PLANETARY SCIENCE MISSION UPDATES: WHERE ARE THEY NOW?

LUNAR AND PLANETARY INFORMATION BULLETIN

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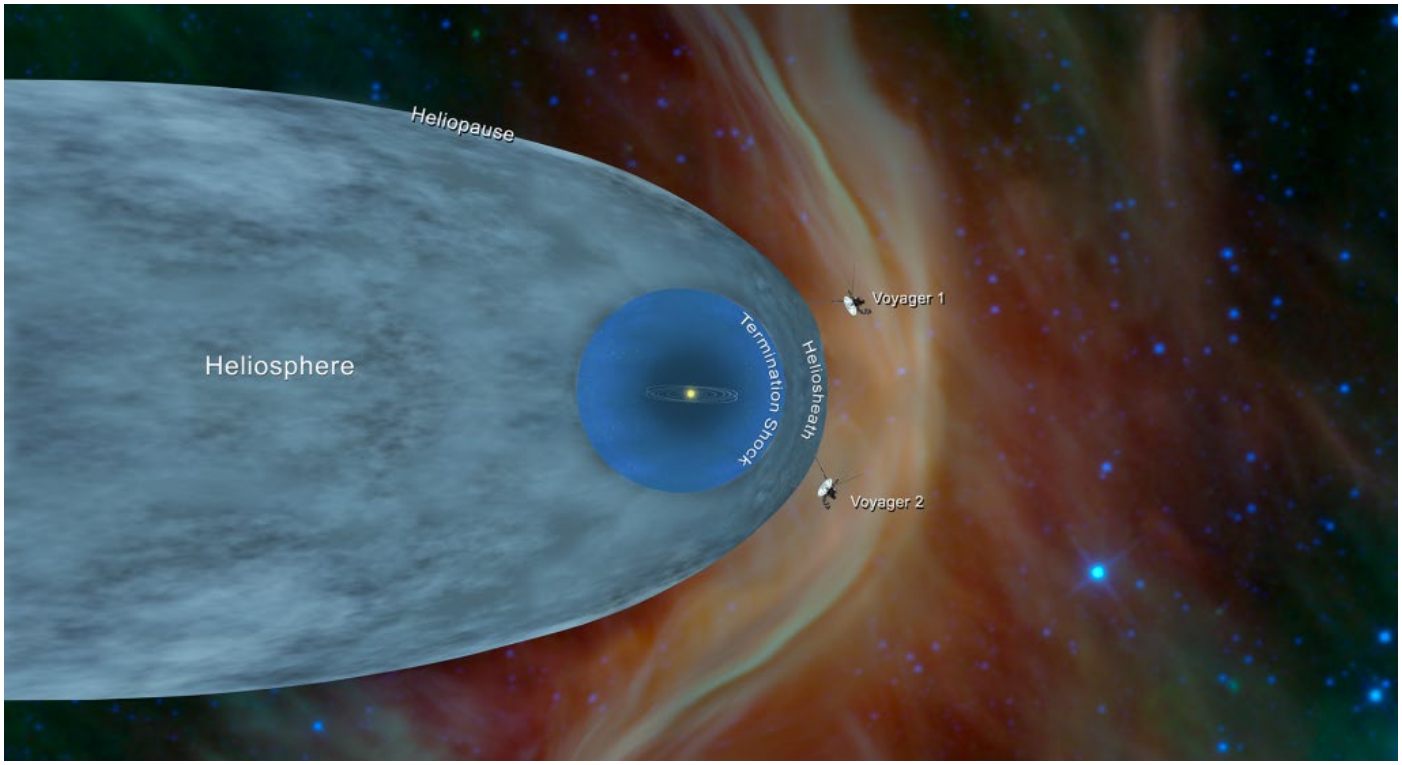


This illustration shows the position of NASA's Voyager 1 and Voyager 2 probes outside the heliosphere, a protective bubble created by the Sun that extends well past the orbit of Pluto. Voyager 1 crossed the heliopause, or the edge of the heliosphere, in August 2012. Heading in a different direction, Voyager 2 crossed another part of the heliopause in November 2018. Credit: NASA/JPL-Caltech.

Humanity's fleet of robotic planetary explorers continues to evolve as missions complete their tasks and new ones are launched to replace them. Thematic emphasis also changes as priorities evolve and mission cadence progresses. Here we review the status of our planetary fleet with an emphasis on target regions.

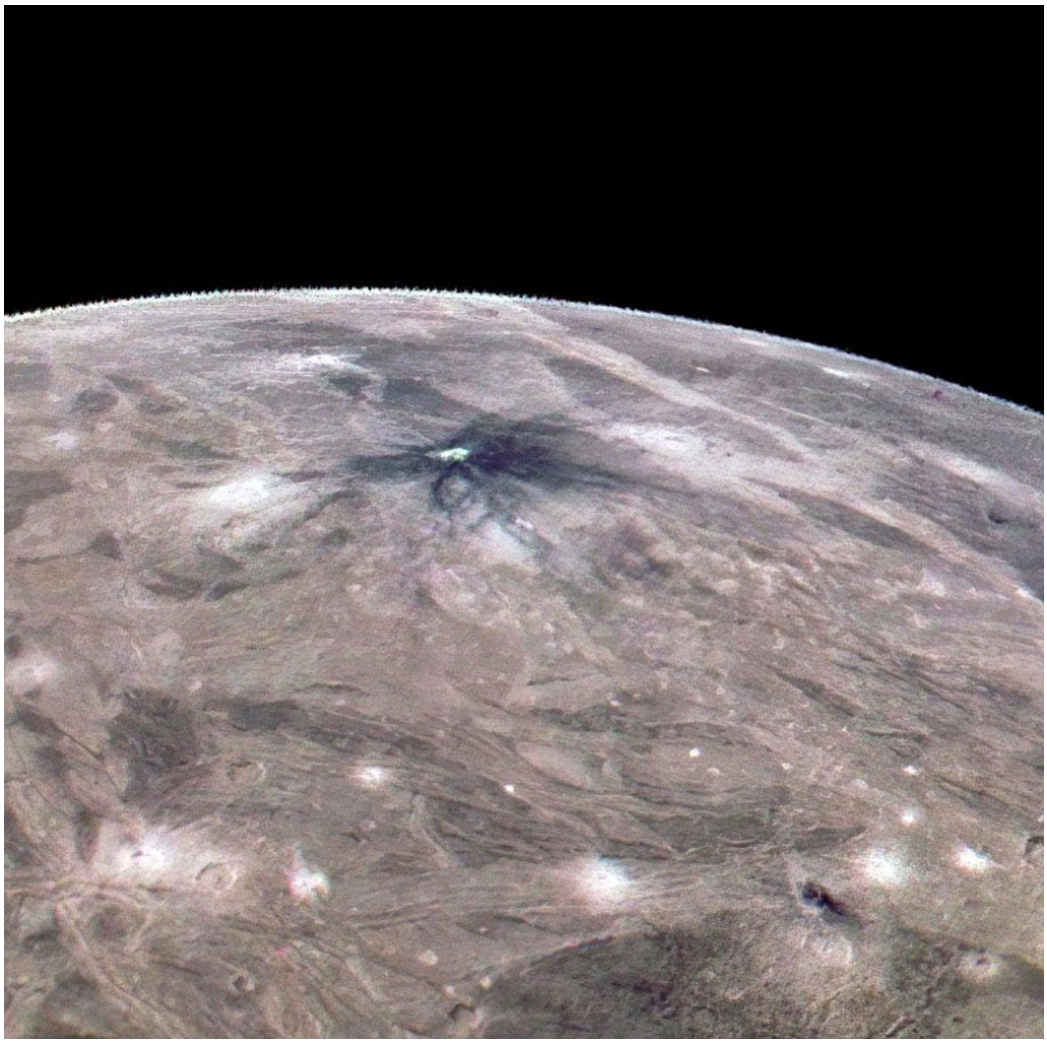
Outer Solar System

As of 2022, only three missions are currently operating in the outer solar system, with one more on the way and three under construction. The oldest of these, Voyagers 1 and 2, continue to operate in deep space at >100 au, with the objective of mapping out the outer edges of the Sun's influence. [One astronomical unit (au) is a unit of length effectively equal to the average, or mean,

"That same changing orbit allowed Juno to conduct the first high-resolution observations of the large satellites Ganymede (in June 2021) and Europa (in September 2022)."

distance between Earth and the Sun, defined as 149,597,870.7 kilometers (92,955,807.3 miles)]. The aging spacecraft, now more than 45 years old, continues to show signs of degradation. Earlier this year, Voyager 1 required the most remote software upgrade ever attempted to correct garbled data transmissions.

New Horizons, exiting the solar system at ~54 au, continues to explore the Kuiper belt by remote observations of distant objects at higher phase angles than possible from Earth, as well as sampling of the solar environment at distances roughly halfway between Earth and the two Voyagers. On the nearside of the outer solar system, the Lucy mission, launched October 16, 2021, is in flight for encounters with Trojan asteroids orbiting in front of and behind Jupiter later this decade to examine the composition and evolution of these ancient bodies.



NASA's Juno mission captured this look at the complex surface of Jupiter's moon Ganymede during a close pass by the giant moon in June 2021. At closest approach, the spacecraft came within just 1046 kilometers (650 miles) of Ganymede's surface. Credit: NASA/JPL-Caltech/SwRI/MSSS (image processing by Thomas Thomopoulos).

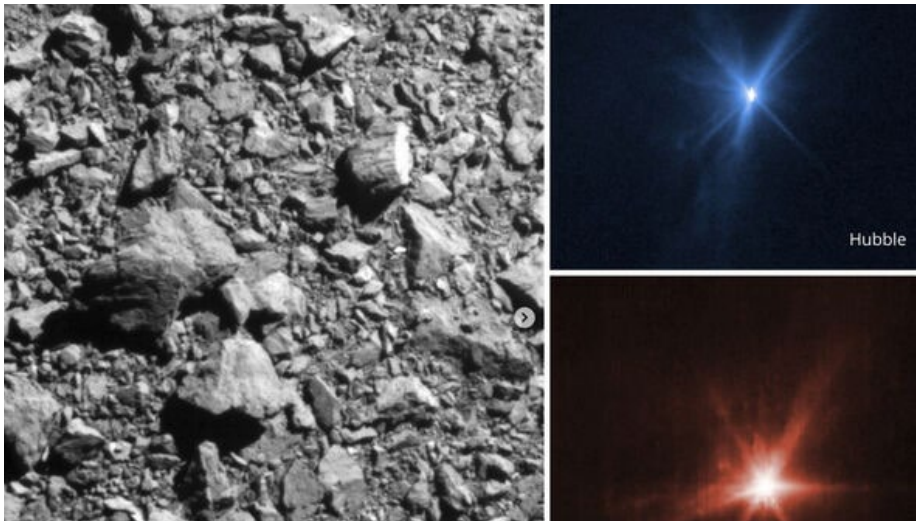
Juno, the only craft currently located among the four giant planets, is in its extended mission phase, which also includes new observations of Jupiter's interior and new and higher latitude views of the giant planet as the spacecraft's orbit evolves. That same changing orbit allowed Juno to conduct the first high-resolution observations of the large satellites Ganymede (in June 2021) and Europa (in September 2022). The Ganymede observations included some of the highest-resolution spectroscopic measurements, the first resolved microwave observations of Ganymede, and new views of areas poorly seen by previous spacecraft. The highly successful Europa encounter just last month should produce similar revelations. Two passes near Io are expected in 2023/2024.

Coming up, construction of both the European Space Agency's Jupiter Icy moons Explorer (JUICE) and NASA's Europa Clipper mapping missions is on schedule, with launches planned for 2023 and 2024. These missions will map Jupiter's moons Ganymede and Europa in unprecedented detail using more than two dozen instruments in an effort to better understand the internal oceans on both bodies and the origins of the magnetic field on Ganymede. NASA's Dragonfly mission, scheduled for launch in 2027, will explore the chemistry and habitability of Saturn's largest moon, Titan, and currently continues in the development and instrument construction phases.

" It explains that Uranus is a compelling destination due to factors such as its extreme axial tilt, which suggests the planet suffered a catastrophic impact in its past."

Standing 3 meters (10 feet) high, the core of NASA's Europa Clipper will be the focus of attention in High Bay 1 of Jet Propulsion Laboratory's storied Spacecraft Assembly Facility, as engineers and technicians assemble the spacecraft for a 2024 launch. Credit: NASA/JPL-Caltech.

Looking to the near future, the National Academy of Sciences' Decadal Survey of Planetary Sciences earlier this year identified an orbital mission to the ice giants Uranus (or Neptune) as the next national priority. A Uranus mission was the last decadal survey's third-ranked flagship, and the new survey recommends that work begins on it as soon as budgets permit. It explains that Uranus is a compelling destination due to factors such as its extreme axial tilt, which suggests the planet suffered a catastrophic impact in its past, as well as the prospect that some of its moons may harbor a subsurface ocean similar to the one on Enceladus. While it is too early to say how such a mission will proceed, it should provide the revolutionary science that resulted from the Cassini mission to Saturn in the last decade.



This combination of images provided by NASA shows three different views of the DART spacecraft impact on the asteroid Dimorphos on Monday, September 26, 2022. At left is the view from a forward camera on DART, at upper right from the Hubble Space Telescope, and at lower right from the James Webb Space Telescope. Credit: NASA.

Asteroid Belt

On September 26 of this year, NASA's Double Asteroid Redirection Test (DART) mission successfully "encountered" Didymos' small moon Dimorphos by directly impacting the small moon at ~6 kilometers per hour (~4 miles per hour). The objective was to attempt to change the small moon's orbit in a test of asteroid deflection techniques in case a small asteroid should threaten Earth's

An illustration of NASA's OSIRIS-REx spacecraft with its sampling arm extended, approaching the surface of the asteroid Bennu. Credit: NASA/GSFC/Univ. of Arizona.

“ After delivering the sample container, the spacecraft will continue on its journey to visit and orbit Apophis, a small asteroid that will make a close pass of Earth in 2029.”

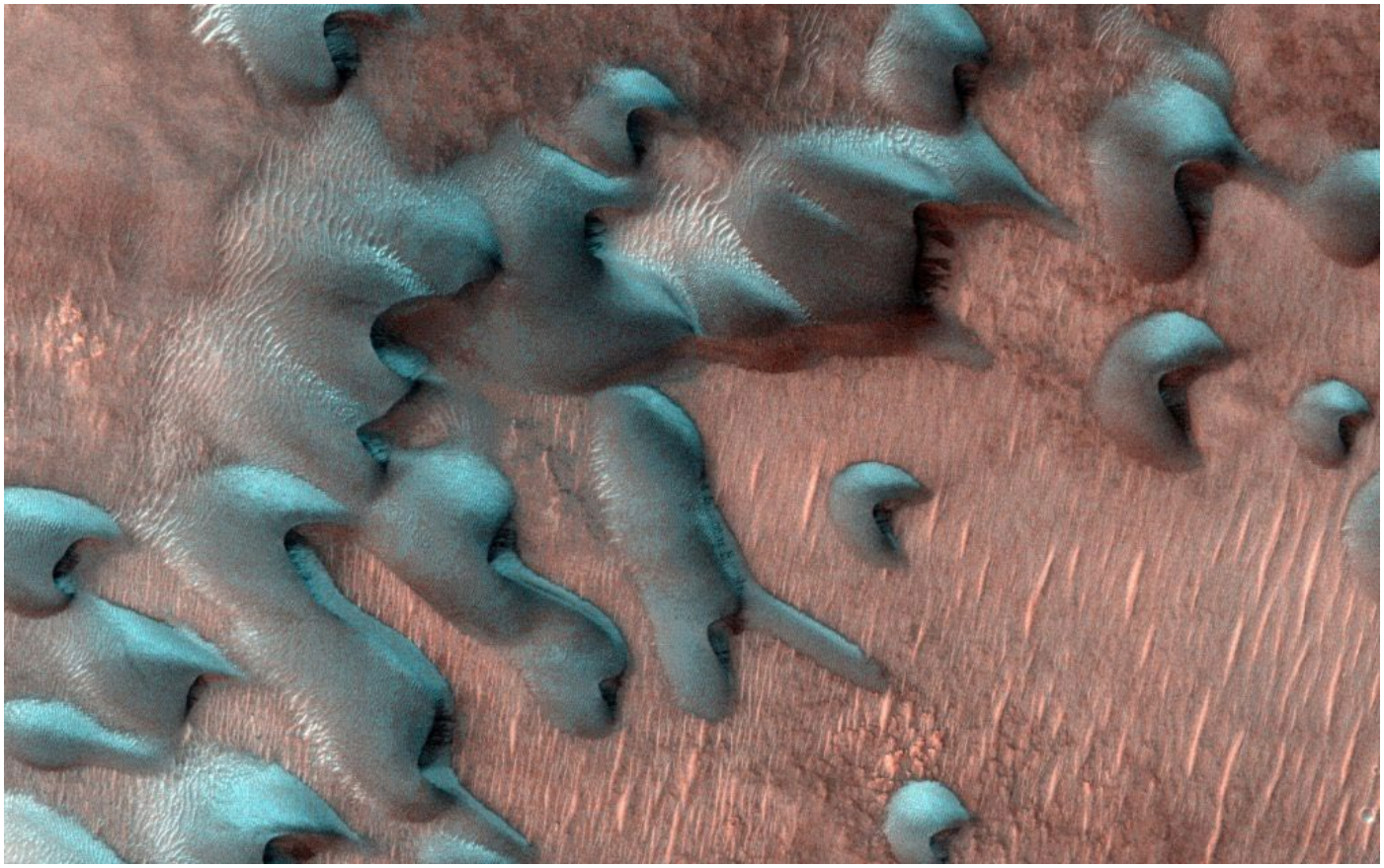
population. The impact was observed by terrestrial telescopes including the James Webb Space Telescope (JWST) and Hubble Space Telescope (HST), as well as a small cubesat that followed behind. While it will take months to fully understand the results of this test, all indications are that it occurred as planned, and the small moon's orbital period was reduced by 32 minutes. For more information, read the article by Lori Glaze in this issue.

The asteroid sample mission Hayabusa2 (launched by the Japan Aerospace Exploration Agency, JAXA) completed its sample return mission from asteroid 162173 Ryugu in 2021 and is now en route to the rapidly rotating 1998 KY_{26}. OSIRIS-REx (NASA) is currently en route to Earth with its surface sample container from the small asteroid Bennu, with the container scheduled to return to Earth in September 2023. After delivering the sample container, the spacecraft will continue on its journey to visit and orbit Apophis, a small asteroid that will make a close pass of Earth in 2029.

NASA's Psyche mission to the asteroid of the same name, due for launch this year, was delayed for a year due to software issues.

Mars

An international fleet continues to operate at Mars in orbit and on the surface. A fleet of orbiters from NASA [Mars Odyssey, Mars Atmosphere and Volatile EvolutioN (MAVEN), and Mars Reconnaissance Orbiter (MRO)], the European Space Agency (ESA) (Mars Express and Trace Gas Orbiter), the



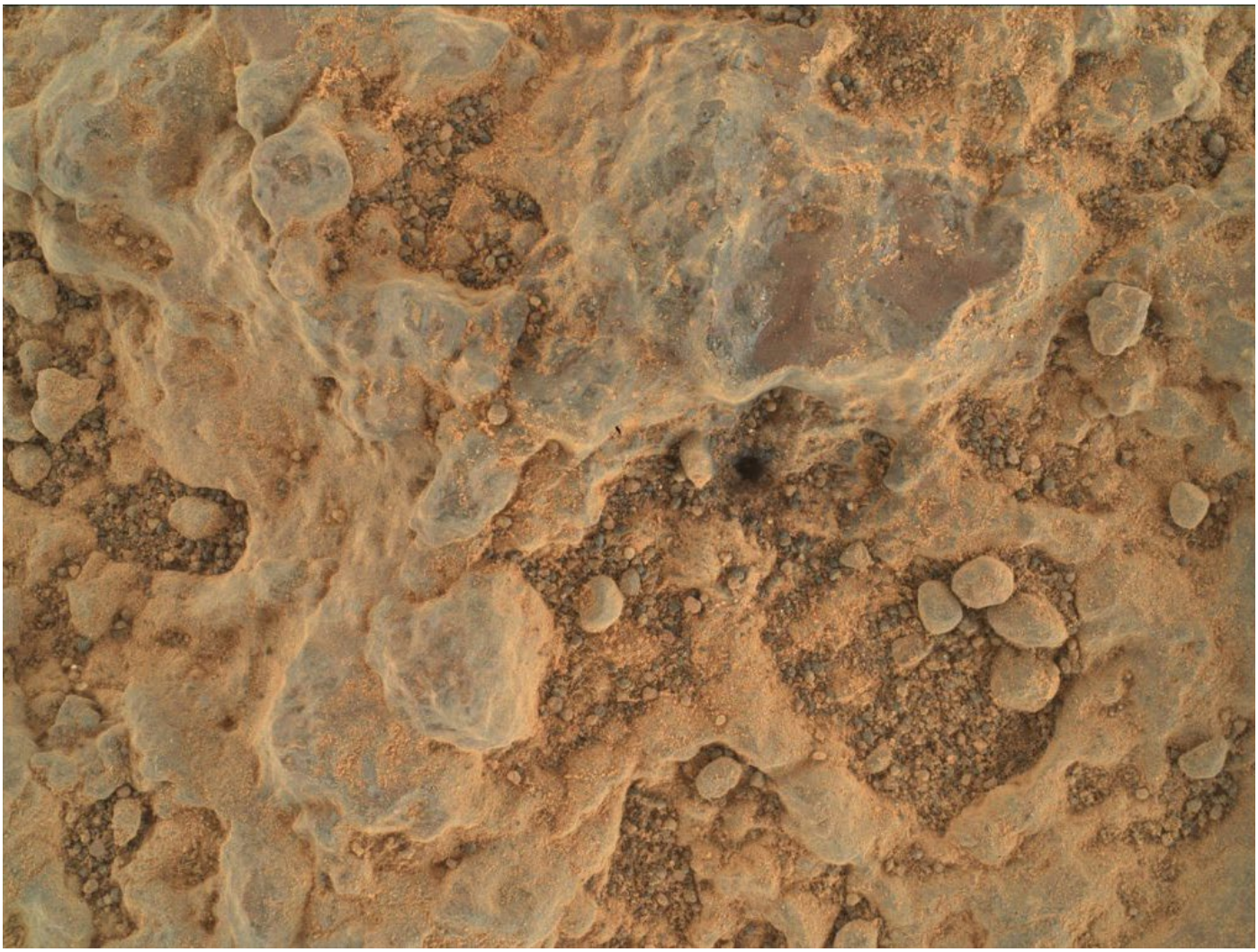
The HiRISE camera onboard the Mars Reconnaissance Orbiter took this picture far north of the martian equator just two days after the winter solstice when the Sun was just a few degrees above the horizon. Sand dunes are moving across this landscape from top left to bottom right. Winter frost covers the colder, north-facing half of each dune (but not the warmer south-facing half). The frost here is a mixture of carbon dioxide ice and water ice and will disappear when spring arrives. Credit: NASA/JPL-Caltech/University of Arizona.

China National Space Administration (CNSA) (Tianwen-1), and the United Arab Emirates (UAE) Space Agency (Hope) continue to operate, completing the global mapping of Mars; monitoring atmospheric conditions, weather, climate, and atmospheric loss; and supporting the landers currently operating. India's Mangalyaan mission ended in September when contact was lost.

The CNSA Zhurong rover, part of the Tianwen-1 lander, carries radar, magnetometer, and climatic instruments as well as cameras and spectrometers to search for evidence of ancient oceans at its Utopia Planitia landing site. The InSight geophysical lander continues to record marsquakes but nears the end of its operational lifetime. NASA's Curiosity and Perseverance rovers continue to explore sedimentary deposits in Gale and Jezero craters, respectively, mapping out geochemical traces of past environments and searching for aquatic conditions suitable for life. Initial results from Perseverance indicate the floor of the crater includes extensive deposits of layered igneous rocks. It will eventually drive up onto what appears to be sedimentary delta-like deposits. The Ingenuity helicopter deployed by Perseverance continues testing the limits of remote-powered flight on other planetary bodies.

Future missions to Mars are planned by several nations, with one highlight being the attempt to return samples from the surface. The last decadal survey's top recommendation for a flagship mission led NASA to develop its Perseverance rover, which landed on Mars a year ago. Now, NASA and ESA are developing the multi-vehicle Mars Sample Return (MSR) mission to retrieve those samples.

"ESA's Mercury Planetary Orbiter, which will help improve our understanding of Mercury's geologic history and composition."



Perseverance took this close-up of a rock target nicknamed "Foux" using its Wide Angle Topographic Sensor for Operations and eNgineering (WATSON) camera, part of the SHERLOC instrument on the end of the rover's robotic arm. The image was taken July 11, 2021, the 139th martian day, or sol, of the mission. Credit: NASA/JPL-Caltech/MSSS.

MSR is currently NASA's most expensive science mission project, and, although it was not directly recommended in the last survey, the new survey states that completing it should be the "highest scientific priority of NASA's robotic exploration efforts this decade."

Venus

Only one orbiter remains at Venus to observe and monitor Venus' cloud physics and dynamics: JAXA's Akatsuki, in orbit since 2015, which is using a suite of instruments to image the clouds in ultraviolet, infrared, microwave, and radio wavelengths and look for evidence of lightning and volcanism on the planet.

Three missions were selected in 2022 to fly to Venus in the early 2030s. These missions are in their early development stages and include NASA's Venus Investigation of Noble gases, Chemistry, and Imaging (DaVINCI) and Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS) missions, which will examine water loss and

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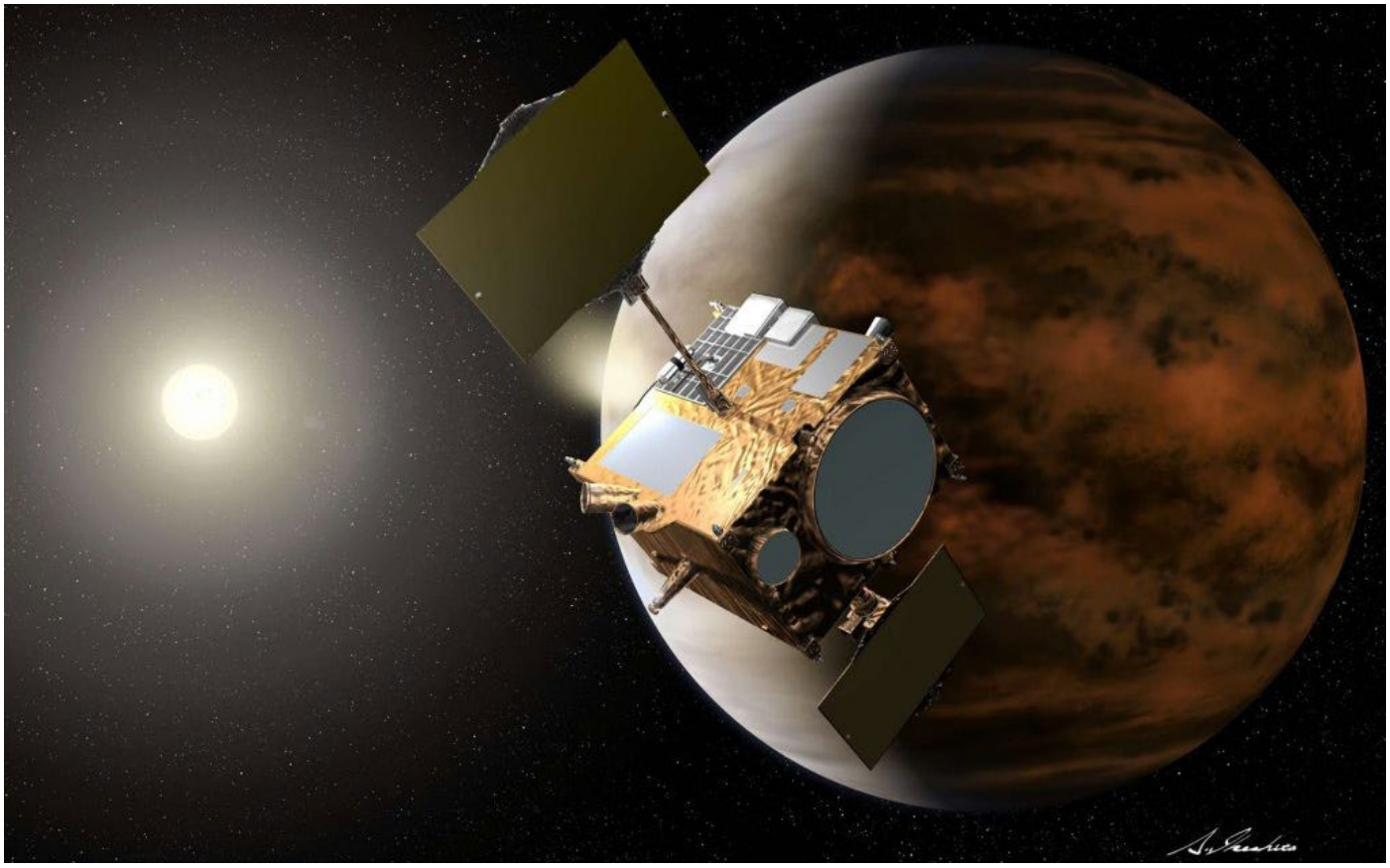


Artist's impression of the Venus Climate Orbiter ("Akatsuki"). Artwork by Akihiro Ikeshita. Credit: JAXA.

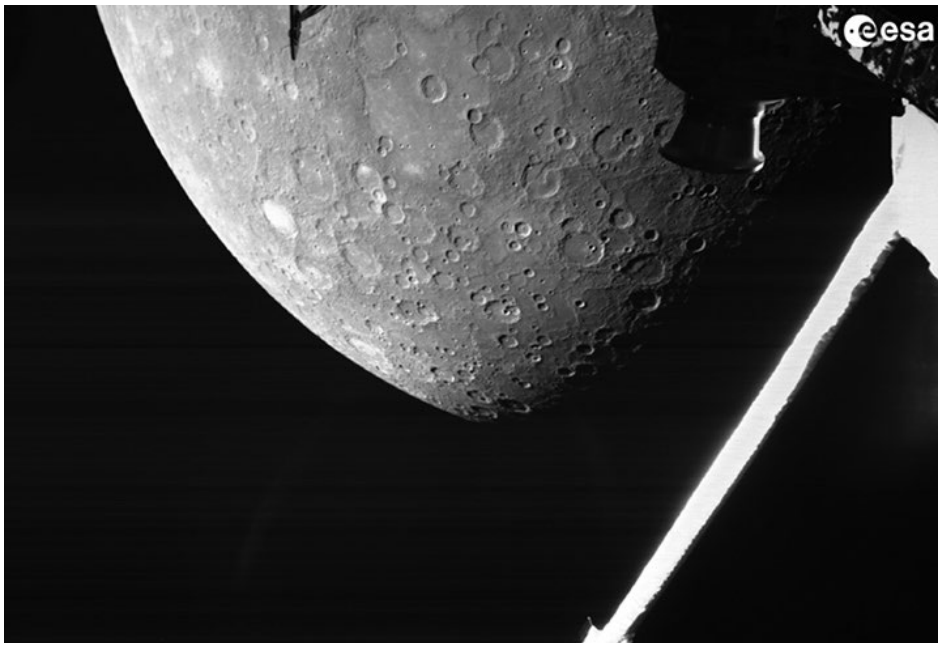
other atmospheric processes with an orbiter and descent lander, and map the surface with radar to map out the planets tectonic and volcanic history in much greater detail. ESA's EnVision mission will use radar to make high-resolution maps of the surface and look for volcanic surface changes.

Mercury

The only mission to Mercury currently in flight or in preparation is ESA-JAXA's BepiColombo, which has completed several flybys of Venus and Mercury in the past two years. These encounters are decreasing the spacecraft's momentum in preparation for orbit insertion in December 2025. The spacecraft will separate into two orbiters: JAXA's Mercury Magnetospheric Orbiter, which will investigate the planet's unusual magnetic field and its origins, and ESA's Mercury Planetary Orbiter, which will help improve our understanding of Mercury's geologic history and composition.

Moon

A total of seven spacecraft from three nations (U.S., China, and India) are currently in operation in lunar orbit or on the surface. China's Chang'e-4 farside lander and rover are currently the only vehicles operating on the lunar surface. NASA's Lunar Reconnaissance Orbiter and India's Chandrayaan-2



BepiColombo captured this view of Mercury's northern hemisphere on October 1, 2021, as it flew past the planet for a gravity assist. Parts of the spacecraft also can be seen. Credit: ESA/BepiColombo/MTM.

This image, taken by Chang'e-4's onboard cameras, shows the Yutu 2 rover rolling down tracks and leaving the Chang'e-4 lander behind after its landing in January 2019. Chang'e-4 made history by being the first spacecraft to ever land on the farside of the Moon. Credit: CNSA.seen. Credit: ESA/BepiColombo/MTM.

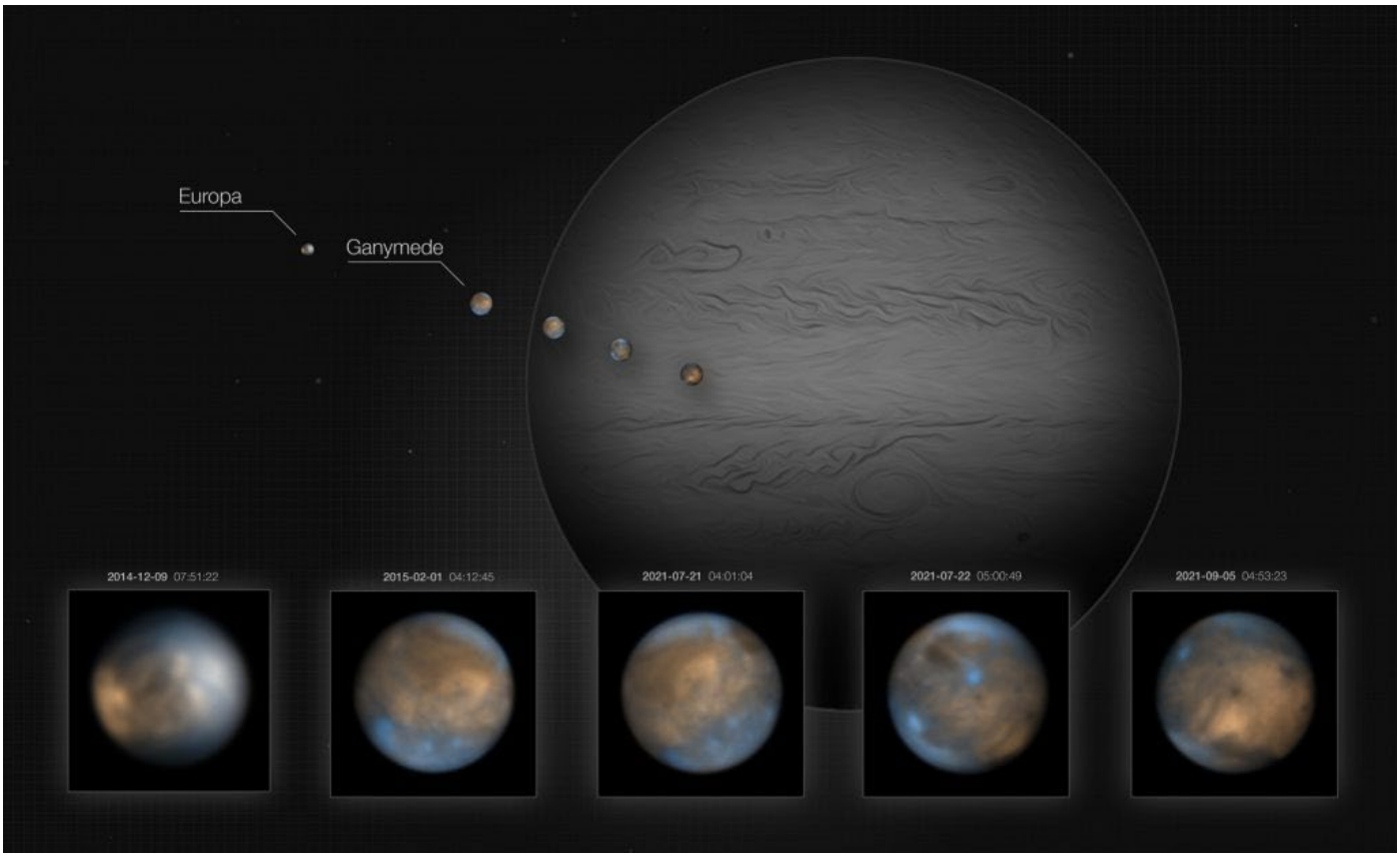
orbiters continue to fill gaps in the global mapping of morphology, topography, and composition while mapping out potential landing sites for future manned and unmanned landers.

The Danuri orbiter (also known as the Korean Pathfinder Lunar Orbiter or KPLO) is currently en route to the Moon to map lunar resources. Launched on August 5, Danuri will study the Moon's surface and help us plan future missions to the lunar poles. Danuri represents the first step in South Korea's Moon exploration plans, which aims for a robotic landing mission and more.

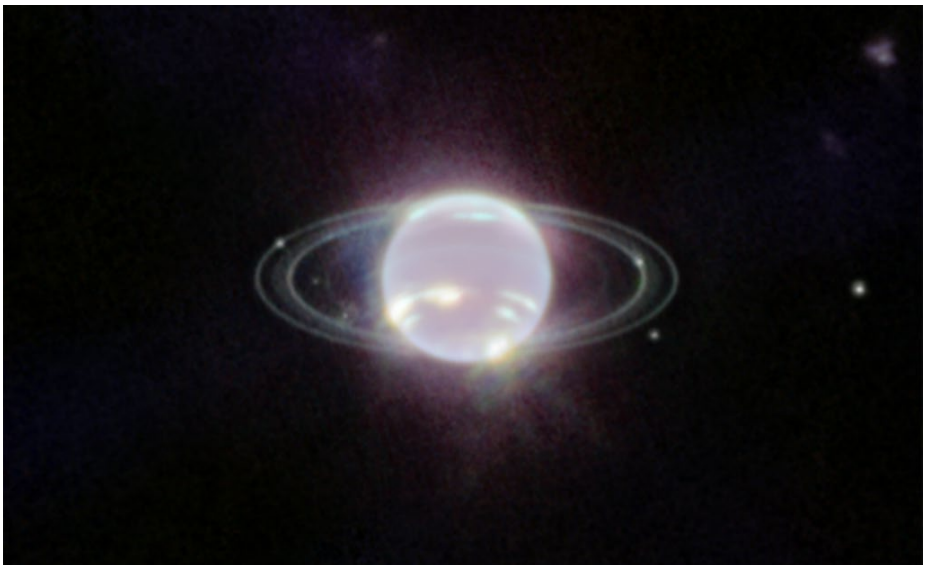
Plans for future lunar exploration are in flux but include as many as 20 separate programs by at least 6 nations. Landing reattempts by India and Israel are planned within the next year, as well as commercial lunar missions in the near future. Some of these are technology demonstrators, while others such as NASA's Volatiles Investigating Polar Exploration Rover (VIPER) mission will scout out lunar resources.

The Solar System at Large

Major advances have been made recently in our ability to study the planets with near-Earth observatories. The successful launch and deployment



This European Southern Observatory (ESO) image shows two of Jupiter's moons, the icy Ganymede and Europa, which have been imaged in the infrared using the SPHERE instrument on ESO's Very Large Telescope. While Europa is quite similar in size to our own Moon, Ganymede is the largest moon in the whole solar system — it's even bigger than the planet Mercury! Credit: ESO/King and Fletcher. Jupiter background image: NASA/ESA/A. Simon/M. H. Wong/OPAL team.



In this Webb image, Neptune resembles a pearl with rings that look like ethereal concentric ovals around it. There are two thinner, crisper rings and two broader, fainter rings. A few extremely bright patches on the lower half of Neptune represent methane ice clouds. Six tiny white dots, which are six of Neptune's 14 moons, are scattered among the rings. The background of the image is black. Credit: NASA/ESA/CSA/STScI.

of JWST will open up a high-resolution study of the planets in the infrared, as the first images of Neptune and Jupiter (released this summer) demonstrate. HST continues to study the planets with its unique capabilities. Earth-bound observatories can now challenge these. The Very Large Telescope in Chile rivals JWST in resolving power and has started observing the solar system. Many other observatories also routinely monitor the solar system, but telescope time for these objects is severely limited, and amateur astronomers continue to make highly valuable contributions by monitoring the planets, supporting missions such as Juno or our Mars fleet by observing transient events such as dust storms or impacts into Jupiter's cloud tops. These efforts will be the subject of an article in a future issue.

FROM THE DESK OF **LORI GLAZE**

FIRST LINE OF DEFENSE

Lori S. Glaze

Director, NASA's Planetary Science Division, October 2022

I am writing this in the immediate wake of the successful DART kinetic impact on September 26, 2022, and I still have an adrenaline rush from the amazing and historic feat! The impact was the first step in a new era of spaceflight — one where we now have the capability and knowledge to potentially protect Earth from the devasting effects of an asteroid impact.

As I wrote in my last piece for the LPIB, it's rare to see Planetary Science Division (PSD) hardware go from launch to *planned* finale in less than a year, and I can't quite believe the huge excitement over the purposeful destruction of our beloved DART spacecraft. Crashing a spacecraft sounds like a relatively simple endeavor. But DART's bullseye hit — while traveling at about 22,500 kilometers per hour (14,000 miles per hour) and almost 113 million kilometers (7 million miles) from Earth — is a credit to the hard work of the mission team and to the technological systems incorporated on the spacecraft, including the Small-body Maneuvering Autonomous Real-Time Navigation (SMART Nav) system developed by the Johns Hopkins University Applied Physics Laboratory (APL) that steered DART to its fate.

I was happy to join the team at APL during the impact evening's events and was lucky to be live on NASA TV as DART made its final approach and impact. I even managed to remain somewhat sensible live on air as I shared with the world the thrill of seeing the final images from the onboard Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO) instrument. With 60 minutes to go before impact, the Didymos/Dimorphos binary asteroid pair were still inseparable in the DRACO images. Yet in the final minutes of DART's approach, we witnessed both bodies come into sharper focus and become "real" asteroids for the first time — looking a lot like rubble piles we've learned to recognize from Bennu and Ryugu. And then, just as quickly, they were gone again as the live feed dropped out at the heartbreaking/lithobraking moment of impact, and the start of our illogical celebrations.

The DRACO images, as well as those returned by DART's companion LICIACube (a cubesat contributed by Agenzia Spaziale Italiana, ASI), will be a tremendous resource for planetary scientists in the coming months and years, as they study the characteristics of both Didymos (about 0.8 kilometers or 0.5 miles in size) and Dimorphos (about 160 meters or 525 feet in size), as well as the effects of the DART impact on the surface of Dimorphos.

By sharing the images in real-time in the mission's final minutes and seconds, we gave the general public (including some very nontraditional audiences) a true taste of what it's like to be a mission scientist experiencing the thrill of obtaining new data every day. I'm ecstatic to see the tremendous interest and response we've already had for DART from the public, in addition to the space science community. It really did seem like all eyes were on DART and Didymos/Dimorphos on September 26. The gorgeous images from the James Webb Space Telescope and the Hubble Space Telescope, as well as the timelapse image series of the impact from the Asteroid Terrestrial-impact Last Alert System (ATLAS), as a couple of examples, are testaments to that.

But now is when the application of science for the mission really begins! Over the next few weeks, observatories around the world will be focusing their telescopes on the Didymos system so that we can accurately measure the change in Dimorphos' orbital period. Prior to impact, Dimorphos orbited Didymous with a period of 11 hours and 55 minutes, and as I write this we are all eagerly awaiting the result of Dimorphos' new orbital period.

Despite all the excitement surrounding DART, the members of our Planetary Defense Coordination Office (PDCO) team are definitely not just sitting back and taking a break — DART is just one milestone in the PDCO's vision. For example, in addition to the PDCO's ongoing search for near-Earth objects and research activities, we are already working on the next essential planetary defense missions. Next up will be the Near-Earth Object (NEO) Surveyor mission that recently completed its Preliminary Design Review and is ready to proceed into "Phase C" (Final Design and Fabrication) later this year. NEO Surveyor will be a space-based infrared telescope designed to detect, track, and characterize NEOs. Its main objective will be to find two-thirds of potentially hazardous asteroids greater than 140 meters (46 feet) in diameter within five years (and more than 90% of them within 10 years). Another key objective of NEO Surveyor will be to collect and verify observations so that they can be used to improve orbital and physical characterizations of objects of specific interest. Although there are current budget challenges for NEO Surveyor, we are working hard to ensure that the mission is ready to launch and start work as soon as possible. (NEO Surveyor is currently planned for launch no earlier than 2028).

In PSD we are also thinking about what comes next after NEO Surveyor, and I'm grateful in this regard for the planetary-defense-focused recommendations in the recent Decadal Survey for Planetary Science and Astrobiology. The Survey recommends that among high-priority missions for planetary defense are a rapid-response, flyby reconnaissance mission to a challenging NEO and a future characterization/mitigation mission. We concur with these recommendations, and we will continue to support the PDCO as future missions and threat mitigation strategies are considered and developed with our partners in planetary defense.

I'm heartened to know that we at NASA, along with our partners from other U.S. government and international agencies, are working diligently with the PDCO in the unifying pursuit of planetary defense. With the DART results imminent, and a slate of future planetary defense missions being developed and considered, I'm confident we are doing everything within our power to ensure our home, and humanity, remain protected for the foreseeable future.

Note added in press: Analysis of data obtained over the past two weeks by the DART investigation team shows the spacecraft's kinetic impact with its target asteroid, Dimorphos, successfully altered the asteroid's orbit.

WEBB CAPTURES STELLAR GYMNASTICS IN THE CARTWHEEL GALAXY

This image of the Cartwheel Galaxy and its companion galaxies is a composite from Webb's Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI). MIRI data are colored red while NIRCam data are colored blue, orange, and yellow. Credit: NASA, ESA, CSA, STScI.

NASA's James Webb Space Telescope has peered into the chaos of the Cartwheel Galaxy, revealing new details about star formation and the galaxy's central black hole. Webb's powerful infrared gaze produced a detailed image of the Cartwheel and two smaller companion galaxies against a backdrop of many other galaxies. This image provides a new view of how the Cartwheel Galaxy has changed over billions of years.

The Cartwheel Galaxy, located about 500 million light-years away in the Sculptor constellation, is a rare sight. Its appearance, much like that of the wheel of a wagon, is the result of an intense event, a high-speed collision between a large spiral galaxy and a smaller galaxy not visible in this image. Collisions of galactic proportions cause a cascade of different, smaller events between the galaxies involved; the Cartwheel Galaxy is no exception.

The collision most notably affected the galaxy's shape and structure. The Cartwheel Galaxy sports two rings, a bright inner ring and a surrounding, colorful ring. These two rings expand outward from the center of the collision, like ripples in a pond after a stone is tossed into it. Because of these distinctive features, astronomers call this a "ring galaxy," a structure less common than spiral galaxies like our Milky Way.

The bright core contains a tremendous amount of hot dust with the brightest areas being home to gigantic young star clusters. On the other hand, the outer ring, which has expanded for about 440 million years, is dominated by star formation and supernovas. As this

ring expands, it plows into surrounding gas and triggers star formation.

Other telescopes, including the Hubble Space Telescope, have previously examined the Cartwheel Galaxy. But this dramatic galaxy has been shrouded in mystery, perhaps literally, given the amount of dust that obscures the view. Webb, with its ability to detect infrared light, now uncovers new insights into the nature of this galaxy.

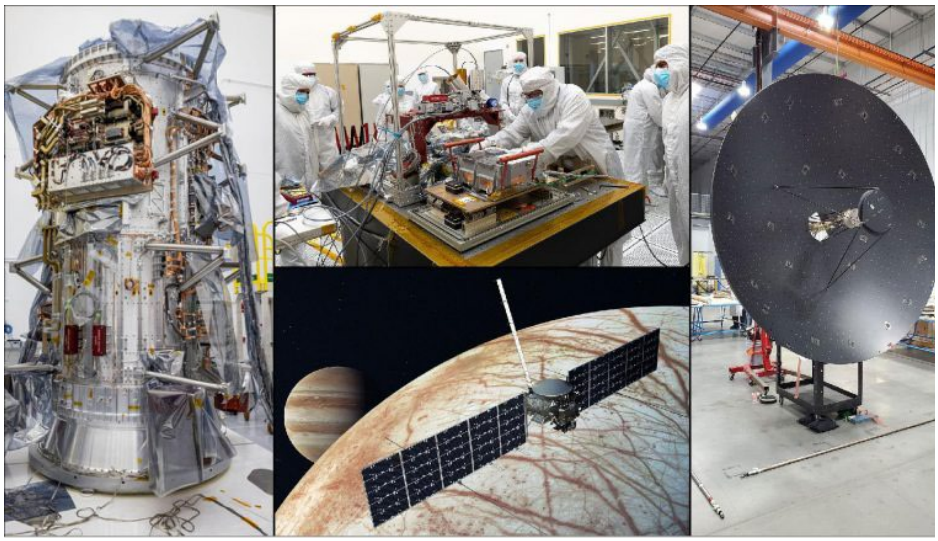
The Near-InfraRed Camera (NIRCam), Webb's primary imager, looks in the near-infrared range from 0.6 to 5 micrometers, seeing crucial wavelengths of light that can reveal even more stars than observed in visible light. This is because young stars, many of which are forming in the outer ring, are less obscured by the presence of dust when observed in infrared light. In this image, NIRCam data are colored blue, orange, and yellow. The galaxy displays many individual blue dots, which are individual stars or pockets of star formation. NIRCam also reveals the difference between the smooth distribution, or shape, of the older star populations and dense dust in the core compared to the clumpy shapes associated with the younger star populations outside of it.

Learning finer details about the dust that inhabits the galaxy, however, requires Webb's Mid-Infrared Instrument (MIRI). MIRI data are colored red in this composite image, revealing regions within the Cartwheel Galaxy rich in hydrocarbons and other chemical compounds, as well as silicate dust, like much of the dust on Earth. These regions form a series of spiraling spokes that essentially form the galaxy's skeleton. These spokes are evident in previous Hubble observations released in 2018, but they are much more prominent in this Webb image.

Webb's observations underscore that the Cartwheel Galaxy is in a transitory stage. The galaxy, which was presumably a normal spiral galaxy like the Milky Way before its collision, will continue to transform. While Webb gives us a snapshot of the current state of the Cartwheel Galaxy, it also provides insight into what happened to this galaxy in the past and how it will evolve in the future.

NASA'S EUROPA CLIPPER SPACECRAFT KICKS ASSEMBLY INTO HIGH GEAR

The core of NASA's Europa Clipper spacecraft has taken center stage in the Spacecraft Assembly Facility at the agency's Jet Propulsion Laboratory (JPL) in Southern California. Standing 3 meters (10 feet) high and 1.5 meters (5 feet) wide, for the next two years the spacecraft's main body will be the focus of attention in the facility's ultra-hygienic High Bay 1 as engineers and technicians assemble the spacecraft for its launch to Jupiter's moon Europa in October 2024.



Images of Europa Clipper (clockwise from left): the propulsion module, the ultraviolet spectrograph (called Europa-UVS), the high-gain antenna, and an artist's illustration of the spacecraft at Europa. Credit: NASA/JPL-Caltech/Johns Hopkins APL.

Scientists believe the ice-enveloped moon harbors a vast internal ocean that may have conditions suitable for supporting life. During nearly 50 flybys of Europa, the spacecraft's suite of science instruments will gather data on the moon's atmosphere, surface, and interior. Scientists will use this information 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.

Several of Europa Clipper's science instruments already have been completed and will be installed on the spacecraft at JPL. Most recently, the plasma-detection instrument, called the Plasma Instrument for Magnetic Sounding, and the Europa Imaging System wide-angle camera arrived from the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland. The thermal-emission imaging instrument, called E-THEMIS, and the ultraviolet spectrograph, called Europa-UVS, have already been installed on the spacecraft's nadir

deck which will support many of the instrument sensors by stabilizing them to ensure they are oriented correctly.

Fabricated at JPL, the core of the Europa Clipper will soon move into the Spacecraft Assembly Facility's High Bay 1, the same clean room where historic missions such as Galileo, Cassini, and all of NASA's Mars rovers were built.

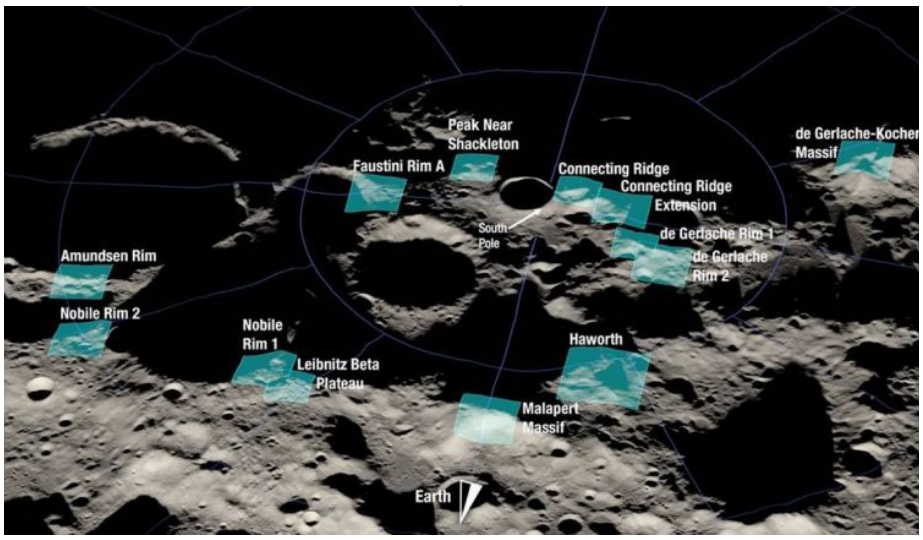
Also moving soon to High Bay 1 will be the aluminum electronics vault, which will be bolted to the main body of the spacecraft. This vault will protect the electronics inside from Jupiter's intense radiation. The electronics enable Europa Clipper's computer to communicate with the spacecraft's antennae, science instruments, and the subsystems that will keep them alive.

Bright copper cabling snaking around the orbiter's aluminum core contains thousands of wires and connectors handcrafted at APL. If placed end to end, the cabling would stretch almost 640 meters (2100 feet), long enough to wrap around a U.S. football field twice.

Inside the core are Europa Clipper's two propulsion tanks. The fuel and oxidizer they will hold will flow to an array of 24 engines where they will create a controlled chemical reaction to produce thrust in deep space.

By the end of 2022, most of the flight hardware and the remainder of the science instruments are expected to be complete. Then, the next steps will be a wide variety of tests as the spacecraft moves toward its 2024 launch period. After traveling for nearly six years and over 2.9 billion kilometers (1.8 billion miles), it will achieve orbit around Jupiter in 2030.

NASA IDENTIFIES CANDIDATE REGIONS FOR LANDING NEXT AMERICANS ON MOON



Shown here is a rendering of 13 candidate landing regions for Artemis III. Each region is approximately 15 kilometers by 15 kilometers (9.3 by 9.3 miles). A landing site is a location within those regions with an approximate 100-meter (328-foot) radius. Credit: NASA.

As NASA prepares to send astronauts back to the Moon under Artemis, the agency has identified 13 candidate landing regions near the lunar South Pole. Each region contains multiple potential landing sites for Artemis III, which will be the first of the Artemis missions to bring crew to the lunar surface, including the first woman and the first person of color to set foot on the Moon.

"Selecting these regions means we are one giant leap closer to returning humans to the Moon for the first time since Apollo," said Mark Kirasich, deputy associate administrator for the Artemis Campaign Development Division at NASA Headquarters in Washington. "When we do, it will be unlike any mission that's come before as astronauts venture into dark areas previously unexplored by humans and lay the groundwork for future long-term stays."

NASA identified the following candidate regions for an Artemis III lunar landing:

- Faustini Rim A
- Peak Near Shackleton
- Connecting Ridge
- Connecting Ridge Extension
- de Gerlache Rim 1
- de Gerlache Rim 2
- de Gerlache-Kocher Massif
- Haworth
- Malapert Massif
- Leibnitz Beta Plateau
- Nobile Rim 1
- Nobile Rim 2
- Amundsen Rim

Each of these regions is located within six degrees of latitude of the lunar south pole, and collectively they contain diverse geologic features. Together, the regions provide landing options for all potential Artemis III launch opportunities. Specific landing sites are tightly coupled to the timing of the launch window, so multiple regions ensure flexibility to launch throughout the year.

To select the regions, an agency-wide team of scientists and engineers assessed the area near the lunar south pole using data from NASA's Lunar Reconnaissance Orbiter and decades of publications and lunar science findings. In addition to considering launch window availability, the team evaluated regions based on their ability to accommodate a safe landing using criteria including terrain slope, ease of communications with Earth, and lighting conditions. To determine accessibility, the team also considered combined capabilities of the Space Launch System rocket, the Orion spacecraft, and the SpaceX-provided Starship human landing system.

All regions considered are scientifically significant because of their proximity to the lunar South Pole, which is an area that contains permanently shadowed regions rich in resources and in terrain unexplored by humans.

"Several of the proposed sites within the regions are located among some of the oldest parts of the Moon, and together with the permanently shadowed regions, provide the opportunity to learn about the history of the Moon through previously unstudied lunar materials," said Sarah Noble, Artemis lunar science lead for NASA's Planetary Science Division.

The analysis team weighed other landing criteria with specific Artemis III science objectives, including the goal to land close enough to a permanently shadowed region to allow crew to conduct a moonwalk, while limiting disturbance when landing. This will allow crew to collect samples and conduct scientific analysis in an uncompromised area, yielding important information about the depth, distribution, and composition of water ice that was confirmed at the Moon's south pole.

The team identified regions that can fulfill the moonwalk objective by ensuring proximity to permanently shadowed regions and factored in other lighting conditions. All 13 regions contain sites that provide continuous access to sunlight throughout a 6.5-day period, the planned duration of the Artemis III surface mission. Access to sunlight is critical for a long-term stay on the Moon because it provides a power source and minimizes temperature variations.

"Developing a blueprint for exploring the solar system means learning how to use resources that are available to us while also preserving their scientific integrity," said Jacob Bleacher, chief exploration scientist for NASA. "Lunar water ice is valuable from a scientific perspective and also as a resource, because from it we can extract oxygen and hydrogen for life support systems and fuel."

NASA will discuss the 13 regions with broader science and engineering communities through conferences and workshops to solicit input about the merits of each region. This feedback will inform site selections in the future, and NASA may identify additional regions for consideration. The agency will also continue to work with SpaceX to confirm Starship's landing capabilities and assess the options accordingly.

NASA will select sites within regions for Artemis III after it identifies the mission's target launch dates, which dictate transfer trajectories and surface environment conditions.

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

NASA SCIENTISTS HELP PROBE DARK ENERGY BY TESTING GRAVITY

Could one of the biggest puzzles in astrophysics be solved by reworking Albert Einstein's theory of gravity? A new study co-authored by NASA scientists says not yet.

The universe is expanding at an accelerating rate, and scientists don't know why. This phenomenon seems to contradict everything researchers understand about gravity's effect on the cosmos. It's as if you threw an apple in the air, and it continued upward, faster and faster. The cause of the acceleration, dubbed dark energy, remains a mystery.

A new study from the international Dark Energy Survey, using the Victor M. Blanco 4-meter Telescope in Chile, marks the latest effort to determine whether this is all simply a misunderstanding, that expectations for how gravity works at the scale of the entire universe are flawed or incomplete. This potential misunderstanding might help scientists explain dark energy. But the study — one of the most precise tests yet of Albert Einstein's theory of gravity at cosmic scales — finds that the current understanding still appears to be correct.

The results were presented Wednesday, August 23, at the International Conference on Particle Physics and Cosmology (COSMO'22) in Rio de Janeiro, Brazil. The work helps set the stage for two upcoming space telescopes that will probe our understanding of gravity with even

This image – the first released from NASA's James Webb Space Telescope – shows the galaxy cluster SMACS 0723. Some of the galaxies appear smeared or stretched due to a phenomenon called gravitational lensing. This effect can help scientists map the presence of dark matter in the universe. Credit: NASA, ESA, CSA, STScI.

higher precision than the new study and perhaps finally solve the mystery.

More than a century ago, Albert Einstein developed his theory of general relativity to describe gravity, and so far it has accurately predicted everything from the orbit of Mercury to the existence of black holes. But if this theory can't explain dark energy, some scientists have argued, then maybe they need to modify some of its equations or add new components.

To find out if that is the case, members of the Dark Energy Survey looked for evidence that gravity's strength has varied throughout the history of the universe or over cosmic distances. A positive finding would indicate that Einstein's theory is incomplete, which might help explain the universe's accelerating expansion. They also examined data from other telescopes in addition to Blanco, including the European Space Agency's (ESA's) Planck satellite, and reached the same conclusion.

The study finds Einstein's theory still works, so no explanation for dark energy yet. But this research will feed into two upcoming missions: ESA's Euclid mission, slated for launch no earlier than 2023, which has contributions from NASA, and NASA's Nancy Grace Roman Space Telescope, targeted for launch no later than May 2027. Both telescopes will search for changes in the strength of gravity over time or distance.

How do scientists know what happened in the universe's past? By looking at distant objects. A light-year is a measure of the distance light can travel in a year (about 9.5 trillion kilometers, or about 6 trillion miles). That means an object one light-year away appears to us as it was one year ago, when the light first left the object. And galaxies billions of light-years away appear to us as they did billions of years ago. The new study looked at galaxies stretching back about 5 billion years in the past. Euclid will peer 8 billion years into the past, and Roman will look back 11 billion years.

The galaxies themselves don't reveal the strength of gravity, but how galaxies look when viewed from Earth does. Most matter in our universe is dark matter, which does not emit, reflect, or otherwise interact with light. While scientists don't know what dark matter is made of, they know it's there because its gravity gives it away. Large reservoirs of dark matter in our universe warp space itself. As light travels through space, it encounters these portions of warped space, causing images of distant galaxies to appear

" That means an object one light-year away appears to us as it was one year ago, when the light first left the object. "

curved or smeared. This was on display in one of first images released from NASA's James Webb Space Telescope.

Dark Energy Survey scientists search galaxy images for more subtle distortions due to dark matter bending space, an effect called weak gravitational lensing. The strength of gravity determines the size and distribution of dark matter structures, and the size and distribution in turn determine how warped those galaxies appear to us. That is how images can reveal the strength of gravity at different distances from Earth and at distant times throughout the history of the universe. The group has now measured the shapes of over 100 million galaxies, and so far, the observations match what is predicted by Einstein's theory.

"There is still room to challenge Einstein's theory of gravity, as measurements gets more and more precise," said study co-author Agnès Ferté, who conducted the research as a postdoctoral researcher at the Jet Propulsion Laboratory (JPL). "But we still have so much to do before we're ready for Euclid and Roman. So it's essential we continue to collaborate with scientists around the world on this problem as we've done with the Dark Energy Survey."

SWARM OF TINY SWIMMING ROBOTS COULD LOOK FOR LIFE ON DISTANT WORLDS

Some day, a swarm of cellphone-sized robots could whisk through the water beneath the kilometers-thick icy shell of Jupiter's moon Europa or Saturn's moon Enceladus, looking for signs of alien life. Packed inside a narrow ice-melting probe that would tunnel through the frozen crust, the tiny robots would be released underwater, swimming far from their mothercraft to take the measure of a new world.

In the Sensing With Independent Micro-Swimmers (SWIM) concept, illustrated here, dozens of small robots would descend through the icy shell of a distant moon via a cryobot, depicted on the left, to the ocean below. The project has received funding from the NASA Innovative Advanced Concepts program. Credit: NASA/JPL-Caltech.

That's the vision of Ethan Schaler, a robotics mechanical engineer at NASA's Jet Propulsion Laboratory (JPL) in Southern California, whose Sensing With Independent Micro-Swimmers (SWIM) concept was recently awarded $600,000 in Phase II funding from the NASA Innovative Advanced Concepts (NIAC) program. The funding, which follows his 2021 award of $125,000 in Phase I NIAC funding to study feasibility and design options, will allow Schaler and his team to make and test 3D-printed prototypes over the next two years.

A key innovation is that these micro-swimmers would be much smaller than other concepts for planetary ocean exploration robots, allowing many to be loaded compactly into an ice probe. They would add to the probe's scientific reach and could increase the likelihood of detecting evidence of life while assessing potential habitability on a distant ocean-bearing celestial body.

"My idea is, where can we take miniaturized robotics and apply them in interesting new ways for exploring our solar system?" Schaler said. "With a swarm of small swimming robots, we are able to explore a much larger volume of ocean water and improve our measurements by having multiple robots collecting data in the same area."

Not yet part of any NASA mission, the early-stage SWIM concept envisions wedge-shaped robots, each about 12 centimeters (5 inches) long and about 60 to 75 cubic centimeters (3 to 5 cubic inches) in volume. About four dozen of them could fit in a 10-centimeter-long (4-inch-long) section of a cryobot 25 centimeters (10 inches) in diameter,

taking up just about 15% of the science payload volume. That would leave plenty of room for more powerful but less mobile science instruments that could gather data during the long journey through the ice and provide stationary measurements in the ocean.

The Europa Clipper mission, planned for a 2024 launch, will begin gathering detailed science during multiple flybys with a large suite of instruments when it arrives at the jovian moon in 2030. Looking further into the future, cryobot concepts to investigate such ocean worlds are being developed through NASA's Scientific Exploration Subsurface Access Mechanism for Europa (SESAME) program, as well as through other NASA technology development programs.

As ambitious as the SWIM concept is, its intent would be to reduce risk while enhancing science. The cryobot would be connected via a communications tether to the surface-based lander, which would in turn be the point of contact with mission controllers on Earth. That tethered approach, along with limited space to include a large propulsion system, means the cryobot would likely be unable to venture much beyond the point where ice meets ocean.

"What if, after all those years it took to get into an ocean, you come through the ice shell in the wrong place? What if there's signs of life over there but not where you entered the ocean?" said SWIM team scientist Samuel Howell of JPL, who also works on Europa Clipper. "By bringing these swarms of robots with us, we'd be able to look 'over there' to explore much more of our environment than a single cryobot would allow."

"SWIM would also allow data to be gathered away from the cryobot's blazing-hot nuclear battery, which the probe would rely on to melt a downward path through the ice."

Howell compared the concept to NASA's Ingenuity Mars Helicopter, the airborne companion to the Perseverance rover on the Red Planet. "The helicopter extends the reach of the rover, and the images it is sending back are context to help the rover understand how to explore its environment," he said. "If instead of one helicopter you had a bunch, you would know a lot more about your environment. That's the idea behind SWIM."

SWIM would also allow data to be gathered away from the cryobot's blazing-hot nuclear battery, which the probe would rely on to melt a downward path through the ice. Once in the ocean, that heat from the battery would create a thermal bubble, slowly melting the ice above and potentially causing reactions that could change the water's chemistry, Schaler explained.

Additionally, the SWIM robots could "flock" together in a behavior inspired by fish or birds, thereby reducing errors in data through their overlapping measurements. That group data could also show gradients: temperature or salinity, for example, increasing across the swarm's collective sensors and pointing toward the source of the signal they are detecting.

"If there are energy gradients or chemical gradients, that's how life can start to arise. We would need to get upstream from the cryobot to sense those," Schaler said.

Each robot would have its own propulsion system, onboard computer, and ultrasound communications system, along with simple sensors to measure temperature, salinity, acidity, and pressure. Chemical sensors to monitor for biomarkers — signs of life — will be part of Schaler's Phase II study.

NASA WILL INSPIRE WORLD WHEN IT RETURNS MARS SAMPLES TO EARTH IN 2033

NASA has finished the system requirements review for its Mars Sample Return Program, which is nearing completion of the conceptual design phase. During this phase, the program team evaluated and refined the architecture to return the scientifically selected samples, which are currently in the collection process by NASA's Perseverance rover in the Red Planet's Jezero Crater.

The architecture for the campaign, which includes contributions from the European Space Agency (ESA), is expected to reduce the complexity of future missions and increase the probability of success.

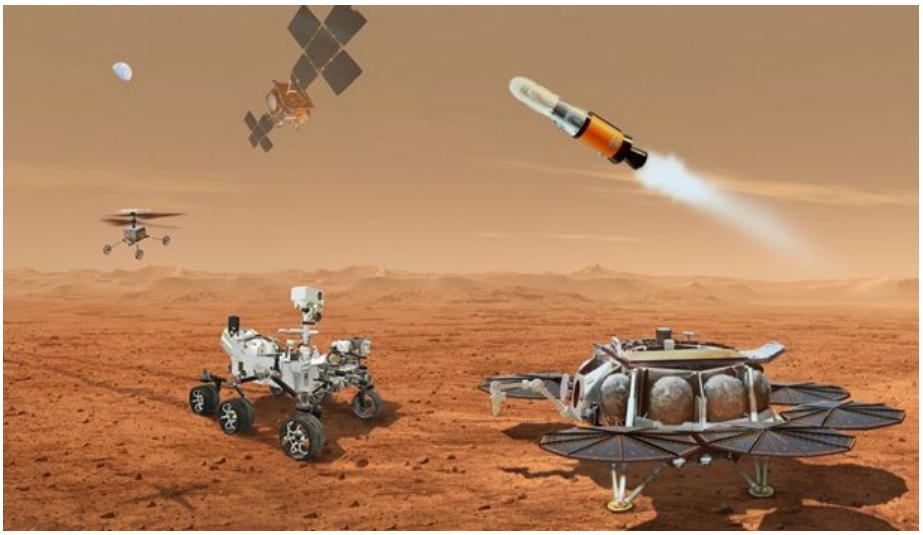
"The conceptual design phase is when every facet of a mission plan gets put under a microscope," said Thomas

Zurbuchen, associate administrator for science at NASA Headquarters in Washington. "There are some significant and advantageous changes to the plan, which can be directly attributed to Perseverance's recent successes at Jezero and the amazing performance of our Mars helicopter."

This advanced mission architecture takes into consideration a recently updated analysis of Perseverance's expected longevity. Perseverance will be the primary means of transporting samples to NASA's Sample Retrieval Lander carrying the Mars Ascent Vehicle and ESA's Sample Transfer Arm.

As such, the Mars Sample Return campaign will no longer include the Sample Fetch Rover or its associated second lander. The Sample Retrieval Lander will include two sample recovery helicopters, based on the design of the Ingenuity helicopter, which has performed 33 flights at Mars and survived over a year beyond its original planned lifetime. The helicopters will provide a secondary capability to retrieve samples cached on the surface of Mars.

The ESA Earth Return Orbiter and its NASA-provided Capture, Containment, and Return System remain vital elements of the program architecture.



This illustration shows a concept for multiple robots that would team up to ferry to Earth samples of rock and soil collected from the martian surface by NASA's Mars Perseverance rover. Credit: NASA/JPL-Caltech.

With planned launch dates for the Earth Return Orbiter and Sample Retrieval Lander in fall 2027 and summer 2028, respectively, the samples are expected to arrive on Earth in 2033.

With its architecture solidified during this conceptual design phase, the program is expected to move into its preliminary design phase this October. In this phase, expected to last about 12 months, the program will complete technology development and create engineering prototypes of the major mission components.

" ESA is continuing at full speed the development of both the Earth Return Orbiter that will make the historic round-trip from Earth to Mars and back again"

This refined concept for the Mars Sample Return campaign was presented to the delegates from the 22 participating states of Europe's space exploration program, Terrae Novae, in May. At their next meeting in September, the states considered the discontinuation of the development of the Sample Fetch Rover.

"ESA is continuing at full speed the development of both the Earth Return Orbiter that will make the historic round-trip from Earth to Mars and back again and the Sample Transfer Arm that will robotically place the sample tubes aboard the Orbiting Sample Container before its launch from the surface of the Red Planet," said David Parker, ESA director of Human and Robotic Exploration.

The respective contributions to the campaign are contingent upon available funding from the U.S. and ESA participating states. More formalized agreements between the two agencies will be established in the next year.

"Working together on historic endeavors like Mars Sample Return not only provides invaluable data about our place in the universe but brings us closer together right here on Earth," said Zurbuchen.

The first step in the Mars Sample Return Campaign is already in progress. Since it landed at Jezero Crater on February 18, 2021, the Perseverance rover has collected 11 scientifically

compelling rock core samples and one atmospheric sample.

Bringing Mars samples to Earth would allow scientists across the world to examine the specimens using sophisticated instruments too large and too complex to send to Mars and would enable future generations to study them. Curating the samples on Earth would also allow the science community to test new theories and models as they are developed, much as the Apollo samples returned from the Moon have done for decades. This strategic NASA and ESA partnership will fulfill a solar system exploration goal, a high priority since the 1970s and in the last three National Academy of Sciences Planetary Science Decadal Surveys.

NASA HELPS DECIPHER HOW SOME DISTANT PLANETS HAVE CLOUDS OF SAND

Brown dwarfs — celestial objects that fall between stars and planets — are shown in this illustration with a range of temperatures, from hottest (left) to coldest (right). The two in the middle represent those in the right temperature range for clouds made of silicates to form. Credit: NASA/JPL-Caltech.

A new study using archival observations by the now-retired Spitzer Space Telescope found a common trait among distant worlds where exotic clouds form.

Most clouds on Earth are made of water, but beyond our planet they come in many chemical varieties. The top of Jupiter's atmosphere, for example, is blanketed in yellow-hued clouds made of ammonia and ammonium hydrosulfide. And on worlds outside our solar system, there are clouds composed of silicates, the family of rock-forming minerals that make up over 90% of Earth's crust. But researchers haven't been able to observe the conditions under which these clouds of small dust grains form.

A new study appearing in the *Monthly Notices of the Royal Astronomical Society* provides some insight. The research reveals the temperature range at which silicate clouds can form and are visible at the top of a distant planet's atmosphere. The finding was derived from observations by NASA's retired Spitzer Space Telescope of brown dwarfs — celestial bodies that fall in between planets and stars — but fits into a more general understanding of how planetary atmospheres work.

"Understanding the atmospheres of brown dwarfs and planets where silicate clouds can form can also help us understand what we would see in the atmosphere of a planet that's closer in size and temperature to Earth," said Stanimir Metchev, a professor of exoplanet studies at Western University in London, Ontario, and co-author of the study.

The steps to make any type of cloud are the same. First, heat the key ingredient

until it becomes a vapor. Under the right conditions, that ingredient could be a variety of things, including water, ammonia, salt, or sulfur. Trap it, cool it just enough for it to condense, and voilà — clouds! Of course, rock vaporizes at a much higher temperature than water, so silicate clouds are visible only on hot worlds, such as the brown dwarfs used for this study, and some planets outside our solar system.

Although they form like stars, brown dwarfs aren't massive enough to kick-start fusion, the process that causes stars to shine. Many brown dwarfs have atmospheres almost indistinguishable from those of gas-dominated planets, such as Jupiter, so they can be used as a proxy for those planets.

Before this study, data from Spitzer already suggested the presence of silicate clouds in a handful of brown dwarf atmospheres. (NASA's James Webb Space Telescope will be able to confirm these types of clouds on distant worlds.) This work was done during the first six years of the Spitzer mission (which launched in 2003), when the telescope was operating three cryogenically cooled instruments. In many cases, though, the evidence of silicate clouds on brown dwarfs observed by Spitzer was too weak to stand on its own.

For this latest research, astronomers gathered more than 100 of those marginal detections and grouped them by the temperature of the brown dwarf. All of them fell within the predicted temperature range for where silicate clouds should form, between about 1000°C (about 1900°F) and 1700°C (3100°F). While the individual detections are marginal, together they reveal a definitive trait of silicate clouds.

"We had to dig through the Spitzer data to find these brown dwarfs where there was some indication of silicate clouds, and we really didn't know what we would find," said Genaro Suárez, a postdoctoral researcher at Western University and lead author of the new study. "We were very surprised at how strong the conclusion was once we had the right data to analyze."

In atmospheres hotter than the top end of the range identified in the study, silicates remain a vapor. Below the bottom end, the clouds will turn into rain or sink lower in the atmosphere, where the temperature is higher.

In fact, researchers think that silicate clouds exist deep in Jupiter's atmosphere, where the temperature is much higher than it is at the top, because of atmospheric pressure. The silicate clouds can't rise higher because at lower temperatures, the silicates will solidify and won't remain in cloud form. If the top of the atmosphere were thousands of degrees hotter, the planet's ammonia and ammonium hydrosulfide clouds would vaporize, and the silicate clouds could potentially rise to the top.

Scientists are finding an increasingly varied menagerie of planetary environments in our galaxy. For example, they have found planets with one side permanently facing their star and the other permanently in shadow, a planet where clouds of different compositions might be visible, depending on the side observed. To understand those worlds, astronomers will first need to understand the common mechanisms that shape them.

NASA'S STRATOSPHERIC BALLOON MISSION GETS TELESCOPE WITH GIANT MIRROR

Telescopes designed to operate in space have to be constructed differently than those meant to operate on the ground. But what about telescopes that operate in between?

An upcoming NASA mission will use a balloon larger than a football field to send a telescope 40,000 meters (about 130,000 feet) above Antarctica. From that height, the telescope will study a phenomenon that chokes off star formation in some galaxies, effectively killing them.

The mission, called the Astrophysics Stratospheric Telescope for High Spectral Resolution Observations at Submillimeter-wavelengths, or ASTHROS, will use a primary mirror (this telescope's main light-gathering tool) that is tied for the largest ever to fly on a high-altitude balloon. Construction of the 2.5-meter (8.2-foot) mirror wrapped up in June. Designing and building it proved challenging because of two key demands: The mirror and its support structure must be exceptionally light to travel by balloon, yet strong enough to keep the pull of Earth's gravity from deforming its almost perfect parabolic shape by any more than about 2.5 micrometers (0.0001 inches), a fraction of the width of a human hair.

Managed by NASA's Jet Propulsion Laboratory (JPL) in Southern California, ASTHROS is set to launch no earlier than December 2023, circling the South Pole for up to four weeks. NASA's Scientific Balloon Program, operated by the agency's Wallops Flight Facility in Virginia, launches 10 to 15 balloon missions each year. These missions typically cost less than space missions and take less time to move from early planning to deployment, and they employ new technologies that can be used on future space missions.

High up in the stratosphere, ASTHROS will observe wavelengths of light that

are blocked by Earth's atmosphere in a range called far-infrared. Its large mirror will enhance the telescope's ability to observe fainter light sources and resolve finer details of those sources.

Those capabilities are essential to the mission's approach to studying stellar feedback, the process by which clouds of gas and dust — the ingredients for making stars — are dispersed in galaxies, sometimes to the point that star formation halts entirely. Many processes contribute to feedback, including eruptions from living stars and the explosive deaths of massive stars as supernovae. ASTHROS will look at several star-forming regions in our galaxy where these processes take place and will create high-resolution 3D maps of the distribution and motion of gas. The mission will also look at distant galaxies containing millions of stars to see how feedback plays out at large scales and in different environments.

The ASTHROS mission's primary mirror is one of the largest to ever fly on a high-altitude balloon. The lightweight mirror is coated in gold and nickel to make it more reflective in far-infrared wavelengths. Credit: Media Lario.

"It's difficult to explore feedback all the way from where it originates, at the scale of individual stars, to where it has an effect, on the scale of galaxies," said Jorge Pineda, principal investigator for ASTHROS at JPL. "With a large mirror we can connect those two."

NASA contracted Media Lario, an optics company in Italy, to design and produce ASTHROS' full telescope unit, including a primary mirror, secondary mirror, and supporting structure called the cradle. Media Lario previously developed a unique method for manufacturing lightweight infrared and optical telescope mirrors, which the company used to produce many of the panels for the primary mirrors of the Atacama Large Millimeter Array, a group of 66 ground-based telescopes in Chile.

The ASTHROS primary mirror features nine panels, which are significantly easier to fabricate than a one-piece mirror. The bulk of the mirror panels consist of lightweight aluminum formed into a honeycomb structure that reduces its total mass. The panel surfaces are made of nickel and coated with gold, which improves the mirror's reflectivity at far-infrared wavelengths.

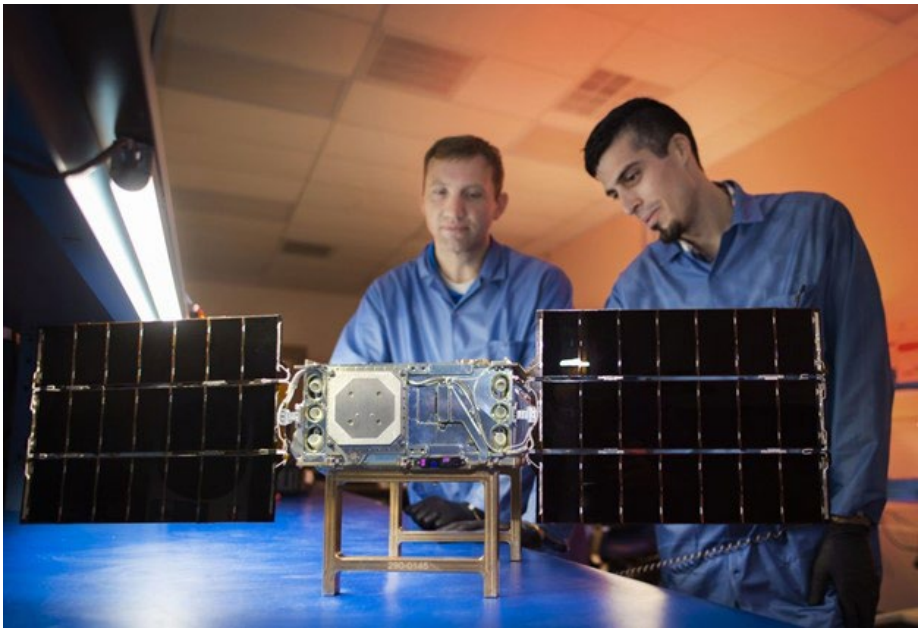
"We had to combine techniques from groundbased telescopes that observe in similar wavelengths with advanced manufacturing techniques used for professional racing sailboats. It's pretty unique."

Because the ASTHROS team won't be able to fine-tune the alignment of the panels once the telescope lifts off, the cradle supporting the mirror needs to be lightweight yet exceptionally strong and rigid to prevent any deformation. Carbon fiber would do the trick. So, to build the cradle and other structural components, Media Lario turned to local companies in Italy that typically produce specialized structures for competitive racing boats and cars.

"I think this is probably the most complex telescope ever built for a high-altitude balloon mission," said Jose Siles, the ASTHROS project manager at JPL. "We had specifications similar to a space telescope but on a tighter budget, schedule, and mass. We had to combine techniques from groundbased telescopes that observe in similar wavelengths with advanced manufacturing techniques used for professional racing sailboats. It's pretty unique."

Media Lario was scheduled to deliver the full telescope unit to NASA in late July. The ASTHROS team will integrate it with the gondola (the structure that holds the entire payload and attaches to the balloon) and other key components. Then they will begin a series of tests to ensure everything is ready for flight.

FIRST OF NASA'S SUNRISE SMALLSATS ROLLS OFF PRODUCTION LINE



The first of six SunRISE SmallSats is shown here at a Utah State University Space Dynamics Laboratory clean room being worked on by engineers. Pointed toward the camera is the SmallSat's Sun-facing side, including its fully deployed solar arrays. Credit: SDL/Allison Bills.

Building a 10-kilometer-wide (6-mile-wide) telescope in space may sound like science fiction. But through the combined power of six toaster-sized satellites, that's what NASA's SunRISE will be, a huge radio telescope in orbit that will help deepen scientists' understanding of explosive space weather events. These phenomena generate particle radiation that can jeopardize astronauts and technology in space while also negatively impacting communications and power grids on Earth.

In anticipation of the planned 2024 launch of SunRISE, short for Sun Radio Interferometer Space Experiment, the first of those small satellites has already been completed at Utah State University Space Dynamics Laboratory (SDL) in Logan, which is contracted to build, test, and commission all six satellites for NASA.

"It's really exciting to see the space vehicles coming together," said Jim Lux, SunRISE project manager at NASA's Jet Propulsion Laboratory in Southern California. "In a couple of years, these satellites will form a vast space telescope observing the Sun in a way that is impossible from Earth's surface."

Each small satellite, or SmallSat, will act as a single antenna to detect bursts of radio waves from the Sun's superheated atmosphere, known as the corona. Equipped with four telescoping antenna booms that extend about 2.5 meters (10 feet) to form an "X," they will orbit Earth from about 36,000 kilometers (22,000 miles) away, swarming together to trace out one virtual radio telescope.

After NASA's Deep Space Network receives the signals from all six SmallSats, scientists will use the technique of interferometry to create a large-aperture radio telescope as wide as the distance between the SmallSats that are farthest apart, about 10 kilometers (6 miles).

Groundbased radio telescopes, such as the iconic Karl G. Jansky Very Large Array in New Mexico, often use interferometry to combine the observing power of many individual antennas. But SunRISE will have a unique advantage over its groundbased cousins. It will be able to "see" the long radio wavelengths that are blocked by a portion of our planet's upper atmosphere known as the ionosphere. This means SunRISE will pinpoint where solar radio bursts, or sudden event-type emissions of radio waves, erupt higher up in the Sun's corona. Then the SunRISE team can create detailed maps of their positions in 3D.

The Sun's corona is a hotbed of activity, where powerful magnetic fields and superheated solar particles mix, erupting with solar flares and coronal mass ejections (CMEs). Flares and CMEs can, in turn, accelerate solar energetic particles, which also originate in the corona, creating a hazard for human activities throughout the solar system. Solar radio bursts have been associated with solar energetic particle events and are known to precede their arrival at Earth by tens of minutes.

By pinpointing the locations of solar radio bursts, SunRISE will illustrate how an early warning of incoming solar energetic particle events might be beneficial. And if scientists can locate regions of particle acceleration by tracking solar radio bursts relative to where CMEs occur, they can investigate how CMEs lead to radio bursts. In addition to delivering 3D images, SunRISE will map the pattern of solar magnetic field lines that reach far into interplanetary space as the radio bursts are generated along them. The telescope will be constantly watching the Sun for radio bursts popping off randomly throughout the corona.

"The ultimate goal of the mission is to help scientists better understand the mechanisms driving these explosive space weather events," said Justin Kasper, SunRISE principal investigator at the University of Michigan in Ann Arbor. "These high-energy solar particles can jeopardize unprotected

astronauts and technology. By tracking the radio bursts associated with these events, we can be better prepared and informed."

The mission's observations will be used in conjunction with data from other space missions and groundbased observatories. For example, SunRISE may image solar radio bursts as NASA's Parker Solar Probe zips through them, providing an opportunity to see how the solar energetic particles are accelerated. And by combining SunRISE data with observations made by the NASA-ESA Solar and Heliospheric Observatory (SOHO), scientists will be able to determine how and where CMEs can trigger different types of radio bursts as they travel from the Sun, and how many of the accelerated particles arrive in Earth's vicinity.

GIANT IMPACT COULD HAVE FORMED THE MOON MORE RAPIDLY

Scientists from the Institute for Computational Cosmology at Durham University used supercomputer simulations to reveal an alternate explanation for the Moon's origin, as a satellite placed immediately into orbit following a giant impact between Earth and a Mars-sized body. Credit: Durham University.

Scientists from Durham University's Institute for Computational Cosmology used the most detailed supercomputer simulations yet to reveal an alternative explanation for the Moon's origin, with a giant impact immediately placing a Moon-like body into orbit around Earth. The research team included scientists at NASA Ames Research Center and the University of Glasgow, and their simulation findings have been published in the journal *Astrophysical Journal Letters*.

The researchers simulated hundreds of different impacts, varying the angle and speed of the collision as well as the masses and spins of the two colliding bodies in their search for scenarios that could explain the present-day Earth-Moon system. These calculations were performed using the SWIFT open-source simulation code, run on the DiRAC Memory Intensive service ("COSMA"), hosted by Durham University on behalf of the DiRAC High-Performance Computing facility.

The extra computational power revealed that lower-resolution simulations can miss out on important aspects of large-scale collisions, allowing researchers to discover features that weren't accessible for previous studies. Only the high-resolution simulations produced the Moon-like satellite, and the extra detail showed how its outer layers were richer in material originating from Earth.

If much of the Moon formed immediately following the giant impact, then this could also mean that less became molten during formation than in the standard theories where the Moon grew within a debris disk around Earth. Depending upon details of the subsequent solidification, these theories should predict different internal structures for the Moon.

As explained by the co-author of the study, Vincent Eke, "This formation route could help explain the similarity in isotopic composition between the lunar rocks returned by the Apollo astronauts and Earth's mantle. There may also be observable consequences for the thickness of the lunar crust, which would allow us to pin down further the type of collision that took place."

Furthermore, they found that even when a satellite passes so close to Earth that it might be expected to be torn apart by the "tidal forces" from Earth's gravity, the satellite can not only survive but also be pushed into a wider orbit, safe from future destruction.

According to the lead researcher of the study, Jacob Kegerreis, "This opens up a whole new range of possible starting places for the Moon's evolution. We went into this project not knowing exactly what the outcomes of these very-high-resolution simulations would be. So, on top of the big eye-opener that standard resolutions can give you wrong answers, it was extra exciting that the new results could include a tantalizingly Moon-like satellite in orbit."

The Moon is thought to have formed following a collision 4.5 billion years ago between the young Earth and a Mars-sized object called Theia. Most theories create the Moon by gradual accumulation of the debris from this impact. However, this has been challenged by measurements of lunar rocks showing their composition is like that of Earth's mantle, while the impact produces debris that comes mostly from Theia.

This immediate-satellite scenario opens new possibilities for the initial lunar orbit as well as the predicted composition and internal structure of the Moon. The many upcoming lunar missions should reveal new clues about what kind of giant impact led to the Moon, which in turn will tell us about the history of Earth itself.

BEYOND DEFINITIONS: Operationalizing Diversity, Equity, Inclusion, and Accessibility

Andy Shaner (Lunar and Planetary Institute), Susan Shebby (McREL International), Jeanette Joyce (McREL International)

On January 18, 2022, NASA released the Policy Statement on Diversity, Equity, Inclusion, and Accessibility [DEIA] for NASA's Workforce and Workplaces. In addition to affirming the agency's commitment to DEIA, this letter from administrator Bill Nelson included definitions for diversity, inclusion, equity, and accessibility. These definitions are similar to those adopted by many organizations in that they are broad value statements. As such, they are helpful in understanding NASA's vision for DEIA but are only a first step for operationalizing — and evaluating — the integration of DEIA in different contexts.

Planetary Resources and Content Heroes (ReaCH) is funded through the NASA Science Mission Directorate's Science Activation program. Throughout the project's lifetime, ReaCH will develop and continuously refine a model of effective practices for training planetary scientists to better engage Black and Latinx youth and families based on DEIA principles. The ReaCH model, which includes strategies for engaging diverse communities in planetary-themed hands-on activities, will be implemented in professional learning workshops across the U.S.

The ReaCH team is diverse. The 16 team members come from various professional backgrounds: planetary scientists, informal educators, and evaluators. In addition, team members come from a diversity of cultural backgrounds and experiences that have shaped our individual understanding and approaches toward engaging public audiences. This team diversity is a great strength, but it also presented an early challenge when defining a common vocabulary for the ReaCH team's definition of DEIA principles and engagement approach.

As mentioned already, the NASA definitions, while appropriate and valuable from an organizational perspective, are broad. We quickly realized that ReaCH team members were each interpreting the definitions differently. Consider, for example, the NASA definition of inclusion: "The full participation, belonging, and contribution of organizations and individuals."

	NASA Definition	ReaCH Operationalization
Diversity	The representation of varied identities and differences (race, ethnicity, gender identity, disability, socioeconomic status, tribe, sexual orientation, communication style).	Focus on Black and Latinx audiences through intentional engagement.
Equity	The consistent and systematic provision of fair, just, and impartial treatment to all individuals, including individuals who belong to underserved communities that have been denied such treatment.	Acknowledge and reduce systemic barriers encountered by Black and Latinx audiences through an asset-based approach.
Inclusion	The full participation, belonging, and contribution of organizations and individuals.	Create a sense of belonging through intentional relationship-building and attention to relevance.
Accessibility	The capability for full and independent use by all people, including people with disabilities, of technology, programs, and services through inclusive design, construction, development, and maintenance of facilities.	Support full and independent participation by all people by building awareness of the diversity of individual needs.

Now, take a moment to reflect on your understanding of this definition, given the context of a professional learning activity designed to prepare planetary scientists and informal educators to better engage Black and Latinx youth. For example, what does full participation look like? Does "full" refer to mindsets or populations? To whom does participation refer? Participation in what? Without a shared understanding of inclusion, how would the ReaCH team test, improve, and share their model with other groups?

Recognizing that a common vocabulary was a critical foundation for the ReaCH model, the team drafted statements to guide how DEIA is manifested in its efforts. The table below displays NASA's definitions of DEIA alongside the ReaCH team's operationalizations, or shared understanding of what these definitions look like, in our work.

While NASA has provided guidance and stressed the importance of incorporating the pillars of DEIA into multiple projects, teams and individuals must do the difficult work of making the definitions concrete. These operationalizations represent the first step for our team in creating the ReaCH model. As the Planetary ReaCH team works to both incorporate these operationalizations in its work and measure progress toward successful integration, we offer these first steps of our journey and lessons learned to guide others who are on the same path.

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NICOLE MANN BECOMES FIRST INDIGENOUS WOMAN IN SPACE

Credit: NASA.

Astronaut Nicole Mann made history on October 5, 2022, as the first Indigenous woman in space. A member of the Wailacki of the Round Valley Indian Tribes, she'll do research onboard the International Space Station with NASA's SpaceX Crew5 mission.

The California native holds a Bachelor of Science in Mechanical Engineering and a Master of Science in Mechanical Engineering. Mann is a Colonel in the U.S. Marine Corps and served as a test pilot in the F/A-18 Hornet and Super Hornet. She deployed twice onboard aircraft carriers in support of combat operations in Iraq and Afghanistan.

Mann was selected in June 2013 as one of eight members of the 21st NASA astronaut class. Her astronaut candidate training included intensive instruction in International Space Station systems, spacewalks, Russian language training, robotics, physiological training, T-38 flight training, and water and wilderness survival training. She completed astronaut candidate training in July 2015. She has served as the T-38 Safety and Training Officer and as the Assistant to the Chief Astronaut for Exploration where she led the astronaut corps in the development of the Orion spacecraft, Space Launch System, and Exploration Ground Systems for missions to the Moon.

To learn more about Nicole Mann, visit www.nasa.gov/astronauts/biographies/nicole-a-mann/biography.

INCLUSION PLAN BEST PRACTICES WORKSHOP

The virtual Inclusion Plan Best Practices Workshop is scheduled for November 1–2, 2022, from 1:00 p.m. to 3:00 p.m. EDT each day.

Inclusion is one of NASA's core values, and one of the agency's highest priorities is moving toward an increasingly diverse and inclusive workforce that fully engages varied talents, ideas, and perspectives. Many programs within NASA's Research Opportunities in Space and Earth Sciences (ROSES) are

now requiring proposers to contain an inclusion plan that outlines how the team will work against barriers to create and sustain inclusive work environments and how the team will equip members in such a way that they can go on to lead and contribute to other teams that are diverse and inclusive. As a result, in coordination with social scientists, NASA's Science Mission Directorate (SMD) is hosting this Inclusion Plan Best Practices Workshop to discuss best practices to consider when creating and maintaining inclusive teams. Topics will include common barriers to inclusive working environments; recruitment best practices; understanding the distinction between inclusion, diversity, equity, and accessibility; and more.

The goal of this workshop is to provide proposers with some background and tools needed to be active participants in creating and maintaining inclusive work environments. This workshop is open to any member of the science community and may be of particular interest to those writing ROSES or mission proposals requiring inclusion plans. Registration fees are not being collected for this workshop, but registration is required.

For more information about the workshop, visit www.hou.usra.edu/meetings/inclusionplan2022/.

PRIDE IN STEM COMMUNITY AND CAREERS CONFERENCE

Pride in STEM is proud to mark the International Day of LGBTQIA+ people in STEM with a special conference.

As part of a suite of events to celebrate LGBTQ+ in STEM Day, Pride in STEM is hosting its 2022 LGBTQ+ STEM Day conference at Burlington House, the Royal Society of Chemistry. A careers event that's not a careers event, the day will be packed full of talks and panels loaded with practical advice for navigating the world of STEM as a queer person. Hear from experts in academia, industry, and healthcare on everything from work-life balance, science in the media, intersectionality, and knowing your rights.

The event is going to be a hybrid conference with limited in-person tickets. The venue is fully accessible and BSL interpreters will be present throughout the day. We expect in-person attendees to wear masks. The online livestream will have automated captions and following the events, the videos will be closed-caption and edited, and shared once again.

To learn more and to register, visit www.iop.org/events/pride-stem-community-careers-conference.

NASA AWARDS $4 MILLION THROUGH NEW SPACE GRANT KIDS OPPORTUNITY

Students from Chesterfield Career and Technical Center in Chesterfield, Virginia, calculate plant growth measurements and monitor environmental conditions for their basil plants for the Plant the Moon Challenge. Credit: NASA's Virginia Space Grant Consortia.

NASA is awarding more than $4 million to institutions across the U.S. to help bring the excitement of authentic NASA experiences to groups of middle- and high-school students who are traditionally underserved and underrepresented in STEM.

The new Space Grant K–12 Inclusiveness and Diversity in STEM (SG KIDS) opportunity will boost these students' sense of belonging in STEM subjects, a critical first step toward STEM degrees and careers.

SG KIDS is a pilot program made possible through NASA's National Space Grant and Fellowship Project, which comprises Space Grant Consortia led by an institution in each of the 50 states, the District of Columbia, and Puerto Rico. This opportunity represents a new approach by asking the awarded consortia to reach beyond state boundaries to create regional projects tailored to students in those areas. Through partnerships, the awardees will be able to share these exciting STEM opportunities with students residing in other states.

SG KIDS addresses the White House Executive Order on Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, as well as NASA Administrator Bill Nelson's focus on providing authentic STEM opportunities to K–12 students.

The projects funded under SG KIDS will provide students with hands-on experiences and lessons that bring NASA's missions to life, provide training and resources to the educators teaching those students, and boost the STEM ecosystem in these regions.

Each of the four grantees, Virginia Space Grant Consortium, Georgia Space Grant Consortium, Ohio Space Grant Consortium and Texas Space Grant Consortium, will receive approximately $1,050,000 in cooperative agreements to put their proposals into action during the next three years. The grantees are:

- Old Dominion University Research Foundation, Norfolk, Virginia
- Georgia Institute of Technology, Atlanta
- Ohio Aerospace Institute, Cleveland
- University of Texas at Austin

To learn more about the grantees and their proposed projects, visit www.nasa.gov/feature/nasa-awards-4-million-through-new-space-grant-kids-opportunity/.

To learn more about NASA Space Grant or to find the consortium director and website for your state, visit go.nasa.gov/3ym50oe.

3RD ANNUAL RISING BLACK SCIENTISTS AWARDS

Cell Press is excited to announce that this year's Rising Black Scientists Award essay competition will expand beyond the life sciences to include all scientific disciplines published by Cell Press (life, health, Earth and environmental, data, and physical sciences). In partnership with Cell Signaling Technology and the Elsevier Foundation, the goal is to support talented and motivated young Black scientists on their journey. The award is meant to break down barriers and create opportunities by providing funds to support professional development.

Four awardees — two undergraduate students and two graduate students/postdoctoral scholars — will be recognized. Four honorable mentions — two undergraduate students and two graduate students/postdoctoral scholars — will also be recognized. We encourage submissions from any Black aspiring scientists or active researchers at American institutions within the U.S.

The application deadline is November 11, 2022, at 11:59 p.m. ET.

For more information and to apply, visit www.cell.com/diversity/awards.

STUDENTS GET INSPIRED BY FORMER ASTRONAUT JOSÉ HERNÁNDEZ DURING HISPANIC HERITAGE MONTH EVENT

On September 22, 2022, NASA Johnson Space Center's External Relations Office, in collaboration with NASA's Office of STEM Engagement (OSTEM), the Exploration Systems Development Mission Directorate, and Hispanic Employee Resource Group, provided a Hispanic Heritage Month experience to the Seabrook Intermediate science magnet students in Seabrook, Texas.

OSTEM's Alicia Baturoni-Cortez guided nearly 60 students and teachers as they took part in a virtual connection featuring special guest and former astronaut José Hernández. This live event with Hernández was offered to teachers in NASA's new community of practice for educators: CONNECTS. CONNECTS was created and is supported by NASA OSTEM's Next Gen STEM project.

Growing up as a migrant worker, Hernández pursued his dream to fly in space after watching a broadcast of an Apollo moonwalk. After applying 12 times, he was accepted into the Astronaut Corps, along with educator astronaut Ricky Arnold. Hernández went on to be a part of the STS-128 Discovery crew that flew the 128th Space Shuttle Program mission and 30th mission to the International Space Station.

Students also received copies of First Woman, NASA's Promise for Humanity (Issue No. 1: Dream to Reality), the graphic novel featuring the fictitious young Hispanic astronaut Callie Rodriquez, as well as Artemis I decals and other educational materials. The graphic novel is available online in Spanish, along with interactive experiences, including the First Woman app.

As part of Hispanic Heritage Month, the educators were provided with a Space Loteria (Space Bingo) set, which was developed by Johnson's Hispanic Employee Resource Group. It's a great resource to have or share with your networks. To download the Space Loteria set, visit www.txstate-epdc.net/epdc_posts/space-loteria/.

Seabrook Intermediate science magnet students and their teachers enjoy a NASA CONNECTS live virtual event with former astronaut José Hernández. Credit: NASA.

LEADING THE WAY FOR MORE LGBTQ INCLUSIVITY IN STEM

Credit: IEEE Spectrum.

Arti Agrawal, who is gay, didn't have access to LGBTQ+ support groups when growing up in India, where homosexuality was a crime until 2018. "The society itself was very homophobic," she says. "I had to live under the radar, and it was very difficult and quite traumatizing to live that way."

Agrawal found solace in advocacy and support organizations in London after moving there in 2005. She went on to form her own groups and lead diversity, equity, and inclusion efforts at the universities she worked for in London and Sydney.

This year she started a consulting firm where she helps businesses around the world improve their DEI programs. She also has spearheaded DEI campaigns for the IEEE Photonics Society.

To read more about how Agrawal is fighting for diversity and inclusivity in STEM, launching a DEI startup, and more, visit spectrum.ieee.org/arti-agrawal-profile.

NATIONAL SOCIETY OF BLACK PHYSICISTS 2022 ANNUAL CONFERENCE

The National Society of Black Physicists is pleased to announce the 2022 Conference on November 6–9, 2022, in Charlottesville, Virginia. This year's conference co-host is the National Radio Astronomy Observatory (NRAO). The 44th Annual Conference will be held at the Omni Hotel Charlottesville.

The theme for this year's conference is "Emerging from the Event Horizon and Beaming for the Future."

The conference will consist of three days of educational sessions, exhibits, interactive networking opportunities, a hybrid/virtual component, as well as a student career fair and poster sessions on cutting-edge issues related to current trends in physics and science.

For more information, visit web.cvent.com/event/c58077a3-9713-402a-a64b-72f6d091e5f6/summary.

SEARCHING BEYOND THE STARS:

Seven Women in Science Take on Space's Biggest Questions

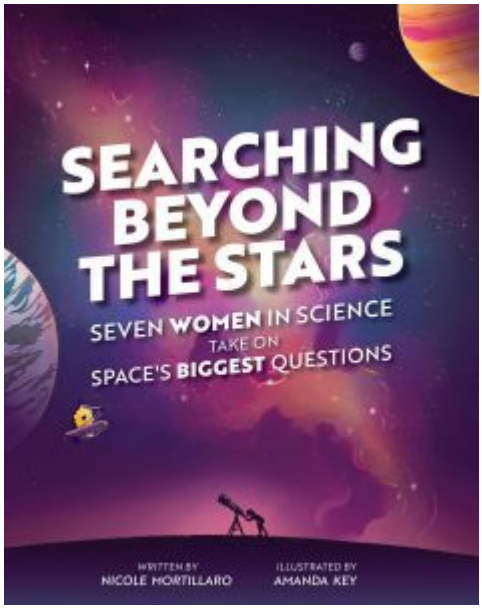
Are we alone in the cosmos? Could we one day live on a different planet? How is life formed? What other secrets does the universe hold?

Through profiles of seven remarkable women scientists and their achievements in their respective fields, *Searching Beyond the Stars* takes us deep into space, looking at once to the distant past and the distant future to capture the awe and intrigue of some of the biggest questions we can possibly ask.

Making connections across astronomy, chemistry, physics, history, and more, Nicole Mortillaro draws on her own experience as a woman in STEM to highlight the incredible odds each scientist faces while chasing new discoveries and the ways in which sexism and racism, among other barriers, still affect women scientists to this day. Sidebars filled with fascinating facts take readers behind the science and encourage them to delve deeper. Vibrant illustrations by Amanda Key showcase the wonder of space and the passion and eternal curiosity that drive each scientist in their work unfurling the mysteries of our universe.

Scientists profiled in the book include:

Katherine Johnson, research mathematician and aerospace



technologist at NASA. Helped get the first American astronauts into space and safely home again. Lived in Newport News, Virginia.

Jill Tarter, radio astronomer and project scientist at NASA. Opened up possibilities for communicating with aliens. Lives in Berkeley, California.

Sara Seager, astrophysicist and planetary scientist. Credited with laying the foundation for the field of exoplanet atmospheres and the search for life on exoplanets. Originally from Toronto, Ontario, and now lives in Massachusetts.

Emily Lakdawalla, planetary scientist, journalist, speaker, and expert science communicator formerly of The Planetary Society. Lives in Los Angeles, California.

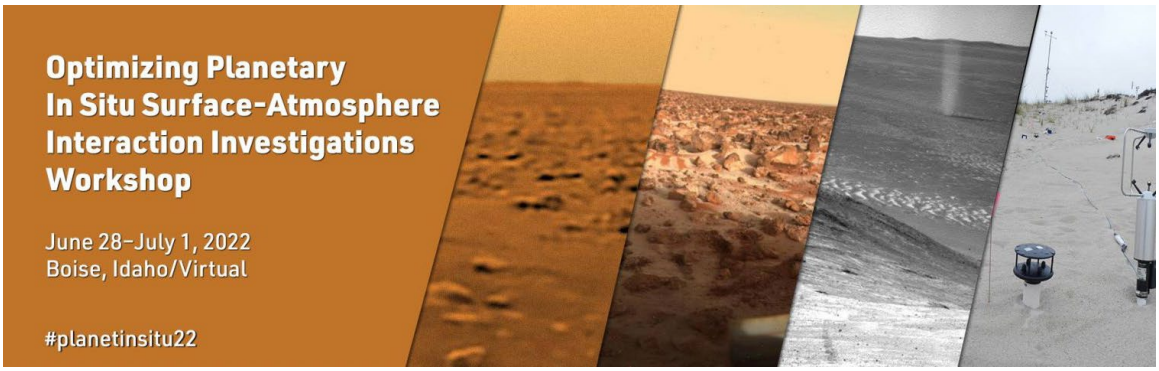
Tanya Harrison, planetary scientist and geologist. Was on the science operations team for NASA's Mars Reconnaissance Orbiter analyzing imaging from a geologist's standpoint to see whether we might one day live on Mars. Director of Science Strategy at Planet Labs. Lives in Washington, DC.

Renée Hložek, astrophysicist and cosmologist. Her work is to imagine, dream, and calculate the mathematical equations that govern and predict the end of the universe. Originally from South Africa, and now lives in Toronto, Ontario.

Ashley Walker, astrochemist, science communicator, and activist. Co-organizer of #BlackinChem, #BlackInAstro, and #BlackInPhysics to highlight and amplify the voices of Black researchers and scholars in these fields. Lives in Chicago, Illinois.

To learn more, visit www.annickpress.com/Books/S/Searching-Beyond-the-Stars.

MEETING HIGHLIGHTS



The Optimizing Planetary In Situ Surface-Atmosphere Interaction Investigations (#planetinsitu22) hybrid workshop was held in Boise, Idaho, and online June 28–July 1, 2022. This workshop aimed to advance opportunities for in situ studies of planetary surface-atmosphere interactions and foster collaborations (including for mission concept and instrument development over the next decade) through discussion about how to collect the most needed measurements and optimize their science value. The ~20 in-person and ~50 virtual registrants hailed from the U.S., U.K., Europe, and Australia; from terrestrial and planetary science communities; and from instrument and spacecraft development. Attendees also spanned career levels — of the in-person participants, ~10 were students or postdoctoral scholars, and many of these had travel supported through NASA via a ROSES TWSC grant (grant # 80NSSC22K0852).

The PlanetInsitu22 workshop was an experiment, with a topical focus on measurement methodology rather than science questions, a discussion-focused program with no live abstract-driven presentations, and an effort for engagement of both in-person and virtual attendees. In general, this experiment was successful — we gainfully filled all of our discussion time, covered all planned topics in-depth, and saw potential collaborations starting among participants. At the conclusion of the workshop, when discussing next steps, folks were very interested in continuing these types of discussion through other forums. Additionally, ~70% of post-workshop survey respondents thought that PlanetInsitu was a better hybrid and/or discussion-focused workshop than others they had attended (and zero thought it was worse).

Furthermore, all plenary discussions and presentations, along with pre-recordings for abstract-submitted topics, are available to the general public via the workshop website at www.hou.usra.edu/meetings/planetinsitu2022/. These videos, especially those from the field trip, have been accessed numerous times since the workshop, demonstrating the broad community interest in these topics.

To foster the discussion, the workshop started with several short, invited overview talks to introduce a shared understanding of *in situ* studies and their value for studies of terrestrial processes and to identify the measurements most needed to advance planetary process studies. The remainder of the first day and an additional full day were devoted to group discussion. This discussion was generally conducted using small groups, divided based on specific thought prompts, followed by a plenary discussion that brought together and expanded key points raised within the small groups. For all discussions, both remote and in-person attendees contributed questions, comments, and ideas.

The mid-conference field trip enabled detailed exploration of instrument and mission concepts, an experience that many of the in-person participants found valuable. Unfortunately, it was not possible to enable remote participation in the field trip as the field site had no Wi-Fi and limited cell service. To mitigate this omission for the remote participants and enable them to be aware of the general field trip activities and discussions, we (1) reviewed the instrument demonstrations and field trip plans at the conclusion of the first day, (2) posted short videos from the field trip upon our return from the trip, and (3) provided a brief summary of the field trip at the start of the workshop on the next day. (As reflected in our post-workshop survey, these efforts were generally appreciated by remote attendees.)

To summarize the present capabilities, gaps, and critical considerations from the groups, discussion chairs presented a brief summary of key points on Friday morning. These summaries fed into our final discussion, identifying next steps for the workshop conveners, the relevant community groups, and interested individuals. Based on this discussion, we aim to develop a mailing list and regular telecon to build further collaborations and forward momentum.

In all aspects of the workshop, we sought to create an inclusive and accessible environment that fostered equitable participation and collaboration among all workshop attendees and learned many valuable lessons about what works and what doesn't in a hybrid meeting.

— *Text provided by Serina Diniega, Jet Propulsion Laboratory*

OPPORTUNITIES FOR STUDENTS

INTERNSHIPS

LUNAR AND PLANETARY INSTITUTE SUMMER INTERN PROGRAM

The LPI Summer Intern Program in Planetary Science provides undergraduate students with an opportunity to perform cutting-edge research, learn from leading scientists, and explore exciting careers in planetary science. During the ten-week internship, students have opportunities to participate in enrichment activities, including lectures and career development workshops. Applications for the 2023 program will close in December 2022. Click LPI Internships to learn more.

SETI SUMMER RESEARCH INTERNSHIP PROGRAM

The SETI Institute, a non-profit private scientific research institution located in California's Silicon Valley, invites highly motivated college students interested in astronomy, astrobiology, and planetary science research to apply for a summer Research Experience for Undergraduates program. Students will work with scientists at the SETI Institute and at the nearby NASA Ames Research Center on projects spanning the field of astrobiology, from microbiology to observational astronomy. Applications for the 2023 program will open in Fall 2022 and close in January. Click SETI REU Program to learn more.

AIR FORCE RESEARCH LABORATORY SCHOLARS PROGRAM

The Air Force Research Laboratory (AFRL) Scholars Program, administered by the Universities Space Research Association (USRA), offers paid internship opportunities for undergraduate and graduate students pursuing STEM degrees, as well as upper-level high school students. Interns gain valuable hands-on experience working with full-time AFRL scientists and engineers on cutting-edge research and technology and are able to contribute to unique, research-based projects. Applications for the 2023 program will open in Fall 2022 and close in January. Click AFRL Scholars to learn more.

NOAA OCEAN EXPLORATION EXPLORER-IN-TRAINING PROGRAM

The NOAA's Explorer-in-Training Program equips undergraduate and graduate students with skills to meet the current and future demands of the ocean exploration workforce, providing meaningful experiential learning opportunities that support NOAA Ocean Exploration's mission. The program features two paid internship options: (a) two- to four-week expedition-based opportunities (Hydrography & Seafloor Mapping) and (b) ten-week summertime opportunities (Exploration Education, Media, & Science Communication). Applications for the 2023 program will open in Fall 2022 and close in January. Click NOAA Ocean Exploration to learn more.

UCAR UNIDATA SUMMER INTERNSHIPS

The Unidata Summer Internship program offers graduate students and upper-level undergraduates the opportunity to work closely with Unidata's professional staff on a variety of projects. As part of the University Corporation for Atmospheric Research, Unidata interns build software development skills, learn about data-enabled geoscience, and get to know what it's like to work in a community-focused organization supporting Earth Science research and education. Applications for the 2023 program will close in December 2022. Click Unidata Summer Internships to learn more.

NATIONAL MAGLAB REU PROGRAM

The National High Magnetic Field Laboratory (MagLab) is the largest and highest-powered magnet lab in the world. The MagLab's Research Experiences for Undergraduates (REU) program is a paid summer internship offering research experiences in physics, chemistry, biological science, geochemistry, materials science, magnet science, and engineering. Students work closely with MagLab mentors on a novel research project. The 2023 program will run from May 30 to August 4. Applications for 2023 will open in October 2022 and close in February. Click MagLab REU to learn more.

AMERICAN MUSEUM OF NATURAL HISTORY REU IN PHYSICAL SCIENCE

The Division of Physical Sciences of the American Museum of Natural History (AMNH) offers paid summer research opportunities in astrophysics and Earth and planetary sciences. The program brings approximately eight undergraduate students to the AMNH in New York City each summer for a ten-week experience. Students work with curators, faculty, and post-doctoral fellows to conduct original research projects. Applications for the 2023 program will open in Fall 2022 and close in January. Click REU Physical Sciences Program to learn more.

IRIS INTERNSHIP PROGRAM

Incorporated Research Institutions for Seismology (IRIS) is a consortium of over 125 U.S. universities and is a world leader in advancing discovery, research, and education in seismology to understand the planet and benefit society. Each summer, undergraduate interns spend eight to ten weeks working on a paid seismological research project with researchers at IRIS member institutions. Applications for the 2023 program will open in Fall 2022 and close in February. Click IRIS Internship Program to learn more.

NASA SPACE LIFE SCIENCES TRAINING PROGRAM

The Space Life Sciences Training Program (SLSTP) provides undergraduate students with professional experience in space life science disciplines. The ten-week, paid summer program is hosted by NASA's Ames Research Center. Students work closely with renowned NASA scientists and engineers on cutting-edge research exploring the effects of spaceflight on living systems, the development of advanced biotechnologies and facilities, and more. Applications for 2023 will open in Fall 2022 and close in January. Click NASA Space Life Sciences Training Program to learn more.

MICKEY LELAND ENERGY FELLOWSHIP PROGRAM

The U.S. Department of Energy's (DOE) Mickey Leland Energy Fellowship (MLEF) Program is a ten-week, paid summer research fellowship for undergraduate and graduate students in STEM majors. Participants complete a cutting-edge research project at one of the Department's national laboratories or DOE Headquarters in support of the Department's mission to minimize the environmental impacts of energy resource recovery and use while working towards net-zero emissions. Applications for 2023 are now open. The deadline to apply is January 23, 2023. Click SCGSR Program to learn more and apply.

SCHOLARSHIPS AND FELLOWSHIPS

NATIONAL MUSEUM OF NATURAL HISTORY FELLOWSHIPS

The Department of Mineral Sciences at the National Museum of Natural History (NMNH) invites fellowship applications for graduate student, postdoctoral, and senior fellows. Active areas of research include geochemistry, petrology, experimental petrology, volcanology, mineralogy, biomineralogy, environmental mineralogy, meteorite studies, solar system formation, and planetary formation and evolution. The department houses the National Meteorite Collection, the National Rock and Ore Collection, the National Gem and Mineral Collection, and the Global Volcanism Program. The deadline to apply is November 1, 2022. Click NMNH Opportunities to learn more.

FORD FOUNDATION FELLOWSHIPS

On behalf of the Ford Foundation, the National Academies of Sciences, Engineering, and Medicine administers a national competition to award predoctoral, dissertation, and postdoctoral fellowships. Through these fellowships, the Ford Foundation seeks to increase the diversity of the nation's college and university faculties. The 2023 competition is now open. Applications are due in December. Click Ford Foundation Fellowship Programs to learn more.

AMERICAN METEOROLOGICAL SOCIETY STUDENT AWARDS

The American Meteorological Society (AMS) administers an array of graduate fellowships and undergraduate scholarships with the support of its members, corporations, and government agencies nationwide. The fellowships and scholarships range from $1,000 to $25,000 and help further the education of outstanding graduate and undergraduate students pursuing a career in the atmospheric and related oceanic or hydrologic sciences. Applications for AMS Graduate Fellowships are now open. Applications are due on January 1, 2023. Click AMS Scholarships and Fellowships to learn more.

L'ORÉAL USA FOR WOMEN IN SCIENCE FELLOWSHIP PROGRAM

The L'Oréal USA For Women in Science fellowship program awards five women postdoctoral scientists annually with grants of $60,000 each for their contributions in Science, Technology, Engineering, and Math (STEM) fields and commitment to serving as role models for younger generations. Candidates must have completed their Ph.D. and started a postdoctoral research position by the application deadline. Applications for 2023 will open in Fall 2022. The deadline is in January. Click L'Oréal USA For Women in Science Fellowship Program to learn more.

AGU CONGRESSIONAL SCIENCE FELLOWSHIP PROGRAM

The American Geophysical Union (AGU) Congressional Science Fellowship (CSF) program places highly qualified and accomplished scientists, engineers, and other professionals in the office of an individual member of Congress or on a committee for a one-year assignment. For four decades, CSFs have been directly involved in water policy, climate research, energy conservation, and a range of other science-based issues. There are no restrictions on age, education, career level, or scientific background. Applications for the 2023–2024 fellowship opened in October 2022. Click AGU Congressional Science Fellowship Program to learn more.

AAAS MASS MEDIA SCIENCE & ENGINEERING FELLOWSHIP PROGRAM

The AAAS Mass Media Science & Engineering Fellowship program is a ten-week, paid summer program that places science, engineering, and mathematics students (undergraduate, graduate, and postdoctoral) at media organizations nationwide. Fellows use their academic training as they research, write, and report today's headlines, sharpening their skills in communicating complex scientific issues to the public. Applications for 2023 opened in October 2022. Click AAAS Mass Media Science & Engineering Fellowship Program to learn more.

THE GEOLOGICAL SOCIETY OF AMERICA®

GSA GRADUATE STUDENT RESEARCH GRANTS

The Geological Society of America (GSA) offers research grants to provide partial support of master's and doctoral thesis research in the geological sciences for graduate students enrolled in universities in the United States, Canada, Mexico, and Central America. Applications for 2023 will open in Fall 2022 and close in February. Click GSA Graduate Student Research Grants to learn more.

POSTDOCTORAL POSITIONS

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

NASA Postdoctoral Program

LPI Postdoctoral Positions

JPL Postdoctoral Positions

STScI Postdoctoral Fellowships

JHU APL Doctoral Level Opportunities

Center for Astrophysics Fellowships and Visiting Scientist Positions

Smithsonian Institution Fellowship Program

SwRI 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.

ORIONID METEOR SHOWER

Orionid Meteors from Orion. Credit: Lu Shupei.

October – November

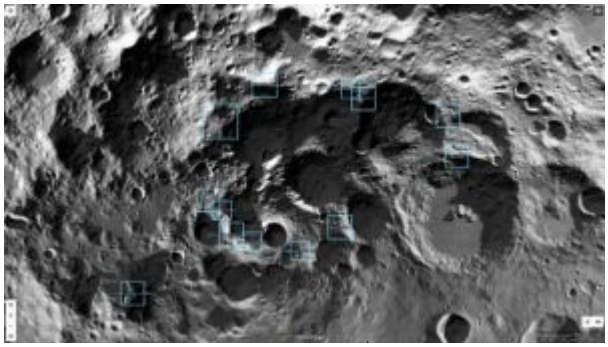
The Orionid meteor shower is active throughout October and November and peaks on the night of October 20 in the hours after midnight and before dawn. This annual event gets its name from the fact that you can trace the paths of its meteors back to an area of the sky near the Orion constellation. These meteors are fragments of dust left behind by Comet Halley in a trail that extends along its orbit. The Orionid meteors occasionally leave persistent trains and sometimes produce bright fireballs.

DART'S SUCCESSFUL IMPACT WITH DIMORPHOS

(Left) The last complete image taken by NASA's DART mission 2 seconds before impact. Credit: NASA/Johns Hopkins APL. (Right) One of LICIA-Cube's stunning views of DART's impact. Credit: ASI/NASA.

On September 26, 2022, the Double Asteroid Redirection Test (DART) spacecraft, NASA's first planetary defense test mission, slammed into Dimorphos, an asteroid moonlet approximately 11 million kilometers away, at 14,000 mph! The spectacular impact was observed by DART's companion, LICIACube, as well as by ground-based telescopes. As the dust clears, astronomers will monitor the asteroid's orbit for change. Stay up to date on the DART mission.

ALL ABOUT THE MOON



Map of the Artemis regions from Moon Trek. Credit: NASA.

Each year, International Observe the Moon Night unites enthusiasts and curious people worldwide in appreciation of our Moon. This year, the event happened on October 1. In 2023, the event will occur on October 21. But you don't have to wait a year to bring incredible lunar science, imagery, activities, and resources to your audiences! Check out NASA's lunar science resources, share the interactive Moon Trek application, and enjoy the newly released Lunar 100 video series showcasing the top 100 features to observe on the Moon.

MARS IN RETROGRADE

Retrograde Mars and Saturn. Credit: Tunç Tezel (TWAN).

As the planets move around the Sun, inner planets complete their orbits faster than outer planets. About every two years, Earth overtakes Mars. Throughout 2022, Mars has been working its way across the night sky, toward the east. But at the end of October, Mars will appear to begin moving in the opposite direction, westward, relative to background stars. This will continue until late January, when eastward motion will resume. This apparent reversal in Mars' motion is called the retrograde motion of Mars and is an illusion caused by Earth passing Mars. Over the next several months, you can observe this retrograde motion and witness a phenomenon that puzzled early astronomers!

OPPORTUNITIES AND RESOURCES FOR STEM ENGAGEMENT

SCIENCE CAREER PATH TOOL TOWN HALL MEETING

NASA's Science Mission Directorate held a community town hall on the Science Career Path Tool, an interactive online tool that features five distinct science career tracks and summarizes the common roles across the NASA science workforce. This tool can assist scientists, managers, students, and prospective employees to NASA by raising awareness of career opportunities and providing information about how to prepare for different roles.

EARTH SCIENCE WEEK

Each year, the American Geosciences Institute (AGI) organizes a national and international event to help the public gain a better understanding and appreciation for Earth sciences and to encourage stewardship of Earth. The 24th annual Earth Science Week theme was "Earth Science for a Sustainable World" and featured a wide range of exciting activities, programs, and resources. It is important to emphasize the essential role of Earth science in helping people make decisions that maintain and strengthen the planet's ability to support thriving life. Learn more about Earth Science Week.

PROFESSIONAL DEVELOPMENT OPPORTUNITIES — EDX EDUCATION COURSES

Free, online courses

The edX platform brings together the best universities from all around the world to create courses for everyone, everywhere. edX offers online classes and courses in education covering a broad range of topics from educational policy and history to curriculum design and teaching techniques. Explore case studies in teaching and learn about how technology is increasing access to quality education on an unprecedented scale. Explore edX education courses.

ASP2022: VIRTUAL CONFERENCE — SOLAR ECLIPSES TO SPACE TELESCOPES: COMMUNICATING SCIENCE TO STUDENTS AND THE PUBLIC

December 8-10, 2022

The Astronomical Society of the Pacific (ASP) invites all educators, scientists, science communicators, and public engagement professionals in astronomy and related fields to register for the ASP2022: Virtual Conference. This is an opportunity to learn about best practices in sharing science, innovative ideas and new research findings, and evaluation results from a global community. Learn more about ASP2022.

LETTERS TO A PRE-SCIENTIST

STEM professionals are invited to volunteer in the Letters to a Pre-Scientist's (LPS) pen pal program, which connects students to scientists. The program strives to build student awareness, interest, and confidence in exploring a future in STEM. Learn more about the LPS pen pal program.

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

IN MEMORIAM

Credit: Japan Geoscience Union.

KOICHIRO TSURUDA

1937–2020

Koichiro Tsuruda passed away on the morning of December 3, 2020, at the age of 83. Tsuruda was known for his outstanding contributions to magnetospheric and space physics by the developments of innovative instruments for research in very low-frequency (VLF) radio propagation and electric fields in space plasma.

After conducting VLF observations and research, Tsuruda created a new method of electric field measurement and installed it on the S-520-9 sounding rocket, the Akebono satellite, and the Geotail satellite, which was a major breakthrough in solar system plasma science research. He served as the Director of the Institute of Space and Astronautical Science (ISAS) from 2003 to 2005 and guided the Institute through a difficult period after it was integrated into the Japan Aerospace Exploration Agency.

Tsuruda had both a gentle personality and a strong resilience in his spirit, and many people loved him. He suffered from Parkinson's disease in his later years, but he passed away peacefully at home with his family watching over him.

NASA Chief Scientist James Green issued the following statement: "As a young NASA researcher who was the deputy Project Scientist on the Global Geospace Science set of satellites, I had the pleasure of traveling to ISAS and working with the Geotail scientists where I met Dr. Tsuruda. I was already very familiar with his seminal Akebono wave papers. He was an outstanding scientist who took time to explain a number of key plasma wave concepts to me that I will never forget. We again met when he headed ISAS guiding that nations robotic space program with extensive knowledge and skill and forming long lasting relationships with NASA. He is one of our original space pioneers and will be missed."

— *Portions of text courtesy of Masato Nakamura/ISAS*

ANNY-CHANTAL LEVASSEUR-REGOURD

1945–2022

With great sadness we are informing the planetary community that Anny-Chantal Levasseur-Regourd passed away on August 1, 2022.

Anny-Chantal Levasseur-Regourd combined in her work ground-based and space-based observations as well as laboratory and numerical simulations to better understand the physical properties of cometary and interplanetary dust. She was appointed as a professor of astronomy and space physics at the Université Pierre et Marie Curie (Paris VI) in 1985 and became professor emeritus in 2013, combining teaching activities with research at the Service d'Aéronomie and, since 2009, the LATMOS institute. In 1977, she applied to the ESA astronaut selection campaign and was the only woman selected as a finalist.

Levasseur-Regourd started her research with studies of the interplanetary medium and derived the first global map in intensity and polarization of the zodiacal light, providing constraints on the local physical properties of the interplanetary dust particles. She participated in the international campaign for studying Halley's comet both with observations from the ground and as the PI of the OPE experiment onboard the European Giotto spacecraft, which observed the linear polarization in the inner coma of the comet. Results showed the presence of low-density solid particles and light scattering mostly by large particles.

Levasseur-Regourd continued her work on the study of light scattering by irregular particles by developing facilities in the laboratory and in microgravity to simultaneously study the intensity and polarization of aggregated particles. A reduced version of one of these experiments (ICAPS) will soon fly onboard a TEXUS rocket. She also participated in the Rosetta mission, focusing on determining the physical properties of the cometary nucleus and dust particles. She actively participated in the development of the EnVisS camera, a multiwavelength polarimetric imager of the ESA Comet Interceptor spacecraft, expected to be launched in 2029.

Levasseur-Regourd supervised seven Ph.D. students. She was particularly enthusiastic about supporting the recognition and advancement of her female colleagues. In addition, she published five outreach books on astronomy and gave popular television lectures. She served as the President of the French Committee for the organization of the International Year of Astronomy 2009.

Asteroid 6170 is named Levasseur in her honor. In recognition of her scientific work, she was appointed Officier de la Légion d'Honneur in 2013 and was awarded the following prizes: Prix Thorlet de l'Académie des Sciences (1976), Prix Glaxo de Vulgarisation Scientifique (1982), and Prix des Dames de la Société Astronomique de France (1986).

— Text courtesy of colleagues Edith Hadamcik, Jérémie Lasue, and Jean-Baptiste Renard

LPI ANNOUNCES SHOEMAKER IMPACT CRATERING AWARD RECIPIENT

Emily Bamber from University of Texas at Austin. Credit: Lunar and Planetary Institute.

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2022 recipient of the Eugene and Carolyn Shoemaker Impact Cratering Award is Emily Bamber from the University of Texas at Austin.

Bamber is pursuing a Ph.D. addressing the past evolution of impact crater lakes on Mars, Earth, and elsewhere with fieldwork, satellite observations, and landscape modeling.

The award is to be applied to the study of impact craters, whether they be on Earth or any other solid body in the solar system. The focus of the proposed work can be on the cratering process, the bodies (asteroidal or cometary) that make the impacts, or the geological, chemical, or biological results of impact cratering.

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.

This award began as the Eugene M. Shoemaker Memorial Fund for Crater Studies. It was established by Dr. Carolyn Shoemaker in memory of her husband in 1998. She established the endowment so that students would have an opportunity to pursue studies of impact craters, which was the focus of her husband's graduate student studies and a large part of his professional career. Dr. Carolyn Shoemaker had a brief but extraordinary scientific career. In a twelve-year window, she discovered a world-record 32 comets, including Comet Shoemaker-Levy 9. After Dr. Carolyn Shoemaker passed away in 2021, the award was renamed the Eugene and Carolyn Shoemaker Impact Cratering Award in memory of their collective contributions to impact cratering science.

Additional details are available at www.lpi.usra.edu/science/kring/Awards/Shoemaker_Award/.

NASA ANNOUNCES PENDING DEPARTURE OF SCIENCE ASSOCIATE ADMINISTRATOR

Dr. Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate, will leave the agency at the end of 2022 after six years of dedicated service.

"NASA explores to better understand our place in the universe, and to use what we learn to support life on Earth. Thomas has made an indelible mark at NASA — indeed, he has held this job continuously longer than any other person — and I am thankful for his dedication to our agency," said NASA Administrator Bill Nelson.

As the head of science, Zurbuchen oversees nearly 100 science missions. He helped select 36 new missions during his tenure, including Dragonfly, SPHEREx, and the Mars Sample Return mission. He has worked tirelessly to ensure NASA's science missions build partnerships across disciplines and with

NASA Associate Administrator for Science Thomas Zurbuchen gives remarks following the presentation of the 2022 John L. "Jack" Swigert, Jr., Award for Space Exploration to the OSIRIS-REx team by the Space Foundation during the 37th Space Symposium, April 4, 2022, in Colorado Springs, Colorado. Credit: NASA/Bill Ingalls.

industry and other nations to generate new questions and help advance the frontiers of knowledge and exploration.

Zurbuchen brought a wealth of scientific research, engineering experience, and hands-on knowledge to NASA's world-class team of scientists and engineers. He led the mission directorate during some of the agency's most inspirational moments, such as sending the first spacecraft to touch the Sun, launching and sharing the first images from the James Webb Space Telescope, and landing the Perseverance rover on Mars along with the first powered, controlled flight on another planet with the Ingenuity helicopter, to name a few.

Zurbuchen's many honors include multiple NASA achievement awards, induction as a member of the International Academy of Astronautics, the 2020 Outstanding Leadership Medal, the 2021 Presidential Rank Award, and the 2022 Distinguished Service Medal.

NASA is conducting a nationwide search and open competition for a new associate administrator.

AAS DIVISION FOR PLANETARY SCIENCES ANNOUNCES 2022 PRIZE WINNERS

The Division for Planetary Sciences (DPS) of the American Astronomical Society (AAS) has named its prize winners for 2022. The 2022 DPS prizes were presented at the 54th annual meeting of the Division for Planetary Sciences, which took place in London, Ontario, and online from October 2–7, 2022.

The DPS awards the 2022 Gerard P. Kuiper Prize for outstanding contributions to the field of planetary science to Bonnie Buratti of NASA's Jet Propulsion Laboratory at the California Institute of Technology for her distinguished achievements in the understanding of planetary and small body surfaces through photometry, her career-spanning leadership in the planetary science community, and the legacy she has created through mentoring early-career scientists. Nearly every planetary mission that has involved photometry over the past several decades has benefitted from Dr. Buratti's modeling of the scattering of light and analysis of the physical properties of planetary surfaces.

The DPS is pleased to award the Claudia J. Alexander Prize recognizing outstanding contributions by a mid-career scientist to Martha Scott Gilmore of Wesleyan University for her work on Venus geology and the oldest rock units on Venus located in tessera terrain. Gilmore has shown that the emissivity of tesserae differ from the presumably basaltic plains in a manner consistent with more iron-poor felsic compositions, which is the strongest evidence to date that these rocks contain evolved magmas formed on a more water-rich planet. She has shown that radar emissivity of tesserae and volcanoes varies regionally across the planet, indicating differences in rock composition and degree of weathering or age. Prof. Gilmore's work has helped usher in a new decade of exploration of Venus with the selection of two new NASA Venus missions.

The 2022 Harold C. Urey Prize for outstanding achievement in planetary research by an early-career scientist is awarded to Juan Lora of Yale University for his development of a novel global circulation model (GCM) of Titan, which he has used to successfully explain Titan's precipitation patterns and surface liquid distribution. The model incorporates the effects of atmospheric hazes as well as the impact of Titan's subsurface hydrology. This model is important for the success of the Dragonfly mission, and Lora is a valued team member. Lora has also applied similar techniques to Earth's hydroclimate to understand changes in atmospheric rivers, which are a key component of the water cycle affected by climate change. This combined use of advanced GCMs represents a novel and compelling way of helping to protect our home planet.

The 2022 Harold Masursky Award for meritorious service to planetary science goes to Jim Green for his twelve years of service as head of NASA's Planetary Science Division and four years as NASA's Chief Scientist. He oversaw the

Planetary Science Division through a period of great expansion, and the implementation of numerous ground-breaking planetary science missions and research. He has made a great effort to expand NASA's international partnerships, promoting the spirit of scientific collaboration and cooperation across boundaries, and he has helped foster the careers of many early-career scientists.

The 2022 Sagan Medal for excellence in public communication goes to Caleb Scharf of Columbia University for broadening public awareness of fields from astrophysics and planetary science to astrobiology, and for stimulating insightful and balanced public conversation on the implications of contemporary research. Dr. Scharf is a prolific writer, having written articles in *Scientific American* that reach a large number of people. He has also written a widely used textbook on extrasolar planets and is a highly regarded author of popular science books on astrobiology, astronomy, and technology. He served on the editorial board of the science magazine *Nautilus* and has contributed to a number of movies, documentaries, and popular television shows on science, inspiring many people.

The Jonathan Eberhart Planetary Science Journalism Award for distinguished popular writing goes to Michael Greshko of National Geographic for his article "Small Wonders," published in *National Geographic* magazine on August 24, 2021. This elegantly written article takes the reader on a journey through the history of small body science, covering objects from NEOs to TNOs. It deals with wide-ranging topics such as discovery and impact monitoring efforts, spacecraft exploration, as well as solar system formation models. It describes how small bodies could be responsible for life on Earth, but also have the potential to destroy it. In the end, the article evokes a sense of belonging and being intimately part of the solar system.

NASA TAPS AXIOM SPACE FOR FIRST ARTEMIS MOONWALKING SPACESUITS

Artist's Illustration: Two suited crew members work on the lunar surface. The crew member in the foreground lifts a rock to examine it, while the other photographs the collection site. Credit: NASA.

NASA has selected Axiom Space to deliver a moonwalking system for the Artemis III mission, which will land Americans on the surface of the Moon for the first time in over 50 years. This award — the first one under a competitive spacesuits contract – is for a task order to develop a next-generation Artemis spacesuit and supporting systems and to demonstrate their use on the lunar surface during Artemis III.

After reviewing proposals from its two eligible spacesuit vendors, NASA selected Axiom Space for the task order, with a base value of $228.5 million. A future task order will be competed for recurring spacesuit services to support subsequent Artemis missions.

Using more than 50 years of spacesuit expertise, NASA defined the technical and safety requirements for the next generation of spacesuits. Axiom Space will be responsible for the design, development, qualification, certification, and production of its spacesuits and support equipment that will meet these key agency requirements for Artemis III.

NASA experts will maintain the authority for astronaut training, mission planning, and approval of the service systems. Axiom Space will be required to test the suits in a spacelike environment before Artemis III.

The spacesuits contract, which will advance spacewalking capabilities in low-Earth orbit and on the Moon, is managed by the Extravehicular Activity (EVA) and Human Surface Mobility (HSM) Program (EHP) at the agency's Johnson Space Center in Houston.

Learn more about spacewalking at nasa.gov/suitup.

NASA AWARDS SERVICES CONTRACT TO HELP IMMERSE STUDENTS IN STEM

NASA has selected Guardians of Honor LLC of Washington, D.C., to provide a wide range of science, technology, engineering, and mathematics (STEM) products and services to the agency, including its Office of STEM Engagement.

The NASA Science, Technology, Engineering, and Mathematics contract is a single award, indefinite-delivery/indefinite-quantity contract with a firm fixed price level-of-effort basis and a maximum potential value of approximately $290 million. The period of performance includes a base period that began October 12, 2022, and runs through October 11, 2023, as well as four option periods that run through October 11, 2027.

Under the small business contract, Guardians of Honor LLC will provide services to execute NASA's vision and mission to immerse students in STEM, especially those underrepresented and underserved in NASA's work and research, enhance STEM literacy, and inspire the next generation of aeronautics and space explorers.

These services include:

- NASA internships and fellowships
- Awards and grants support
- STEM content and products
- Participant recruitment
- NASA workforce and career learning experiences
- NASA K-12 STEM engagement
- NASA K-12 educator professional development
- NASA K-12 collegiate competitions and challenges
- NASA institutional support for research and development
- Performance assessment and evaluation services

For information about NASA STEM engagement, visit www.nasa.gov/stem.

NASA AWARDS NEXT-GENERATION SPACEFLIGHT COMPUTING PROCESSOR CONTRACT

NASA's Jet Propulsion Laboratory has selected Microchip Technology Inc. to develop a high-performance spaceflight computing processor that will support future space missions. Credit: NASA.

NASA's Jet Propulsion Laboratory has selected Microchip Technology Inc. of Chandler, Arizona, to develop a High-Performance Spaceflight Computing (HPSC) processor that will provide at least 100 times the computational capacity of current spaceflight computers. This key capability would advance all types of future space missions, from planetary exploration to lunar and Mars surface missions.

"This cutting-edge spaceflight processor will have a tremendous impact on our future space missions and even technologies here on Earth," said Niki Werkheiser, director of technology maturation within the Space Technology Mission Directorate at NASA Headquarters in Washington. "This effort will amplify existing spacecraft capabilities and enable new ones and could ultimately be used by virtually every future space mission, all benefiting from more capable flight computing."

Microchip will architect, design, and deliver the HPSC processor over three years, with the goal of employing the processor on future lunar and planetary exploration missions. Microchip's processor architecture will significantly improve the overall computing efficiency for these missions by enabling computing power to be scalable based on mission needs. The design also will be more reliable and have a higher fault tolerance. The processor will enable spacecraft computers to perform calculations up to 100 times faster than today's state-of-the-art space computers. As part of NASA's ongoing commercial partnership efforts, the work will take place

under a $50 million firm-fixed-price contract, with Microchip contributing significant research and development costs to complete the project.

Current space-qualified computing technology is designed to address the most computationally intensive part of a mission — a practice that leads to overdesigning and inefficient use of computing power. For example, a Mars surface mission demands high-speed data movement and intense calculation during the planetary landing sequence. However, routine mobility and science operations require fewer calculations and tasks per second. Microchip's new processor architecture offers the flexibility for the processing power to ebb and flow depending on current operational requirements. Certain processing functions can also be turned off when not in use, reducing power consumption. This capability will save a large amount of energy and improve overall computing efficiency for space missions.

In 2021, NASA solicited proposals for a trade study for an advanced radiation-hardened computing chip with the intention of selecting one vendor for development. This contract is part of NASA's High-Performance Space Computing project. HPSC is led by the agency's Space Technology Mission Directorate's Game Changing Development Program with support from the Science Mission Directorate.

THREE COMPANIES TO HELP NASA ADVANCE SOLAR ARRAY TECHNOLOGY FOR THE MOON

NASA has selected three companies to further advance work on deployable solar array systems that will help power the agency's human and robotic exploration of the Moon under Artemis.

Through Artemis missions, NASA will return humans to the Moon and establish a long-term presence near the lunar south pole. A reliable, sustainable power source is required to support lunar habitats, rovers, and even construction systems for future robotic and crewed missions. To help provide this power, NASA is supporting the development of vertical solar arrays that can autonomously deploy up to 32 feet high and retract for relocation if necessary.

The agency will award a total of $19.4 million to three companies to build prototypes and perform environmental testing, with the goal of deploying one of the systems near the Moon's south pole near the end of this decade. The designs must remain stable on sloped terrain and be resistant to abrasive lunar dust, all while minimizing both mass and stowed volume to aid in the system's delivery to the lunar surface. The companies selected are:

- Astrobotic Technology of Pittsburgh, Pennsylvania: $6.2 million
- Honeybee Robotics of Brooklyn, New York: $7 million
- Lockheed Martin of Littleton, Colorado: $6.2 million

Existing space-rated solar array structures are designed for use in microgravity or for horizontal surface deployment. The vertical orientation and height of these new designs will help prevent loss of power at the lunar poles where the Sun does not rise very far above the horizon. When the Sun is low on the horizon, the Moon's terrain can block some of its light, keeping it from reaching solar arrays that are low to the ground. By placing the solar arrays on tall masts, these designs allow for uninterrupted light and therefore produce more power.

Vertical solar arrays, pictured in this illustration, will help power exploration of the Moon under Artemis. Credit: NASA.

The contracts are part of the agency's Vertical Solar Array Technology (VSAT) project, which aims to support NASA's long-term lunar surface operations. In 2021, NASA selected five companies to create initial designs for vertical solar array technologies. VSAT is led by NASA's Space Technology Mission Directorate's Game Changing Development program and Langley in collaboration with NASA's Glenn Research Center in Cleveland.

NASA HELPS MINORITY-SERVING INSTITUTIONS REFINE TECH PROPOSALS

Participants in NASA's Minority Serving Institutions Space Accelerator program surround a full-scale model of the agency's Mars Ingenuity Helicopter as engineer Michael Starch discusses the mission on August 18 during the group's two-day visit to the Jet Propulsion Laboratory. Credit: NASA/JPL-Caltech.

After months of working on technology concepts through a unique NASA program called the Minority Serving Institutions Space Accelerator, three university teams of professors and students received hands-on coaching at a place where their visions could one day become reality: the agency's Jet Propulsion Laboratory in Southern California.

The teams — from Fayetteville State University (FSU) in North Carolina, University of Massachusetts Boston, and California State University, Northridge (CSUN) — participated in the 10-week accelerator program in which they were encouraged to think and act like small startup businesses. During the program, the teams received funding, training, and mentorship to develop their concepts and move their ideas further along toward commercialization. The teams are all working on systems that could operate without human oversight for potential use on future science missions in space or on Earth.

The teams had been selected in early June through a NASA-sponsored competition calling for concepts to advance the agency's goals and meet its needs in the areas of machine learning, artificial intelligence, and the development of autonomous systems. The competition was geared toward engaging underrepresented academic institutions and reducing barriers for them to submit ideas to NASA.

As part of their two-day visit to JPL during the week of August 15, the teams learned about patenting new technologies, writing grant proposals, and telling the "story" of their concepts.

The teams got in-person feedback to hone their projects. They also had a chance to spend time at JPL locations where NASA missions have likewise been refined, including the Mars Yard, where rover technology is tested, and the Lab's venerable Spacecraft Assembly Facility.

The teams received awards of $50,000 as prizes for their initial concepts. And now that they've been through the accelerator, they're better positioned to compete for such awards in the future. The program's goal of promoting entrepreneurship took a leap forward when each of the teams established themselves as limited liability corporations.

Opportunities for additional funding are anticipated: NASA's Advanced Information Systems Technology program is planning an open solicitation — with awards of up to $1 million per year — in the summer of 2023 that may include topics related to trusted autonomy, artificial intelligence, and machine learning.

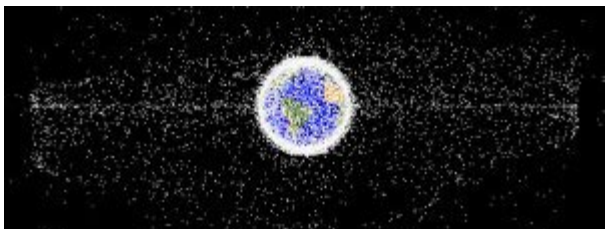
The accelerator is a partnership between NASA's Science Mission Directorate, its Earth Science Technology Office, the Minority University Research Education Project within the agency's Office of STEM Engagement, JPL, and Starburst, a global aerospace accelerator company based in Los Angeles.

To learn more about the Minority Serving Institutions Space Accelerator, visit nasa-space-accelerator.com/.

NASA FUNDS PROJECTS TO STUDY ORBITAL DEBRIS, SPACE SUSTAINABILITY

As part of NASA's efforts to address orbital debris, the agency is funding research proposals from three university-based teams over the next year to analyze the economic, social, and policy issues associated with space sustainability.

Orbital debris consists of human-made objects orbiting Earth that no longer serve a purpose, including mission-related and fragmentation debris, nonfunctional spacecraft, and abandoned rocket stages.



Simulation of orbital debris around Earth demonstrating the object population in the geosynchronous region. Credit: NASA ODPO.

NASA takes the threat of orbital debris seriously as these objects can endanger spacecraft, jeopardize access to space, and impede the development of a low-Earth orbit economy, including commercial participation. These new awards will fund research that supports the agency's commitment to address the problem.

A panel of experts evaluated and selected the following three proposals:

"Adaptive Space Governance and Decision-Support Using Source-Sink Evolutionary Environmental Models," submitted by Richard Linares and Danielle Wood of the Massachusetts Institute of Technology and Moriba Jah of the University of Texas–Austin

"An Integrated Assessment Model for Satellite Constellations and Orbital Debris," submitted by Akhil Rao of Middlebury College, Daniel Kaffine of the University of Colorado-Boulder, and Brian Weeden of the Secure World Foundation

"Communication and Space Debris: Connecting with Public Knowledges and Identities," submitted by Patrice Kohl, Sergio Alvarez, and Philip Metzger of the University of Central Florida

NASA's Office of Technology, Policy, and Strategy (OTPS) will make the teams' results publicly available on the agency's website. Selected teams also can work with the federal Organization for Economic Cooperation and Development as part of an international call for research proposals focused on orbital debris and space sustainability.

Find more information about NASA's OTPS at www.nasa.gov/offices/otps/home/.

NASA SELECTS PROPOSALS TO STUDY STELLAR EXPLOSIONS, GALAXIES, STARS

This image from NASA's Hubble Space Telescope features the spiral galaxy Mrk (Markarian) 1337, which is roughly 120 million light-years away from Earth in the constellation Virgo. Credit: ESA/Hubble and NASA, A. Riess et al.

NASA has selected four mission proposals submitted to the agency's Explorers Program for further study. The proposals include missions that would study exploding stars, distant clusters of galaxies, and nearby galaxies and stars.

Two Astrophysics Medium Explorer missions and two Explorer Missions of Opportunity have been selected to conduct mission concept studies. After detailed evaluation of those studies, NASA plans to select one Mission of Opportunity and one Medium Explorer in 2024 to proceed with implementation. The selected missions will be targeted for launch in 2027 and 2028, respectively.

NASA Explorer missions conduct focused scientific investigations and develop instruments that fill scientific gaps between the agency's larger space science missions. The proposals were competitively selected based on potential science value and feasibility of development plans.

The two Medium Explorer teams selected at this stage will each receive $3 million to conduct a nine-month mission concept study. Astrophysics Medium Explorer mission costs are capped at $300 million each, excluding the launch vehicle. The selected proposals are:

- UltraViolet EXplorer (UVEX)
- Survey and Time-domain Astrophysical Research Explorer (STAR-X)
- Moon Burst Energetics All-sky Monitor (MoonBEAM)
- A LargE Area burst Polarimeter (LEAP)

For more information about the selected proposals, visit www.nasa.gov/press-release/nasa-selects-proposals-to-study-stellar-explosions-galaxies-stars.

For more information about the Explorers Program, visit explorers.gsfc.nasa.gov.

NASA PURSUES ASTRONAUT LUNAR LANDERS FOR FUTURE ARTEMIS MOON MISSIONS

Artist's illustration of an Artemis astronaut stepping from a Moon lander onto the lunar surface. Credit: NASA.

NASA is seeking proposals for sustainable lunar lander development and demonstration as the agency works toward a regular cadence of Moon landings.

Under the solicitation, Human Landing System Sustaining Lunar Development, NASA has provided requirements for companies interested in developing and demonstrating astronaut Moon landers. These efforts will pave the way for multiple companies to provide recurring Moon landing services beyond the Artemis III mission, which is planned for no earlier than 2025.

Companies selected under this contract will be required to perform one uncrewed and one crewed lunar landing demonstration. NASA will certify any lander system to meet its requirements prior to the crewed demonstration mission(s).

The final call for proposals comes after NASA incorporated industry feedback on the draft solicitation, released March 31, encouraging companies to send comments to help shape a key component of the agency's human exploration Artemis architecture.

NASA's existing contract with SpaceX includes both an uncrewed and a crewed lunar landing demonstration that is part of the Artemis III mission, marking humanity's first return to the Moon in more than 50 years. The agency plans to exercise an option under this contract, known as Option B, asking the company to evolve its current Artemis III Starship Human Landing System design to meet an extended set of requirements for sustaining missions at the Moon and conduct another crewed demonstration landing.

These concurrent sustaining lander development efforts will meet NASA's needs for recurring, long-term access to the lunar surface, such as the ability to dock with the Gateway for crew transfer, accommodate an increased crew size, and deliver more mass to the surface.

Proposals for the sustainable lunar lander development and demonstration are due November 15, 2022.

For more information about this procurement, visit www.nasa.gov/nextstep/humanlander4.

NASA'S STAKEHOLDER COLLABORATIONS HELP INFORM MOON TO MARS PLANNING

Credit: NASA.

NASA released a revised version of its *Moon to Mars Objectives*, forming a blueprint for shaping exploration throughout the solar system. These guideposts in the agency's Moon to Mars exploration approach will help shape NASA's investments, as well as those of the agency's industry and international partners, toward the Moon and beyond.

Starting with 50 draft objectives developed by agency leaders across mission directorates earlier this year, NASA invited its workforce, the public, industry, and the agency's international partners to provide feedback and followed up with two workshops with industry and international partners to engage in further discussions.

The resulting revised 63 final objectives reflect a matured strategy for NASA and its partners to develop a blueprint for sustained human presence and exploration throughout the solar system. They cover four broad areas: science, transportation and habitation, lunar and martian infrastructure, and operations. The agency also added a set of recurring tenets to address common themes across objectives.

Under Artemis, NASA has set a vision to explore more of the Moon than ever before. With its Artemis I mission now on the launchpad, the agency plans to return humans to the Moon and establish a cadence of missions including at the lunar south polar region. These missions set up a long-term presence to inform future exploration of farther destinations, including Mars.

The Artemis campaign represents the capabilities and operations needed to safely conduct deep space science and exploration missions at the Moon and is tightly coupled with Mars mission planning. Science is a top priority of the Artemis missions along with key exploration technology objectives.

Following a successful Artemis I launch, NASA plans to send the first humans back to orbit the Moon with Artemis II no earlier than 2024, and to the lunar surface no earlier than 2025 on the Artemis III mission. NASA will use elements of Artemis to test systems and concepts for the journey to and from Mars. The follow-on Mars campaign will remain connected to the agency's sustained presence on the lunar surface by using the Moon as a testbed.

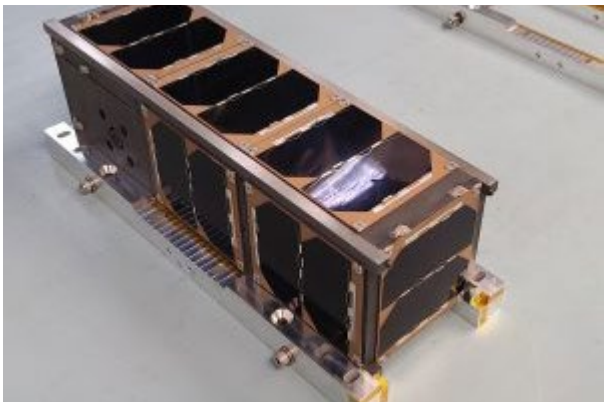
The final framework objectives are available online at go.nasa.gov/3BUkHGL.

NASA ANNOUNCES NEW CUBESAT LAUNCH INITIATIVE PARTNERSHIP OPPORTUNITIES

NASA has announced a new round of opportunities through the agency's CubeSat Launch Initiative (CSLI) for CubeSat developers, including educational institutions, to conduct scientific investigations and technology demonstrations in space and contribute to the agency's exploration goals.

"Small satellites such as CubeSats play a valuable role in the agency's educational, science, and technology investigations, including planetary exploration, Earth observation, and fundamental Earth and space science," said Bradley Smith, director of launch services within the Space Operations Mission Directorate at NASA Headquarters in Washington. "They are a cornerstone in the development of cutting-edge NASA technologies, such as laser communications, satellite-to-satellite communications, and autonomous movement."

With a renewed emphasis on education, the next round of NASA's CSLI opportunities is providing access to low-Earth



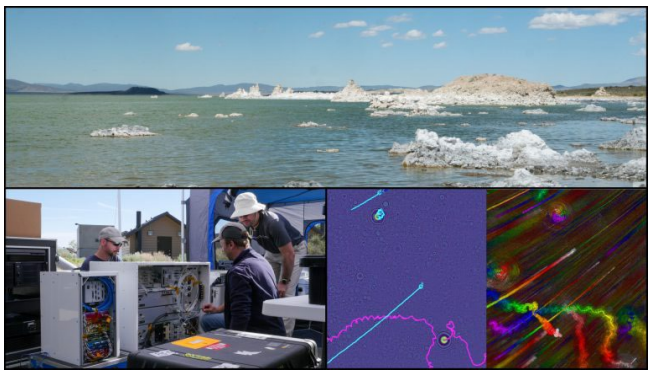
The GPX2 CubeSat is using commercial off-the-shelf differential global positioning systems (dGPS) to demonstrate autonomous, close-proximity operations for small satellites in orbit, such as flying in formation or docking. GPX2 was developed by NASA's Langley Research Center in Hampton, Virginia. Credit: NASA.

orbit for U.S. educational institutions, nonprofits with an education or outreach component, and NASA centers and programs for workforce development. Developers can gain hands-on experience designing, building, and operating these small research satellites.

Applicants must submit proposals by 4:30 p.m. EST, November 18, 2022. NASA anticipates making selections by March 17, 2023, for flight opportunities in 2024–2027, although selection does not guarantee a launch opportunity. Designs that include restrictive orbit requirements may limit launch opportunities and lead to later-than-desired launch dates. Applicants are responsible for funding the development of the small satellites.

CSLI is managed by NASA's Launch Services Program, based at the agency's Kennedy Space Center in Florida. For more information about NASA's CubeSat Launch Initiative, visit go.nasa.gov/CubeSat_initiative.

JPL DEVELOPING MORE TOOLS TO HELP SEARCH FOR LIFE IN DEEP SPACE



Counterclockwise from top: California's Mono Lake was the site of a field test for JPL's Ocean Worlds Life Surveyor. A suite of eight instruments designed to detect life in liquid samples from icy moons, OWLS can autonomously track lifelike movement in water flowing past its microscopes. Credit: NASA/JPL-Caltech.

Are we alone in the universe? An answer to that age-old question has seemed tantalizingly within reach since the discovery of ice-encrusted moons in our solar system with potentially habitable subsurface oceans. But looking for evidence of life in a frigid sea hundreds of millions of miles away poses tremendous challenges. The science equipment used must be exquisitely complex yet capable of withstanding intense radiation and cryogenic temperatures. What's more, the instruments must be able to take diverse, independent, complementary measurements that together could produce scientifically defensible proof of life.

To address some of the difficulties that future life-detection missions might encounter, a team at NASA's Jet Propulsion Laboratory (JPL) has developed OWLS, a powerful suite of science instruments unlike any other. Short for Oceans Worlds Life Surveyor, OWLS is designed to ingest and analyze liquid samples. It features eight instruments — all automated — that, in a lab on Earth, would require the work of several dozen people.

A key difficulty the OWLS team faced was how to process liquid samples in space. On Earth, scientists can rely on gravity, a reasonable lab temperature, and air pressure to keep samples in place, but those conditions don't exist on a spacecraft hurtling through the solar system or on the surface of a frozen moon. The team designed two instruments that can extract a liquid sample and process it in the conditions of space.

Since it's not clear what form life might take on an ocean world, OWLS also needed to include the broadest possible array of instruments, capable of measuring a size range from single molecules to microorganisms. To that end, the project joined two subsystems: one that employs a variety of chemical analysis techniques using multiple instruments and one with several microscopes to examine visual clues.

For more about JPL's OWLS project, go to www.jpl.nasa.gov/go/owls.

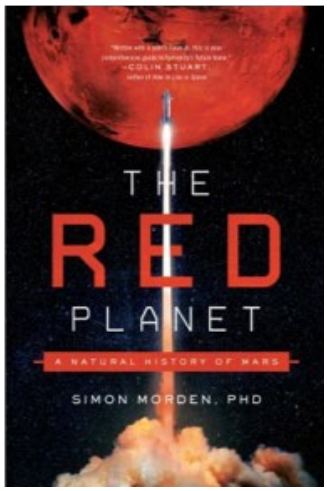
NEW AND NOTEWORTHY

FIRE AND ICE: The Volcanoes of the Solar System

By Natalie Starkey

Bloomsbury Sigma, 2021, 320 pp., Hardcover. $28.00. www.bloomsbury.com

The volcano is among the most familiar and perhaps the most terrifying of all geological phenomena. However, Earth isn't the only planet to harbor volcanoes. In fact, the solar system, and probably the entire universe, is littered with them. Our own Moon, which is now a dormant piece of rock, had lava flowing across its surface billions of years ago, while Mars can be credited with the largest volcano in the solar system, Olympus Mons, which stands 25 kilometers (15 miles) high. While Mars' volcanoes are long dead, volcanic activity continues in almost every other corner of the solar system, in the most unexpected of locations. We tend to think of Earth's volcanoes as erupting hot, molten lava and emitting huge, billowing clouds of incandescent ash. However, it isn't necessarily the same across the rest of the solar system. Some volcanoes aren't even particularly hot. Those on Pluto erupt an icy slush of substances such as water, methane, nitrogen or ammonia that freeze to form ice mountains as hard as rock, while others, like the volcanoes on Jupiter's moon Io, erupt the hottest lavas in the solar system onto a surface covered in a frosty coating of sulfur. Whether they are formed of fire or ice, volcanoes are of huge importance for scientists trying to picture the inner workings of a planet or moon. Volcanoes dredge up materials from the otherwise inaccessible depths and helpfully deliver them to the surface. The way in which they erupt and the products they generate can even help scientists ponder bigger questions on the possibility of life elsewhere in the solar system. *Fire and Ice* is an exploration of the solar system's volcanoes, from the highest peaks of Mars to the intensely inhospitable surface of Venus and the red-hot summits of Io, to the coldest, seemingly dormant icy carapaces of Enceladus and Europa. This book provides an unusual look at how these cosmic features are made and whether such active planetary systems might host life.



THE RED PLANET: A Natural History of Mars

By Simon Morden

Pegasus Books, 2022, 256 pp., Hardcover. $26.95. www.pegasusbooks.com

The history of Mars is drawn not just on its surface, but also down into its broken bedrock and up into its frigid air. Most of all, it stretches back into deep time, where the trackways of the past have been obliterated and there is no discernible trace of where they started from or how they traveled, only where they ended up. From the planet's formation 4.5 billion years ago, through eras that featured cataclysmic meteor strikes, explosive volcanoes, and a vast ocean that spanned the entire upper hemisphere, to the long, frozen ages that saw its atmosphere steadily thinning and leaking away into space, planetary geologist and author Dr. Simon Morden presents a tantalizing vision of our nearest neighbor, its dramatic history, and its astonishing present.

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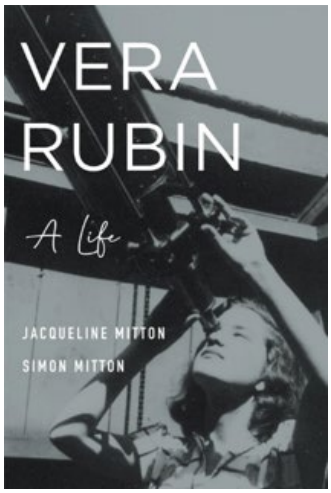
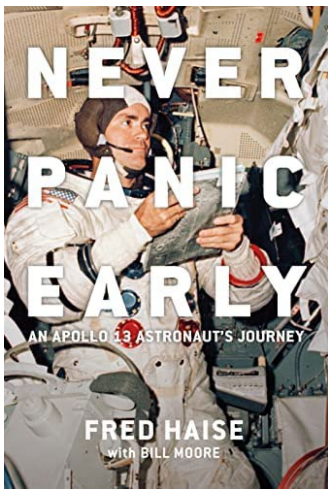


VERA RUBIN: A Life

By Jacqueline Mitton and Simon Mitton

Harvard University Press, 2021, 320 pp., Hardcover. $29.95. www.hup.harvard.edu

One of the great lingering mysteries of the universe is dark matter. Scientists are not sure what it is, but most believe it's out there, and in abundance. The astronomer who finally convinced many of them was Vera Rubin. When Rubin died in 2016, she was regarded as one of the most influential astronomers of her era. Her research on the rotation of spiral galaxies was groundbreaking, and her observations contributed significantly to the confirmation of dark matter, a most notable achievement. In *Vera Rubin: A Life*, prolific science writers Jacqueline Mitton and Simon Mitton provide a detailed, accessible overview of Rubin's work, showing how she leveraged immense curiosity, profound intelligence, and novel technologies to help transform our understanding of the cosmos. But Rubin's impact was not limited to her contributions to scientific knowledge. She also helped to transform scientific practice by promoting the careers of women researchers. Not content to be an inspiration, Rubin was a mentor and a champion. She advocated for hiring women faculty, inviting women speakers to major conferences, and honoring women with awards that were historically the exclusive province of men. Rubin's papers and correspondence yield vivid insights into her life and work, as she faced down gender discrimination and met the demands of family and research throughout a long and influential career. Deftly written, with both scientific experts and general readers in mind, *Vera Rubin* is a portrait of a woman with insatiable curiosity about the universe who never stopped asking questions and encouraging other women to do the same.

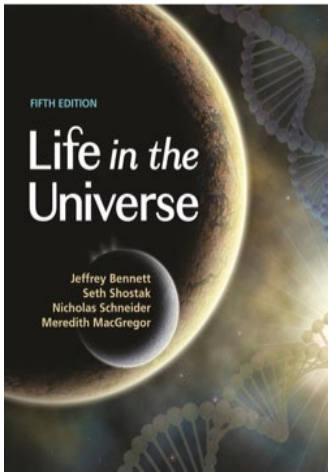


NEVER PANIC EARLY: An Apollo 13 Astronaut's Journey

By Fred Haise and Bill Moore

Smithsonian Books, 2022, 216 pp., Hardcover. $29.95. www.smithsonianbooks.com

In the gripping *Never Panic Early*, Fred Haise, Lunar Module Pilot for Apollo 13, offers a detailed firsthand account of when disaster struck three days into his mission to the Moon. An oxygen tank exploded, a crewmate uttered the now iconic words, "Houston, we've had a problem here," and the world anxiously watched as one of history's most incredible rescue missions unfolded. Haise brings readers into the heart of his experience on the challenging mission — considered NASA's finest hour — and reflects on his life and career as an Apollo astronaut. In this personal and illuminating memoir, illustrated with black-and-white photographs, Haise takes an introspective look at the thrills and triumphs, regrets and disappointments, and lessons that defined his career, including his years as a military fighter pilot and his successful 20-year NASA career that would have made him the sixth man on the Moon had Apollo 13 gone right. Many of his stories navigate fear, hope, and resilience, including when he crashed while ferrying a World War II air show aircraft and suffered second- and third-degree burns over 65% of his body, putting him in critical condition for 10 days before making a heroic recovery. In *Never Panic Early*, Haise explores what it was like to work for NASA in its glory years and demonstrates a true ability to deal with the unexpected.

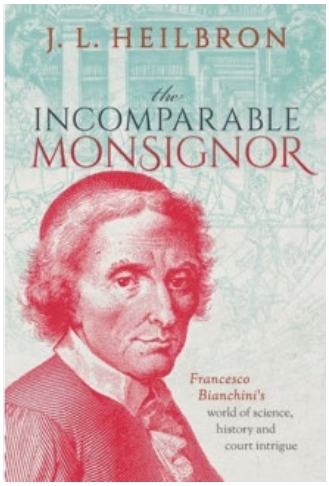


LIFE IN THE UNIVERSE, FIFTH EDITION

By Jeffrey Bennett, Seth Shostak, Nicholas Schneider, and Meredith MacGregor

Princeton University Press, 2022, 544 pp., Paperback. $100.00. press.princeton.edu

Are we alone in the cosmos? How are scientists seeking signs of life beyond our home planet? Could we colonize other planets, moons, or even other star systems? This introductory textbook, written by a team of four renowned science communicators, educators, and researchers, tells the amazing story of how modern science is seeking the answers to these and other fascinating questions. They are the questions that are at the heart of the highly interdisciplinary field of astrobiology, the study of life in the universe. Written in an accessible, conversational style for anyone intrigued by the possibilities of life in the solar system and beyond, *Life in the Universe* is an ideal place to start learning about the latest discoveries and unsolved mysteries in the field. From the most recent missions to Saturn's moons and our neighboring planet Mars to revolutionary discoveries of thousands of exoplanets, from the puzzle of life's beginning on Earth to the latest efforts in the search for intelligent life elsewhere, this book captures the imagination and enriches the reader's understanding of how astronomers, planetary scientists, biologists, and other scientists make progress at the cutting edge of this dynamic field. Enriched with a wealth of engaging features, this textbook brings any citizen of the cosmos up to speed with the scientific quest to discover whether we are alone or part of a universe full of life.

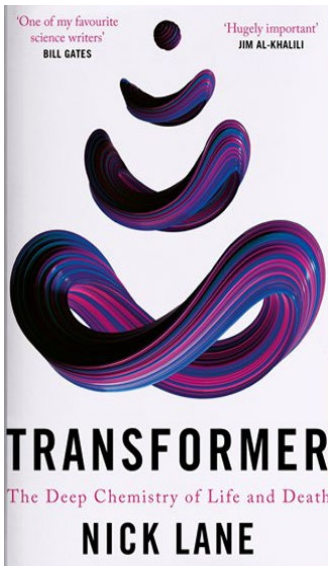


THE INCOMPARABLE MONSIGNOR: Francesco Bianchini's World of Science, History, and Court Intrigue

By J. L. Heilbron

Oxford University Press, 2022, 336 pp., Hardcover. $27.95. global.oup.com

By the time Francesco Bianchini died in 1729 at the age of 67, he had become known as the greatest Italian of this time. But just who was he, and how did he come to master the mathematical and historical sciences, the arts of diplomacy and dissimulation, and the patronage system that brought him into the company of popes and princesses? Author John Heilbron draws on an extensive archive of material to tell us his fascinating story. Bianchini was admired for his many accomplishments, which included writing a universal history from the creation to the fall of Assyria; recovering ancient calendars; discovering, excavating, and interpreting ancient buildings; designing a papal collection of antiquities later partially realized in the Vatican museums; undertaking a geodetic mapping of the papal states; confirming and publicizing Newton's theories of light and color; discovering several comets and a few variable stars; building the most beautiful astronomical instrument, and the most exact solar observatory in the world, detecting the slow decline in the obliquity of the ecliptic and almost discovering the aberration of starlight; and creating a map of non-existent features on the invisible surface of Venus. His international reputation earned him election as a foreign associate (one of only eight) of the Academie royale des sciences of Paris and as a fellow of the Royal Society of London (chosen on Newton's nomination). As a trusted servant of Pope Clement XI, he helped execute the delicate balancing the papacy practiced during the War of the Spanish Succession with one of his assignments resulting in attachment to the cause and person of the Old Pretender, James III, the Stuart claimant to the throne of England, Scotland, and Ireland. Engaging and highly readable, this is a history of not only an extraordinary individual but also a slice of the science, art, and courtly intrigue of the 18th century.

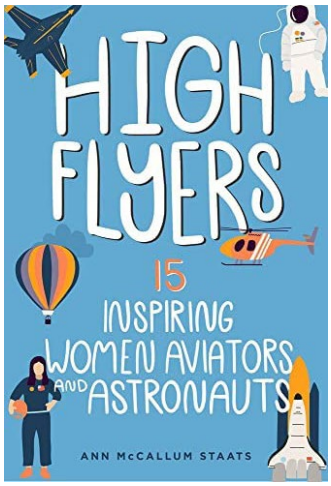


TRANSFORMER: The Deep Chemistry of Life and Death

By Nick Lane

W. W. Norton & Company, 2022, 400 pp., Hardcover. $30.00. www.wwnorton.com

What brings the Earth to life, and our own lives to an end? For decades, biology has been dominated by the study of genetic information, but that is only part of what makes us alive. Our inheritance also includes our living metabolic network, a flame passed from generation to generation, right back to the origin of life. In *Transformer*, biochemist Nick Lane reveals a scientific renaissance that is hiding in plain sight – how the same simple chemistry gives rise to life and causes our demise. Lane is among the vanguard of researchers asking why the Krebs cycle, the "perfect circle" at the heart of metabolism, remains so elusive more than 80 years after its discovery. *Transformer* is Lane's voyage, as a biochemist, to find the inner meaning of the Krebs cycle – and iats reverse – why it is still spinning at the heart of life and death today. Lane reveals the beautiful, violent world within our cells, where hydrogen atoms are stripped from the carbon skeletons of food and fed to the ravenous beast of oxygen. Yet this same cycle, spinning in reverse, also created the chemical building blocks that enabled the emergence of life on our planet. Now it does both. How can the same pathway create and destroy? What might our study of the Krebs cycle teach us about the mysteries of aging and the hardest problem of all, consciousness? *Transformer* unites the story of our planet with the story of our cells – what makes us the way we are, and how it connects us to the origin of life. Enlivened by Lane's talent for distilling and humanizing complex research, this book offers an essential read for anyone fascinated by biology's great mysteries. Life is at root a chemical phenomenon: this is its deep logic.

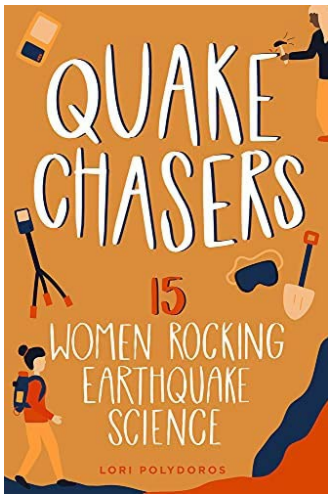


HIGH FLYERS: 15 Inspiring Women Aviators and Astronauts

By Ann McCallum Staats

Chicago Review Press, 2022, 224 pp., Hardcover. $16.99. www.chicagoreviewpress.com

These 15 women fly outside the lines. Soar beside Black Hawk helicopter pilot turned politician Tammy Duckworth, hot air balloonist Edgora McEwan, or medevac pilot Dede Murawsky. Higher up, meet commercial and military aviators such as the Coast Guard's Ronaqua Russell, the first African American female to receive the prestigious Air Medal for her rescue efforts during Hurricane Harvey. Next, ride along with Tammie Jo Shults, whose story includes a harrowing catastrophic engine failure while in command of 148 people onboard Southwest's Flight 1380. Others share their experiences in military high-performance jets, the Stratotanker, or while flying for the Blue Angels. Reaching past the bounds of Earth are astronauts who have launched in the cramped Russian rocket, the Soyuz, orbited Earth while conducting critical science experiments, or lived onboard the International Space Station. In all cases, the women in this book faced obstacles. Throughout their rise to incredible accomplishment, these courageous go-getters persevered and endured, insisting on success. Ultimately, each succeeded on her path to flight. These diverse high-flyers are dreamers and doers who believed, despite the odds, that soaring is possible. This book is part of the Women of Power series, a timely, inclusive, international modern biography collection that profiles diverse, modern women who are changing the world in their fields while empowering others to follow their dreams.

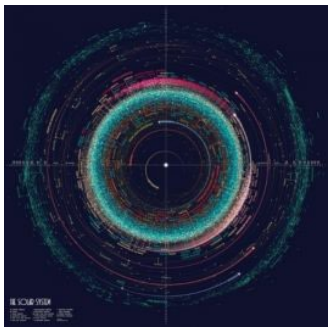


QUAKE CHASERS: 15 Women Rocking Earthquake Science

By Lori Polydoros

Chicago Review Press, 2022, 224 pp., Hardcover. $16.99. www.chicagoreviewpress.com

Sharing perspectives on their journeys into the physical sciences, these 15 heroes provide readers with advice about overcoming adversity. This book explores the lives of 15 diverse, contemporary female scientists with a variety of specialties related to earthquake science. Dr. Debbie Weiser travels to communities after earthquake disasters to evaluate earthquake damage in ways that might help save lives during the next Big One. Geologist Edith Carolina Rojas climbs to the top of volcanoes or searches barren deserts for volcanic evidence to measure seismic activity. Geophysicist Lori Dengler works with governments to provide guidance and protection against future tsunamis. With tenacity, intellect, and innovation, these women have crushed obstacles in society, in the lab, and out in the field. Their accomplishments leave aftershocks as they work toward revealing answers to the many riddles that lie behind earthquakes, saving lives by teaching us how to prepare for these terrifying disasters. Young scientists can take away inspiration and advice on following their own dreams like these inspiring women. This book is part of the Women of Power series, a timely, inclusive, international modern biography collection that profiles diverse, modern women who are changing the world in their fields while empowering others to follow their dreams.



ASTEROID MAP OF THE SOLAR SYSTEM

Designed by Eleanor Lutz

84.3 centimeters × 84.3 centimeters (33.2 inches × 33.2 inches). $35.20. www.redbubble.com/people/EleanorLutz/shop

This map shows the orbit paths of about 18,000 asteroids, comets, and planets in the solar system — everything larger than 10 kilometers (6 miles) in diameter. It's scientifically accurate, colorful, and the perfect choice for your next interplanetary adventure. Printed on 185-grams (6.5-ounces)-per-square-meter semi-gloss paper and custom-cut, this map is available in a variety of sizes and includes a 5-millimeter (3/16-inch) white border to assist in framing.

EXPLORE THE PLANETS

By Carly Madden

Happy Yak, 2022, 18 pp., Hardcover. $13.99. www.quarto.com

In this charming and innovative layered board book from the Adventures of Evie and Juno series, Evie and her pet dog Evie visit all the planets, one by one, and tell readers what they found there. Watch them skateboard on bumpy Mercury, do a spot of hoovering on dusty Mars, and hula-hoop around Saturn. Humorous text and bold, quirky illustrations introduce each of the eight planets. Curved and layered board pages increase in size as you move through the book, developing a child's hand-eye coordination as they turn the pages. The final spread shows all of the planets together in order from the Sun. Fun facts coupled with engaging artwork boost preschoolers' imagination and spark an interest in the world around them. This bright, layered board book provides a great first introduction to the solar system. For ages 2–5.

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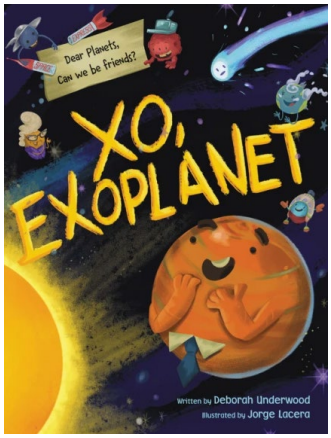


XO, EXOPLANET

By Deborah Underwood

Little, Brown Books for Young Readers, 2021, 40 pp., Hardcover. $17.99. www.lbyr.com

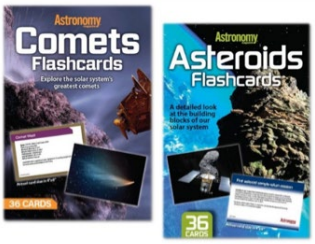
From bestselling author Deborah Underwood comes a lively and heartwarming letter-writing exchange between the planets in outer space to show the power of perspective. It was an ordinary day for Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto, the dwarf planet. The planets were circling the Sun, staring into space, until suddenly they spot something. What could it be? Who could it be? The planets have no idea but they're circling to find out. Whatever it is, that something is most definitely, absolutely, without a doubt NOT a planet. So begins an out-of-this-world pen pal exchange between the planets and an exoplanet. Paired with vibrant illustrations from Jorge Lacera, this STEM-friendly story, told mainly through letters, reminds readers what happens when we consider another person's point of view. For ages 4–8.

SOLAR SYSTEM PUZZLE

Developed for Astronomy Magazine

$27.99. myscienceshop.com

This circular solar system puzzle includes solid wood tokens representing each of the eight planets, a light-up LED Sun, and a two-sided poster with all the planet names. This award-winning educational puzzle from Hape, an industry-leading creator of wooden toys, is designed to help children learn through play. With 102 brightly colored pieces — large enough for little fingers to easily handle — this puzzle comes together to form a kid-friendly illustration of the solar system. After assembling, position the wooden planets to match their locations on the puzzle and light up the glowing LED Sun. For ages 5 and up.



COMETS AND ASTEROIDS FLASHCARDS SETS

Developed for Astronomy Magazine

$19.99. myscienceshop.com

Explore comets and asteroids with these flashcard sets exclusively from *Astronomy* magazine. Blazing trails through our solar system, these intriguing objects orbit the Sun and were formed billions of years ago. These unique flashcard sets dive into the details with 36 cards in each set. Each of the 10-centimeter (4-inch) × 15-centimeter (6-inch) cards features interesting facts, amazing details, and stunning photos of various comets and asteroids.

CALENDAR

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

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

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

Dr. Paul Schenk,
Scientific Editor (schenk@lpi.usra.edu)

Renée Dotson,
Production Editor (rdotson@lpi.usra.edu)

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

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