Jim Al-Khalili invites readers to engage with the world as scientists have been trained to do. The scientific method has served humankind well in its quest to see things as they really are, and underpinning the scientific method are core principles that can help us all navigate modern life more confidently. Discussing the nature of truth and uncertainty, the role of doubt, the pros and cons of simplification, the value of guarding against bias, the importance of evidence-based thinking, and more, Al-Khalili shows how the powerful ideas at the heart of the scientific method are deeply relevant to the complicated times we live in and the difficult choices we make.

WOMEN IN SPACE: 23 Stories of First Flights, Scientific Missions, and Gravity-Breaking Adventures

By Karen Bush Gibson

Chicago Review Press, 2020, 240 pp., Paperback. $14.99. www.chicagoreviewpress.com

When Valentina Tereshkova blasted off onboard Vostok 6 on June 16, 1963, she became the first woman to rocket into space. It would be 19 years before another woman got a chance — cosmonaut Svetlana Savitskaya in 1982, followed by American astronaut Sally Ride a year later. By breaking the stratospheric ceiling, these women forged a path for many female astronauts, cosmonauts, and mission specialists to follow. *Women in Space* profiles 23 pioneers, including Eileen Collins, the first woman to command the space shuttle; Peggy Whitson, who logged more than a year in orbit onboard the International Space Station; and Mae Jemison, the first African American woman in space; as well as astronauts from Japan, Canada, Italy, South Korea, France, and more. Readers will also learn about the Mercury 13, the American women selected by NASA in the late 1950s to train for spaceflight. Although they matched and sometimes surpassed their male counterparts in performance, they were ultimately denied the opportunity to head out to the launching pad. Their story, and the stories of the pilots, physicists, and doctors who followed them, demonstrate the vital role women have played in the quest for scientific understanding.

SIX-INCH SATURN GLOBE

Developed for Astronomy Magazine

$49.95. myscienceshop.com

Now you can display the ringed planet in your office or classroom with a limited-edition six-inch Saturn globe. Exclusively from Astronomy magazine, this custom-produced injection molded globe comes with removable acrylic rings, a clear display base, and a bonus informational guide with fun facts about Saturn, the images used to make the globe, and the globe's production process.

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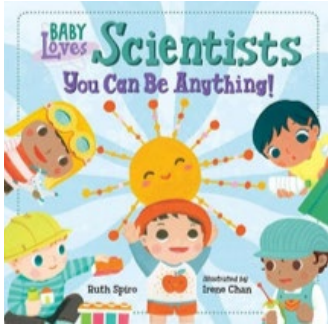
ASTROBUDDY PLUSH TOY

Produced by Celestial Buddies

$29.99. www.celestialbuddies.com

The newest member of the Celestial Buddies is AstroBuddy! This 12-inch plush toy is ready to explore the wonders of space with your little ones. AstroBuddy has a removable zippered backpack that can store all the necessary essentials to make your imaginary spacewalk a success. Made from soft, all new polyester material, this toy meets U.S. and European Union CPSC toy regulations. AstroBuddy comes with a hang tag that provides facts about astronauts. For ages 3 and up.



BABY LOVES SCIENTISTS: *You Can Be Anything!*

By Ruth Spiro

Charlesbridge, 2019, 24 pp., Hardcover. $12.99. www.charlesbridge.com

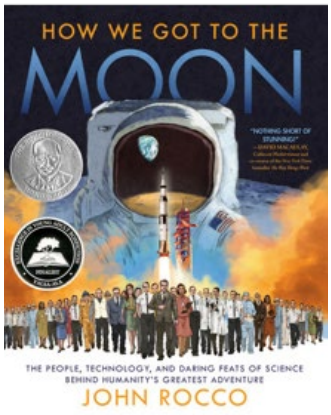
Baby loves to explore the world of science! What's next for Baby after learning about physics, engineering, computers, and the natural world? Becoming a scientist, of course! In this fun look at scientific careers, parents and children can talk about different science fields and the everyday heroes that work in them. Beautiful, visually stimulating illustrations complement age-appropriate text to encourage baby's sense of wonder. Also available as a board book. For ages 0 to 3.

DREAM BIG, LITTLE SCIENTISTS: A Bedtime Book

By Michelle Schaub

Charlesbridge, 2020, 32 pp., Hardcover. $16.99. www.charlesbridge.com

Spark curiosity and exploration with this innovative bedtime story for budding scientists that introduces eleven branches of science. From astronomy to physics to chemistry to geology, this STEM picture book will help kids get excited to explore. Includes further information about each branch of science. For ages 3 to 7.



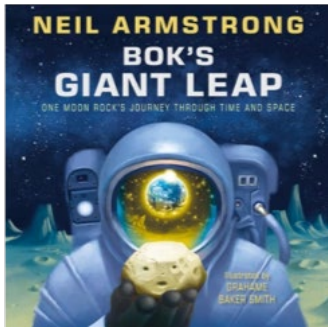
HOW WE GOT TO THE MOON: The People, Technology, and Daring Feats of Science Behind Humanity's Greatest Adventure

By John Rocco

Crown Books for Young Readers, 2020, 264 pp., Hardcover. $29.99. www.penguinrandomhouse.com

The Moon landing is one of the most ambitious, thrilling, and dangerous ventures in human history. This exquisitely researched and illustrated book tells the stories of the 40,000 unsung heroes – the engineers, mathematicians, seamstresses, welders, and factory workers – and their innovations and life-changing technological leaps forward that allowed NASA to achieve this unparalleled accomplishment. From the shocking launch of the Russian satellite Sputnik to the triumphant splashdown of Apollo 11, Caldecott Honor winner John Rocco answers questions about this world-altering mission. Each challenging step in the space race is revealed, examined, and displayed through stunning diagrams, experiments, moments of crisis, and unforgettable human stories. Explorers of all ages will want to pore over every page in this comprehensive chronicle detailing the grandest human adventure of all time! For ages 10 and up.

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



BOK'S GIANT LEAP: One Moon Rock's Journey Through Time and Space

By Neil Armstrong

Crown Books for Young Readers, 2022, 48 pp., Hardcover. $17.99. www.penguinrandomhouse.com

First man on the Moon Neil Armstrong's only children's book is a unique exploration of how Earth and the Moon came to be. The entire epic history of Earth and the Moon is recounted through the observations of one special Moon rock named Bok. Geologists say that rocks remember, and Bok certainly does. It recounts how its life began on Earth, until a collision with an asteroid catapults it into orbit during the creation of the Moon. From the Moon's surface, Bok watches the developing planet change from afar – until a strange creature scoops him up and brings him back to Earth. When NASA honored Apollo 11 astronaut Neil Armstrong and gave him a piece of Moon rock from that mission, Armstrong playfully named the rock Bok in his acceptance speech. Award-winning illustrator Grahame Baker-Smith has created a breathtaking, one-of-a-kind picture book based on that speech, combining fascinating science and history with the grandest human adventure of all. For ages 4 to 8.

FIELD TRIP TO THE MOON

By John Hare

Margaret Ferguson Books, 2019, 40 pp., Hardcover. $17.99. www.holidayhouse.com

Climb aboard the spaceship bus for a fantastic field trip adventure to the Moon! Once their bright yellow ship lands, students debark and set out with their teacher to explore. They jump over trenches and see craters and mountains on the Moon's surface and even Earth in the faraway distance. But when one student takes a break to draw some pictures and falls asleep, they wake up to discover that the rest of the class and the spaceship are gone. How the student passes the time waiting to be rescued makes for a funny and unexpected adventure that will enchant children all over the galaxy. With rich atmospheric art, this wordless picture book invites children to imagine themselves in the story – a story full of surprises, including some friendly space creatures. A perfect complement to discussions and lessons on the Moon landing. For ages 4 to 8.

CALENDAR

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

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

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

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