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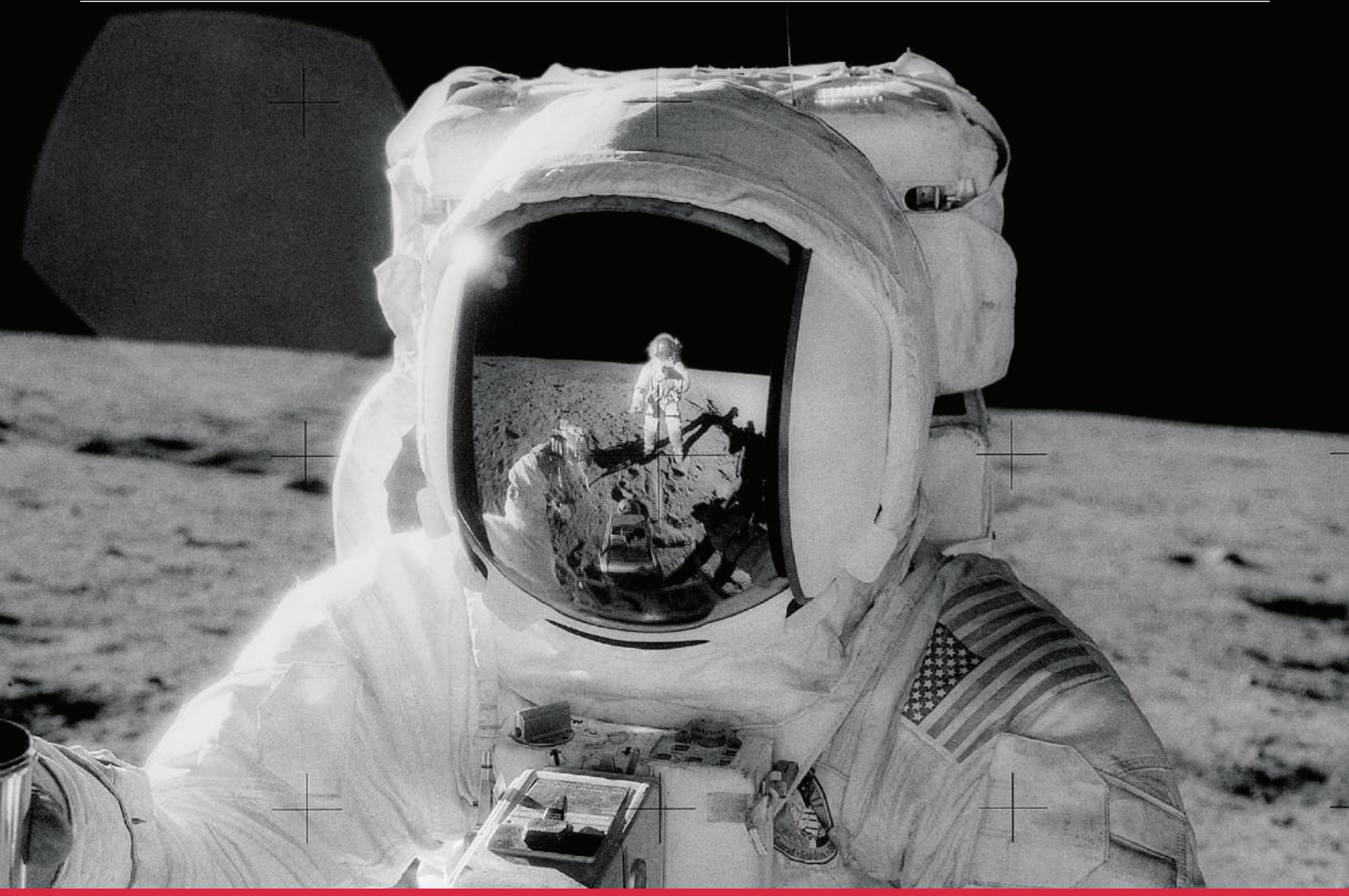

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BACK TO THE FUTURE: Linking Apollo and Artemis Generations of Lunar Explorers with Special Samples from the Moon

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Introduction

Over a period of only 41 months from July 16, 1969, to December 19, 1972, six human missions landed on the Moon as part of the Apollo program. During this very short period, human activity and capability expanded for each mission on the lunar surface. For example, during Apollo 11 astronauts carried out one extravehicular activity (EVA) that lasted approximately 2.5 hours during which they traveled approximately 165 meters (540 feet) away from the Lunar Module (a total distance traveled of 610 meters, or 2000 feet). A short 40 months later, Apollo 17 astronauts carried out three EVAs that lasted approximately 22 hours during which they traveled 10 kilometers (6 miles) away from the Lunar Module (for a total of more than 35 kilometers, or 22 miles). Enabled by the evolving surface capabilities, the sampling of the lunar surface dramatically evolved in capacity and complexity. Twenty-one and a half kilograms (47.5 pounds) of samples were collected during the Apollo 11 mission, whereas Apollo 17 collected 111 kilograms (244 pounds) of samples. In total the Apollo program returned 381 kilograms (840 pounds) of samples from the Moon's surface. The Apollo samples were collected in different manners and stored in several types of innovative containers. The sophistication of lunar sampling continued to evolve during the program. Following Apollo 17, humans have never again returned to the lunar surface.

The Apollo legacy continued over the last 50 years with the samples that were returned. The analyses of these samples provided fundamental insights into the origin and history of the Earth-Moon system and how planets and even solar systems work. The samples have provided ground truth for every post-Apollo mission to the Moon for the interpretation of remotely sensed data. After 50 years of analyses and study, our sophistication for handling and examining samples has greatly increased. Some samples that were collected and preserved in

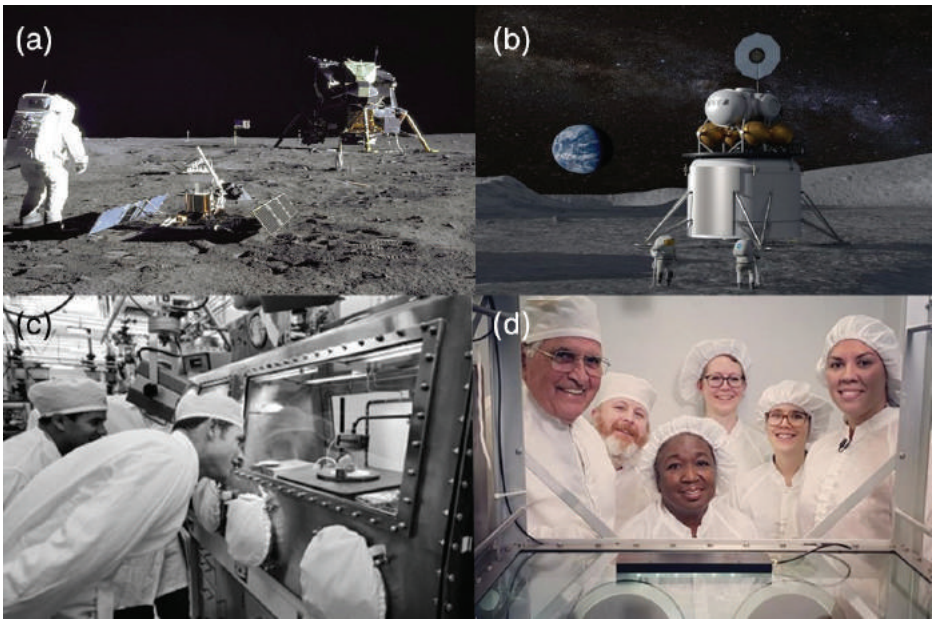


Fig. 1. The ANGSA initiative links the Apollo program to the Artemis program. (a) Apollo on the surface of the Moon. (b) Illustration of a potential design of an Artemis lander on the Moon's surface. (c) Examination of the newly returned Apollo samples by curation staff at the Lunar Receiving Laboratory at the Manned Spacecraft Center in Houston. (d) Members of the Apollo and Artemis teams examining the newly opened Apollo samples at the Lunar Sample Laboratory Facility at the Johnson Space Center.

Fig. 2. The Core Sample Vacuum Container (CSVC) provided a receptacle for a 4-centimeter-diameter (1.6-inch-diameter) drive tube so its sample of subsurface lunar regolith could be returned to Earth without exposure to terrestrial atmosphere or spacecraft cabin gases. The CSVC was a derivative of the Special Environmental Sample Container (SESC), elongated to accommodate the drive tube. The twist-on cap was comprised of a knife-edge indium seal. One drive tube core sample was sealed in a CSVC on Apollo 16 and one on Apollo 17.

special containers or represented unique lunar environments remain unexamined by standard or advanced analytical approaches. The Apollo Next Generation Sample Analysis (ANGSA) initiative was designed to examine a subset of these special samples. The ANGSA consortium consists of nine original teams funded by NASA plus international partners (e.g., the European Space Agency, or ESA). The initiative was purposely designed to function as a new sample return mission with processing, preliminary examination, and analyses utilizing new and improved technologies and recent mission observations. The ANGSA initiative links the first generation of lunar explorers who participated in the Apollo program with future explorers of the Moon during the Artemis program (Fig. 1).

Apollo Program Special Samples

With great foresight, Apollo mission planners and sample scientists devised sample collection, containment, and preservation approaches that more rigorously attempted to capture delicate and potentially transitory characteristics of lunar samples that were disturbed or lost during standard sample collection, curation, and handling. Very early on in the Apollo program there was an overarching philosophy of preserving samples for future generations. This philosophy has continued for the last 50 years.

The teams involved in the ANGSA initiative are examining three distinct types of special samples: (1) Apollo 17 (A-17) double drive tube, consisting of an unopened vacuum-sealed core sample (73001; Core Sample Vacuum Container, or CSVC) and its unsealed but unstudied companion core (73002); (2) drill core and shadowed samples that were placed in cold storage approximately one month after their return in the early 1970s; and (3) Apollo 15 Special Environmental Sample Container (SESC) samples opened in an organically clean helium cabinet and continuously stored in helium.

In many cases, the purpose of samples placed in sealed containers was to protect characteristics that could be modified by interactions with spacecraft cabin conditions, Earth's environment, or agitation of regolith samples. A total of nine containers of lunar samples were sealed on the lunar surface and transported to Earth during the Apollo program. The Gas Sample Containers (GSC), SESC, and CSVC have knife-edge-indium seals (Fig. 2). Current unopened samples include two CSVCs (69001 and 73001) and an SESC (15014). For the CSVC used during the Apollo 16 and 17 missions, aluminum drive tube cores were sealed with Teflon caps and immediately placed in the CSVC on the lunar surface. Upon return to the Lunar Receiving Laboratory each CSVC was placed in an additional vacuum container. The vacuum containers were placed in Teflon bags and stored in the Lunar Laboratory Pristine Sample Vault. These three unopened samples combined contain 1.7 kilograms (3.7 pounds) of unstudied and possibly pristine lunar material. This exceeds the mass returned by all the robotic Soviet Luna missions and projected returned masses for many proposed NASA lunar robotic missions (e.g., MoonRise, Isochron). As such, each unopened sample should be treated as an individual lunar mission with science goals appropriate for the lunar environment they represent.

Sampling a Lunar Landslide with a Double Drive Core

The A-17 double drive tube samples 73001 and 73002 are targets for the ANGSA initiative. The double drive tube core penetrated a lunar landslide deposit in the Taurus-Littrow Valley. The light mantle landslide deposit is derived from the South Massif of the Taurus-Littrow Valley and extends onto the valley floor (Fig. 3). The deposit appears to represent multiple landslide events. One of the Apollo program science goals for this double drive tube was to sample potential gases derived from the Lee-Lincoln scarp and trapped within the overlying landslide deposit. The double drive tube was collected adjacent to Lara Crater at Station 3 during the second Apollo 17 EVA. Astronauts Eugene Cernan and Harrison Schmitt collected surface samples and collected the core by hammering the aluminum double drive tube into the deposit (Fig. 4). The total double drive

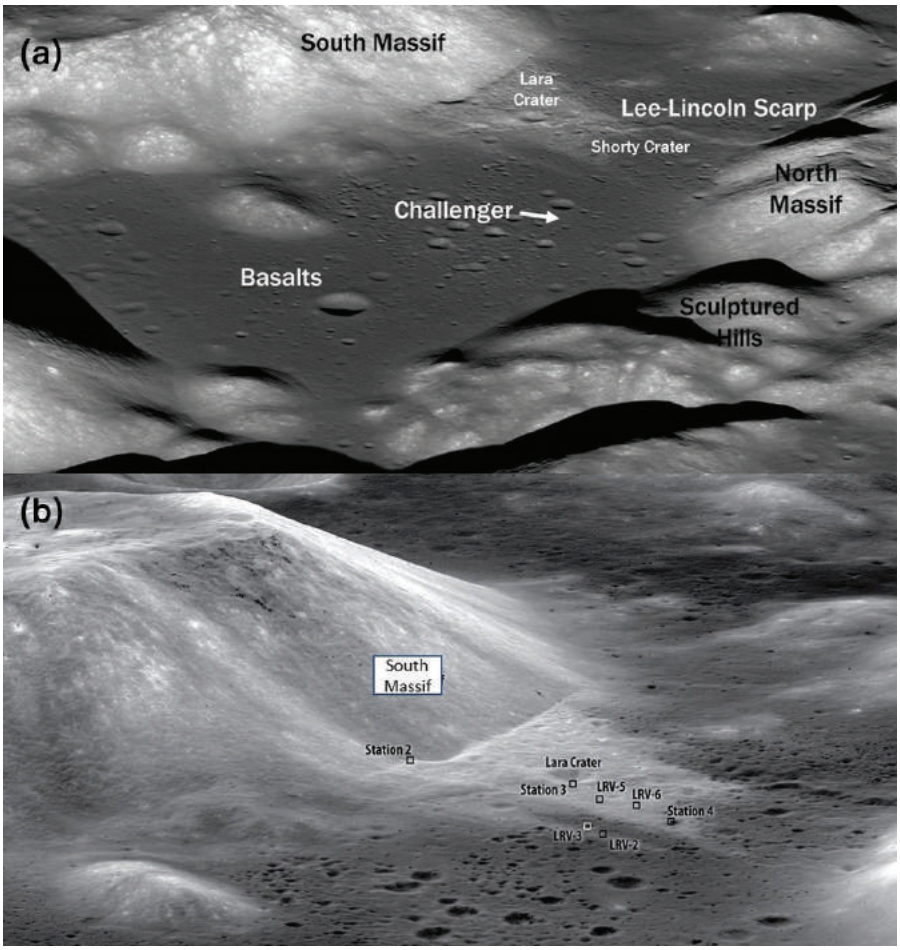


Fig. 3. (a) Lunar Reconnaissance Orbiter Camera (LROC) image of the Taurus Littrow Valley. The light mantle deposit flowing from the South Massif onto the mare basalt valley floor is situated near Lara Crater. Image also illustrates the location of the Lee-Lincoln Scarp, the North Massif, Sculptured Hills, Shorty Crater, and the Challenger landing site. (b) LROC image of the landslide deposits at the base of the South Massif. The locations of Lara Crater, Stations 2, 3, and 4, and Lunar Roving Vehicle (LRV) sampling sites are shown. Multiple landslide deposits are suggested from different intensities of albedo.

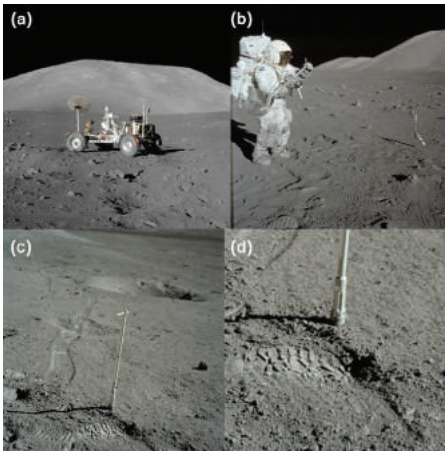


Fig. 4. Working on the landslide deposit at Station 3. (a) Double drive tube at Station 3 collected adjacent to rover. North Massif is in the background. (b) Apollo 17 crew member and ANGSA team member Harrison Schmitt collecting samples at Station 3. (c) Double drive tube was inserted into regolith to collect core samples 63001 and 63002. (d) Close-up of double drive tube tool.

tube core length was approximately 71 centimeters (28 inches) long with 73001 representing the deeper part of the core. At the time it was collected, the temperature at the bottom of the core was estimated to have been approximately 250°K with very limited temperature fluctuations. Sample 73001 was placed in a CSVC on the lunar surface and its upper companion core resided unexamined (until November 2019) in a sealed aluminum double drive tube.

In addition to these sealed samples, the ANGSA initiative will examine Apollo samples that were handled and curated using non-standard approaches (e.g., frozen, helium processing). Upon return, several A-17 sample splits for deep drill core 70001–70006, permanently shadowed soils (72320, 76240), soil (70180), and vesicular high-titanium basalt (71036) were permanently frozen at 253°K. Samples from an Apollo 15 SESC (15012/13) were removed from the SESC and processed in an organic clean space under helium atmosphere rather than nitrogen at the University of California Berkeley. They have been continuously stored in helium at the Johnson Space Center (JSC).

ANGSA Science and Engineering Goals

The ANGSA initiative has numerous investigations being pursued using the samples in the A-17 Station 3 double drive tube, frozen samples, and helium stored samples. Together, these samples leverage the uniqueness of sample containment (e.g., CSVC, SESC), geological setting (e.g., landslide, permanently shadowed areas), and curation processing (e.g., frozen for over 47 years, organic clean lab, helium curation). The following summarizes examples of ANGSA science and engineering goals.

Exploring volatile reservoirs and volatile cycles on the Moon

Over the last decade numerous studies and missions have pointed to a lunar volatile cycle with three principal components: primordial (interior) volatiles, surficial-formed volatiles (space-surface interactions), and polar (sequestered) volatiles. These reservoirs and their in situ resource utilization potential are important for the future human exploration of the Moon and beyond (e.g., Mars) within the aspirations of the Artemis program. Exploring the Moon and commercializing cis-lunar space by "living off of the land" versus bringing all consumable necessities from Earth has two dramatically different human exploration architectures, and therefore an understanding of the lunar volatile cycle has science, explo-

ration, and commercial importance.

Lunar regolith contains evidence for these various volatile reservoirs, their origins, and their interactions. The CSVC may better preserve weakly-bound volatiles and volatile coatings on mineral surfaces as well as limited contamination of lunar hydrogen species, xenon, lead isotopes, and organic compounds. The results of this integrated study of volatiles in lunar regolith and lithic clasts will shed light on (1) the concentration, distribution, and behavior of volatiles in the lunar regolith; (2) the role of volatiles in lunar processes; (3) whether volatiles from the lunar interior are released from fault systems; (4) the interactions among lunar volatile reservoirs; (5) the potential existence of pre-mare degassing events; (6) the noble and other gas composition of the solar wind as recorded on the Moon; (7) the indigenous noble gas content of the Moon; and (8) characteristics and origins of organic species in the lunar regolith. Many of these science goals will be fulfilled through observations made from a variety of scales from atomic to planetary.

Investigating the stratigraphy and chronology of lunar landslide deposits to refine our understanding of lunar surface processes

Establishing a stratigraphy for the double drive tube provides an important context for other data collected from the core. For example, where do volatiles reside, and how are they distributed in the stratigraphy of the regolith? Furthermore, understanding the stratigraphy and chronology of lunar landslide deposits provides scientifically valuable information to understand (1) the regolith evolution processes active in the upper portion of a lunar landslide deposit; (2) important variables (e.g., temperature, volatiles) and their role in lunar landslide events; (3) triggers and chronology (e.g., impact events, activity along lunar scarps) for lunar landslide events; (4) dynamics of a lunar landslide deposit; (5) properties of the regolith that are important for the concentration and retention of lunar volatiles; and (6) identification of exotic South Massif rocks represented in the regolith.

Preparing for the collection and preservation of volatile-rich samples for future exploration

Future lunar missions will emphasize the appraisal of lunar volatile reservoirs and their in situ resource utilization potential. In situ analyses will provide information concerning undisturbed volatile reservoirs prior to sampling. For both in situ measurements and sampling, methods need to be designed that are cleaner and simpler than used for Apollo, and that disturb the soil less drastically. These CSVC samples represent our best chance to evaluate these approaches and to inform future missions on requirements for in situ measurements. Furthermore, they will provide engineering guidance for the design of future collection, containment, storage, and processing of lunar and solar system volatiles.

As the two CSVCs that were collected during the Apollo program were never opened, and no records exist for proposed strategies for opening these containers, ANGSA scientists and engineers have formulated strategies for gas extraction and sample handling. They are in the process of designing and testing gas extraction tools. Tools consist of an apparatus to pierce the thin wall at the base of the CSVC and release into the piercing chamber any volatile component without contaminating the enclosed regolith, along with a manifold to measure pressure and collect volatiles from the piercing tool collection chamber.

Opening Lunar Treasures

Thus far, JSC curation and ANGSA preliminary examination teams have extracted and are dissecting/examining the upper core sample from the double drive tube (73002). Prior to extraction and processing, the core was imaged using X-ray computed microtomography (XCT) through its aluminum drive tube container, which was doubly bagged in Teflon containers. The core was extracted

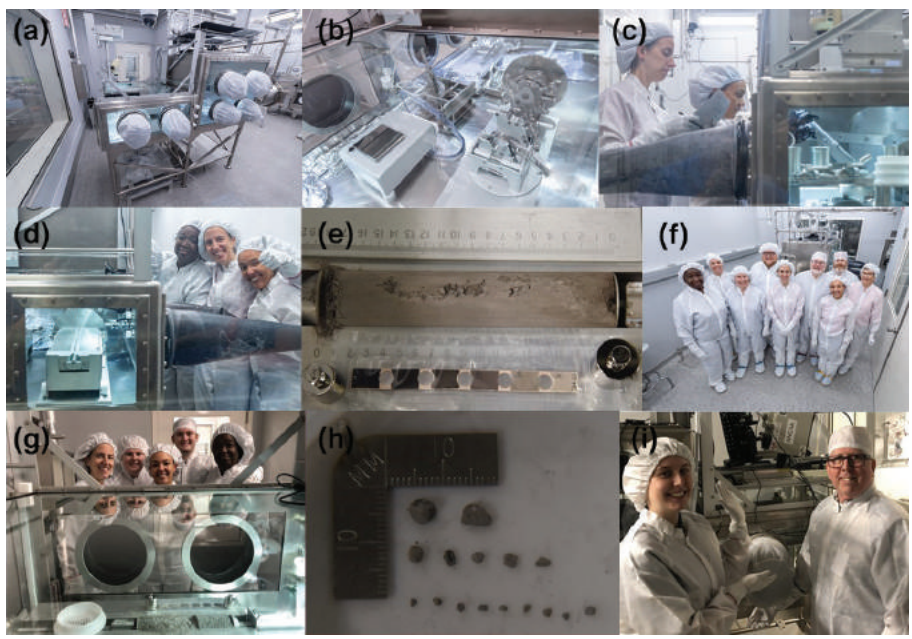


Fig. 5. Mosaic of preliminary examination team members and curators. (a) Core-processing glove box. (b) Core extraction tools. (c) Curation team in the middle of extracting the 73002 core. (d) ANGSA curation team following the successful extrusion of the 73002 core. (e) 73002 core prior to dissection. (f) ANGSA curation and science team members following core extrusion. (g) Curation and visiting preliminary examination teams. (h) >1-millimeter (>0.4-inch) lithic fragments sieved from one of the 0.5-centimeter (0.2-inch) core segments. (i) Multi-spectral analysis team making measurements on the extruded core.

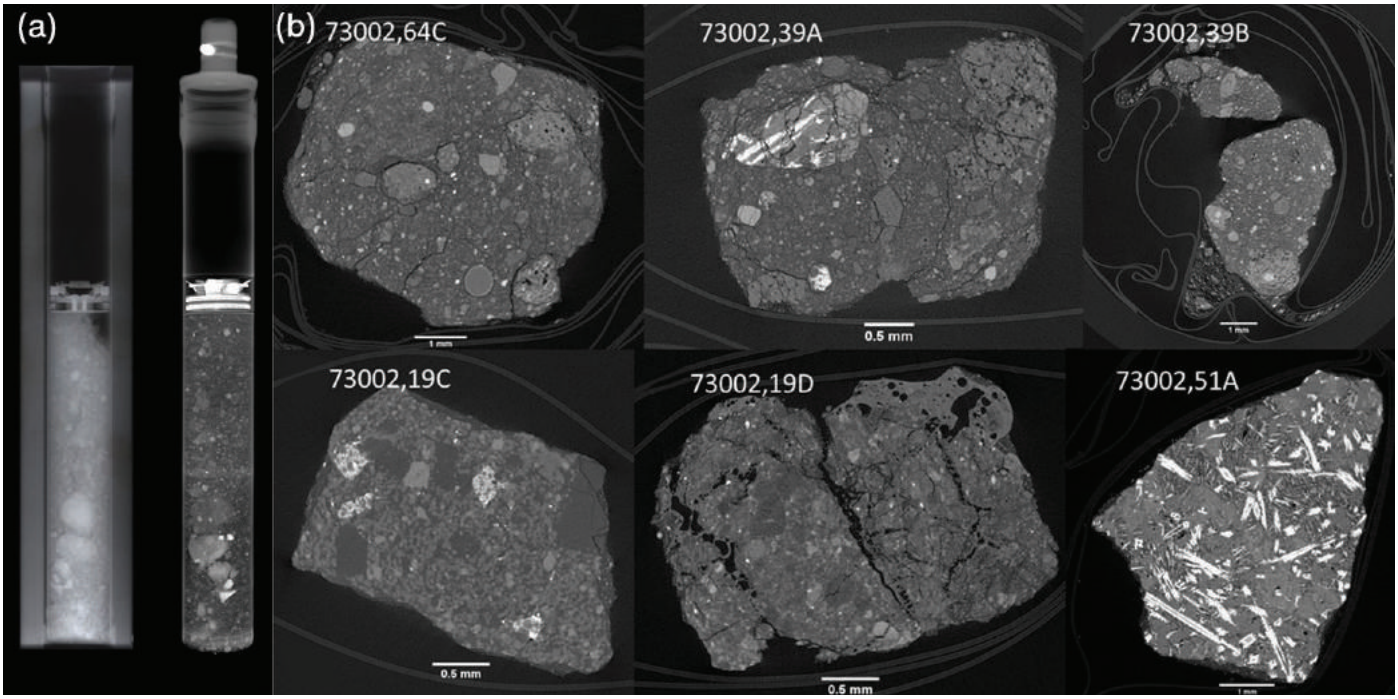


Fig. 6. (a) X-ray scan of sample 73002 taken in 1974 compared to X-ray computed microtomography scan of sample 73002 taken in 2019. (b) X-ray computed microtomography scans of lithic fragments (>1 millimeter, or >0.4 inches) sieved out of the regolith.

from the drive tube on November 5, 2019, in a dry nitrogen core processing glove box by a curation team consisting of Charis Krysher, Andrea Mosie, and Juliane Gross (Fig. 5a–e). Following extrusion, the core was derinded (outer surface removed) and subsamples were collected and analyzed for organics and hydrogen isotopes. Following the derinding step the core will be dissected in 0.5-centimeter (0.2-inch) sections on three different passes (horizontal levels parallel to the length of the core). The 0.5-centimeter subsamples in pass 1 and 2 will be sieved to separate lithic fragments greater than 1 millimeter (0.04 inches). Following pass 3 the remaining core will be encased in epoxy and used to make continuous thin sections to examine the core stratigraphy. During the core dissection of pass 1, ANGSA preliminary examination team members (Fig. 5g) described and photographed both the core and the >1-millimeter lithic fragments (Fig. 5h). During each pass the core will be imaged using a multi-spectral analyzer that examined wavelengths comparable to those collected by orbital instruments on the Lunar Reconnaissance Orbiter (LRO), Kaguya, and Chandrayaan-1 (Fig. 5i) orbital missions. As of March 1, 2020, the first pass of the core had been processed. The gas phase in the CSVC will be documented, extracted, and analyzed during the winter of 2020–2021. The CSVC core will be imaged and extruded during the same period.

Initial Results

An overarching philosophy of the first lunar sample scientists to preserve samples for future generations, advanced analytical approaches, and future missions has already been demonstrated to be astute based on just the initial results by the ANGSA team. Twenty-first-century lunar missions such as LRO, Kaguya, and Chandrayaan-1 have placed the core within the context of regional and planetary geology and new important lunar concepts (e.g., volatile cycles and reservoirs on airless bodies, fault scarps, in situ resource utilization). The participation of a new generation of lunar scientists in the preliminary examination of core sample 73002 has linked them to the Apollo generation and prepared them for Artemis.

Some of the first data derived from 73002 was from XCT imaging of the core and lithic fragments, preliminary examination descriptions, multi-spectral imaging of the core, and sample measurements that could potentially be disturbed by sample processing over a period of time (volatile organics and hydrogen and its isotopic composition). Figure 6a illustrates the significant difference in resolution and clarity of the computed microtomography image compared to an X-ray scan taken in 1974. In addition to this higher resolution and clarity, the XCT imaging has numerous other advantages. Many thousands of image slices can be made through the core, making it transparent. This imaging enables a better strategy for core dissection; provides texture, compositional, and mineralogical information for lithic and mineral fragments (Fig. 6b); and allows the construction of stratigraphy based on grain size analysis. A video of X-ray slices through the 73002 core can be viewed at https://www.nasa.gov/feature/nasa-opens-previously-unopened-apollo-sample-ahead-of-artemis-missions.

The team at the NASA Goddard Astrobiology Analytical Laboratory received one of the early subsamples from the base of the 73002 core. Their aim was to uncover the origin and distribution of amino acids and their volatile precursors in lunar samples, as well as curation effects on these compounds. In addition to this first core sample, they will examine amino acids and their volatile precursors from core samples from varying depths,

samples collected from shadowed and unshadowed environment on the lunar surface, samples stored in the CSVC (73001) versus the upper drive tube (73002), and samples stored frozen versus standard curation. The results on the upper drive tube core and witness plates will provide insights into handling and curation of the core sample in the CSVC.

> "Ultimately, these measurements and observations are linked to the Artemis program and the future of humans on the Moon"

The University of New Mexico stable isotope group received a sample from the upper portion of core sample 73002 for the measurement of hydrogen and its isotopic composition, chlorine isotopes, and oxygen isotopes. The isotopic composition of these elements provides a fingerprint of the sources for these volatile elements. For example, the hydrogen isotopic composition of the regolith identifies the contribution of hydrogen from the solar wind, lunar interior, cold traps, and potential terrestrial alteration. To eliminate the latter, these samples were processed in dry nitrogen gloveboxes at the JSC and the University of New Mexico and analyzed without the sample "seeing" any terrestrial hydrogen.

The University of Hawaii group brought a multispectral imager to the JSC lunar lab and carried out measurements on the core from outside the core processing cabinet. These measurements were made at a variety of wavelengths on analogous instruments on lunar orbital spacecrafts (LRO, Kaguya, and Chandrayaan-1). The measurements were designed to provide a variety of views of the core stratigraphy without terrestrial contamination.

The results of these initial analyses will be released during future science meetings (e.g., the 52nd Lunar and Planetary Conference, American Geophysical Union fall meeting, etc.).

Future

These are the first measurements made during this three-year ANGSA team study. Other team members with establish the chronology and stratigraphy of the landslide deposit to deduce the triggers for these events, identify the distribution and characteristics of lunar volatiles in the core at the nanometer scale, examine how volatile elements behave on the lunar surface using a battery of stable isotopes that are sensitive to lunar processes, and recognize new lunar samples that will further the understanding of the past and current Moon. Ultimately, these measurements and observations are linked to the Artemis program and the future of humans on the Moon. Are there resources that can support human science, exploration, and economic activities between Earth and the Moon, on the lunar surface, and beyond the Moon? How are these resources identified, sampled, and processed? The answers to these and other questions will provide the foundation for how humans will explore our solar system in the future.

FROM THE DESK OF LORI GLAZE

WE CAN PERSEVERE

Lori S. Glaze
Director, NASA's Planetary Science Division, April 2020

I am writing this in the midst of the COVID-19 outbreak and our ongoing "social distancing" efforts. Rather than focus on how the pandemic is affecting NASA's activities and the Planetary Science Division's work, I instead want to take this opportunity to pause for thought amidst the chaos.

It is by now obvious that 2020 is bringing an enormous and unprecedented level of upheaval in our lives. Many of us are suddenly trying to juggle our work alongside increased childcare and other responsibilities. Others are living alone, with extremely limited amounts of social contact. Many are grappling with our own health concerns or those of loved ones. All of us are dealing with life and death on a daily basis. Yet we are all aiming to continue our work and our research even in these most trying of times. And although we are attempting to maintain as much normalcy as possible, some of you may well be reexamining your priorities. Indeed, it might be fair to question the need for planetary science during this time of adversity. I hope, therefore, to offer some words of encouragement, courtesy of a very special 13-year old.

On March 5, we announced the winner of a nationwide competition to name the Mars 2020 rover. In all, more than 28,000 K–12 students from across the United States submitted essay entries. With more than 770,000 votes cast online by the public, the entries were first whittled down to 155 semifinalists, then to 9, and finally to the winning name: Perseverance. The name Perseverance was submitted by 13-year-old Alex Mather from Springfield, Virginia, a seventh grader at Lake Braddock Secondary. As I look back now at his winning essay, Alex's words and motivation were eerily prescient:

"We as humans evolved as creatures who could learn to adapt to any situation, no matter how harsh. We are a species of explorers, and we will meet many setbacks on the way to Mars. However, we can persevere. We, not as a nation, but as humans, will not give up. Even faced with bitter losses . . . the human race will always persevere into the future."

We are all learning to adapt to our current, harsh situation, but as humans and as explorers we are persevering on our

journey to Mars. Within the Planetary Science Division, and the Science Mission Directorate, launching Mars 2020 from Kennedy Space Center in July of this year remains a high priority. Although the vast majority of NASA's workforce is currently adapting to a full telework lifestyle, the engineers whose work is critical to maintaining the Mars 2020 schedule are continuing their efforts apace. The Jet Propulsion Laboratory, Kennedy Space Center, and our other partners are going to extraordinary means to ensure the health and safety of all personnel needed to complete the hands-on work. As the coronavirus situation progresses, we'll make adjustments as appropriate.

"With this mission as just one example of our community's strength, I know that we can persevere."

When asked, Alex explained that a trip two years ago to Space Camp in Alabama initially fueled his interest in space, and that he immediately knew that space was "something that I'm doing for the rest of my life." I think Alex's words are a timely reminder of the power of space and planetary science. In times of angst, such as those we are currently enduring, looking up and out to the cosmos is a salve that we all need. If nothing else, planetary science is the academic awareness that we on Earth are surrounded by something so much bigger.

So, if you're finding yourself questioning the motivation for your work, I urge you to take a breath. Take a moment. Put yourself back in the mind of the 13-year-old you once were. For me, watching the development of the space shuttle program was a pivotal point in my life's journey. What was that spark of inspiration that put you on the path to a career in planetary science? Remember that. Hold on to that.

And if merely reminding yourself of your original inspiration doesn't feel enough, and you want to *do* something to help, I urge you to share your expertise and your enthusiasm with the public – young and old. The NASA At Home website, for instance, is an incredible resource for bringing the universe into everybody's home. I hope that we can all find a way to connect virtually with the public – especially those students who have suddenly been ripped from their schools. Let's try to wash away some distress and perhaps spark a lifelong interest in space, or science for the next generation of chemists, doctors, epidemiologists, and more, upon whom our survival as a race will depend.

The year 2020, so far, is not turning out the way we had anticipated. I very much missed the gathering of our community at the Lunar and Planetary Science Conference that should have taken place a few weeks ago. There will be many more missed opportunities to catch up with friends, colleagues, and science over the coming months. Luckily, we are using the technological capabilities at our fingertips to mitigate many of these lost in-person connections. For many, however, 2020 will still feel like a year of mere grit. I hope, therefore, that the planned launch of Mars 2020 in July will serve as a moment of exhilaration for our community. With this mission as just one example of our community's strength, I know that we can persevere.

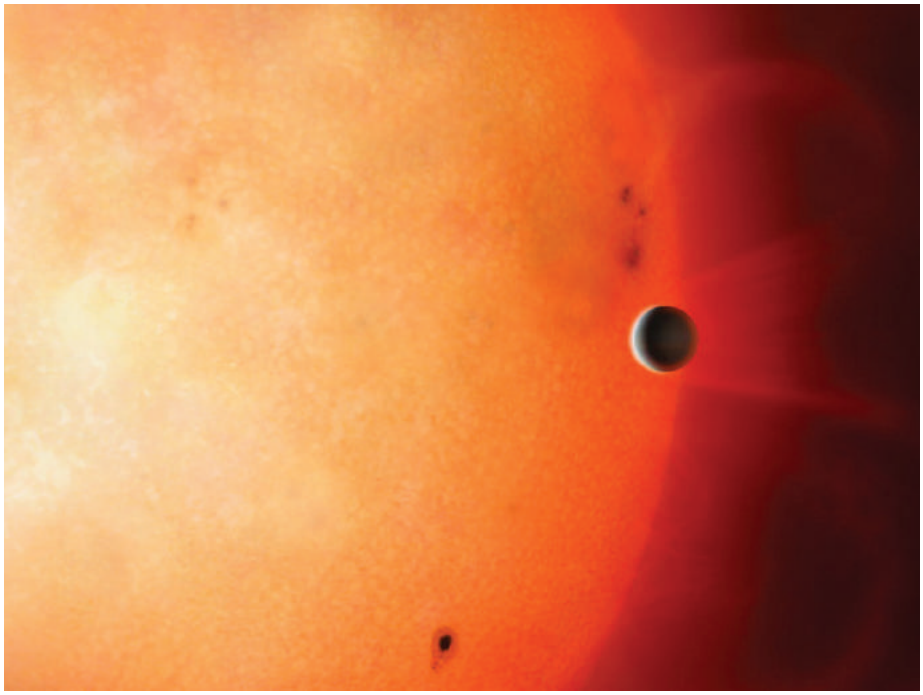
18-HOUR-YEAR PLANET ON THE EDGE OF DESTRUCTION

Astronomers from the University of Warwick have observed an exoplanet orbiting a star in just over 18 hours, the shortest orbital period ever observed for a planet of its type. It means that a single year for this hot Jupiter – a gas giant similar in size and composition to Jupiter in our own solar system – passes in less than one day of Earth time.

The discovery is detailed in a new paper published February 20 for the Monthly Notices of the Royal Astronomical Society, and the scientists believe that it may help to solve a mystery of whether or not such planets are in the process of spiraling toward their suns to their destruction.

The planet NGTS-10b was discovered around 1000 light-years away from Earth as part of the Next-Generation Transit Survey (NGTS), an exoplanet survey based in Chile that aims to discover planets down to the size of Neptune using the transit method. This involves observing stars for a telltale dip in brightness that indicates that a planet has passed in front of it.

At any one time the survey observes 100 square degrees of sky, which includes around 100,000 stars. Out of those 100,000 stars this one caught the astronomers' eye due to the very frequent dips in the star's light caused by the planet's rapid orbit. Lead author Dr. James McCormac from the University of Warwick Department of Physics said, "We're excited to announce the discovery of NGTS-10b, an extremely-short-period Jupiter-sized planet orbiting a star not too dissimilar from our Sun. We are also pleased that NGTS continues to push the boundaries in groundbased transiting exoplanet science through the discovery of rare classes of exoplanets.



Artist's impression of a hot Jupiter orbiting close to its star.
Credit: University of Warwick/Mark Garlick.

"Although in theory hot Jupiters with short orbital periods (less than 24 hours) are the easiest to detect due to their large size and frequent transits, they have proven to be extremely rare. Of the hundreds of hot Jupiters currently known there are only seven that have an orbital period of less than one day."

NGTS-10b orbits so rapidly because it is very close to its sun: only twice the diameter of the star, which, in the context of our solar system, would locate it 27 times closer than Mercury is to our own Sun. The scientists have noted that it is perilously close to the point that tidal forces from the star would eventually tear the planet apart.

The planet is likely tidally locked so one side of the planet is constantly facing the star and constantly hot – the astronomers estimate the average temperature to be more than 1000°C (1832°F). The star itself is around 70% the radius of our Sun and 1000° cooler. NGTS-10b is also an excellent candidate for atmospheric characterization with the upcoming James Webb Space Telescope.

Using transit photometry, the scientists know that the planet is 20% bigger than our Jupiter and just over twice the mass according to radial velocity measurements, caught at a convenient point in its lifecycle to help answer questions about the evolution of such planets. Massive planets typically form far away from the star and then migrate either through interactions with the disk while the planet is still forming, or from interactions with additional planets much further out later in their life. The astronomers plan to apply for time to get high-precision

measurements of NGTS-10b and to continue observing it over the next decade to determine whether this planet will remain in this orbit for some time to come — or will spiral into the star to its death.

Co-author Dr. David Brown said, "It's thought that these ultra-short planets migrate in from the outer reaches of their solar systems and are eventually consumed or disrupted by the star. We are either very lucky to catch them in this short-period orbit, or the processes by which the planet migrates into the star are less efficient than we imagine, in which case it can live in this configuration for a longer period of time."

Co-author Dr. Daniel Bayliss adds, "Over the next 10 years, it might be possible to see this planet spiraling in. We'll be able to use NGTS to monitor this over a decade. If we could see the orbital period start to decrease and the planet start to spiral in, that would tell us a lot about the structure of the planet that we don't know yet. Everything that we know about planet formation tells us that planets and stars form at the same time. The best model that we've got suggests that the star is about 10 billion years old and we'd assume that the planet is too. Either we are seeing it in the last stages of its life, or somehow it's able to live here longer than it should."

Portions of this article were provided by the University of Warwick.

NASA'S MARS PERSEVERANCE ROVER GETS ITS SAMPLE HANDLING SYSTEM

With the launch period for NASA's Mars Perseverance rover opening in just a few months, the six-wheeler is reaching significant pre-launch milestones almost daily at the Kennedy Space Center in Cape Canaveral, Florida. The rover had some components removed prior to being shipped from NASA's Jet Propulsion Laboratory in Southern California to the Cape in early February. In March, Perseverance's assembly, test, and launch operations team integrated two components that will play key roles in the acquisition, containment, and eventual return to Earth of humanity's first samples from another planet: the Adaptive Caching Assembly and the Bit Carousel.

The Bit Carousel contains the nine drill bits Perseverance will use to sample martian rock and dust. Attached to the top front of the rover on March 7 and resembling a flying saucer, it also is the gateway for the samples to move into the belly of the rover for assessment and processing by the Adaptive Caching System. Installed on March 3, the Adaptive Caching Assembly consists of 7 motors and more than 3000 parts, all working in unison to collect samples from the surface of Mars. A chief component of the assembly is the Sample Handling Arm, which will move sample tubes to the main robotic arm's coring drill and then transfer the filled sample tubes into a space to be sealed and stored. The installation and testing of the electrical wiring for both the Adaptive Caching Assembly and Bit Carousel were completed on March 11.

NASA's Mars 2020 rover, now called Perseverance, undergoes processing at a payload servicing facility at NASA's Kennedy Space Center on February 14, 2020. Credit: NASA.

"With the addition of the Adaptive Caching Assembly and Bit Carousel, the heart of our sample collection system is now onboard the rover," said Matt Wallace, deputy project manager of the Mars 2020 mission at NASA's Jet Propulsion Laboratory (JPL). "Our final but most crucial elements to install will be the sample tubes that will contain the first samples that will be brought from another planet back to Earth for analysis.

We will keep these pristine until we integrate them in a couple of months."

Currently, the coronavirus has not impacted the Mars Perseverance rover launch schedule. Launch preparations are continuing.

The Perseverance rover is a robotic scientist weighing just under 1043 kilograms (2300 pounds). It will search for signs of past microbial life, characterize Mars' climate and geology, collect samples for future return to Earth, and help pave the way for human exploration of the Red Planet. No matter what day Perseverance launches during the launch period, which extends from July 17 through August 5, it will alight on Mars' Jezero Crater just after 3:40 p.m. U.S. Eastern Standard Time on February 18, 2021.

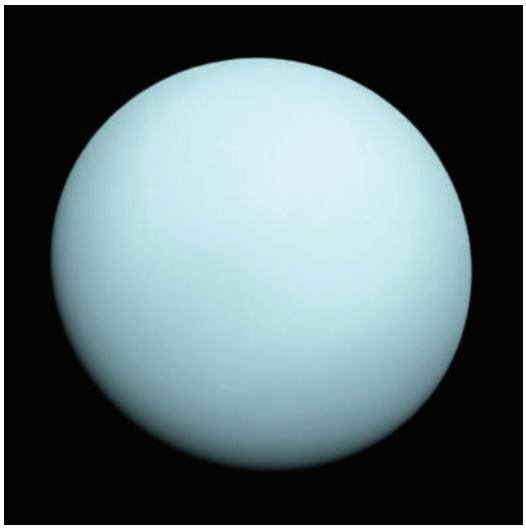
For more information about the mission, visit mars.nasa.gov/mars2020/.

REVISITING DECADES-OLD VOYAGER 2 DATA, SCIENTISTS FIND ONE MORE SECRET

Eight and a half years into its grand tour of the solar system, NASA's Voyager 2 spacecraft was ready for another encounter. It was January 24, 1986, and soon it would meet the mysterious seventh planet, icy-cold Uranus. Over the next few hours, Voyager 2 flew within 81,433 kilometers (50,600 miles) of Uranus' cloud tops, collecting data that revealed 2 new rings, 11 new moons, and temperatures below –214°C (–353°F). These data are still the only up-close measurements we have ever made of the planet.

Three decades later, scientists reinspecting that data found one more secret. Unbeknownst to the entire space physics community, 34 years ago Voyager 2 flew through a plasmoid, a giant magnetic bubble that may have been whisking Uranus' atmosphere out to space. The finding, reported in Geophysical Research Letters, raises new questions about the planet's one-of-a-kind magnetic environment.

Planetary atmospheres all over the solar system are leaking into space. Hydrogen springs from Venus to join the solar wind, the continuous stream of particles escaping the Sun. Jupiter and Saturn eject globs of their electrically charged air. Even Earth's atmosphere leaks. (Don't worry; it will stick around for another billion years or so.)



Voyager 2 took this image as it approached the planet Uranus on January 14, 1986. The planet's hazy bluish color is due to the methane in its atmosphere, which absorbs red wavelengths of light. Credit: NASA/JPL-Caltech.

The effects are tiny on human timescales, but given long enough, atmospheric escape can fundamentally alter a planet's fate. For a case in point, look at Mars.

"Mars used to be a wet planet with a thick atmosphere," said Gina DiBraccio, space physicist at NASA's Goddard Space Flight Center and project scientist for the Mars Atmosphere and Volatile Evolution (MAVEN) mission. "It evolved over time [4 billion years of leakage to space] to become the dry planet we see today."

Atmospheric escape is driven by a planet's magnetic field, which can both help and hinder the process. Scientists believe magnetic fields can protect a planet, fending off the atmosphere-stripping blasts of the solar wind. But they can also create opportunities for escape, like the giant globs cut loose from Saturn and Jupiter when magnetic field lines become tangled. Either way, to understand how atmospheres change, scientists pay close attention to magnetism.

That's one more reason Uranus is such a mystery. Voyager 2's 1986 flyby revealed just how magnetically weird the planet is.

"The structure, the way that it moves . . .," DiBraccio said, "Uranus is really on its own."

Unlike any other planet in our solar system, Uranus spins almost perfectly on its side – like a pig on a spit roast – completing a barrel roll once every 17 hours. Its magnetic field axis points 60° away from that spin axis, so as the planet spins, its magnetosphere – the space carved out by its magnetic field – wobbles like a poorly-thrown football. Scientists still don't know how to model it.

This oddity drew DiBraccio and her coauthor Dan Gershman, a fellow Goddard space physicist, to the project. Both were part of a team working out plans for a new mission to the "ice giants" Uranus and Neptune, and they were looking for mysteries to solve. Uranus' strange magnetic field, last measured more than 30 years ago, seemed like a good place

to start. So they downloaded Voyager 2's magnetometer readings, which monitored the strength and direction of the magnetic fields near Uranus as the spacecraft flew by. With no idea what they'd find, they zoomed in closer than previous studies, plotting a new datapoint every 1.92 seconds. Smooth lines gave way to jagged spikes and dips. And that's when they saw it: a tiny zigzag with a big story.

"Do you think that could be . . . a plasmoid?" Gershman asked DiBraccio, catching sight of the squiggle.

Little known at the time of Voyager 2's flyby, plasmoids have since become recognized as an important way planets lose mass. These giant bubbles of plasma, or electrified gas, pinch off from the end of a planet's magnetotail – the part of its magnetic field blown back by the Sun like a windsock. With enough time, escaping plasmoids can drain the ions from a planet's atmosphere, fundamentally changing its composition. They had been observed at Earth and other planets, but no one had detected plasmoids at Uranus – yet.

"Readings from inside the plasmoid – as Voyager 2 flew through it – hinted at its origins."

DiBraccio ran the data through her processing pipeline and the results came back clean. "I think it definitely is," she said.

The plasmoid DiBraccio and Gershman found occupied a mere 60 seconds of Voyager 2's 45-hour-long flight by Uranus. It appeared as a quick up-down blip in the magnetometer data. "But if you plotted it in 3D, it would look like a cylinder," Gershman said.

Comparing their results to plasmoids observed at Jupiter, Saturn, and Mercury, they estimated a cylindrical shape at least 204,000 kilometers (127,000 miles) long, and up to roughly 400,000 kilometers (250,000 miles) across. Like all planetary plasmoids, it was full of charged particles – mostly ionized hydrogen, the authors believe.

Readings from inside the plasmoid – as Voyager 2 flew through it – hinted at its origins. Whereas some plasmoids have a twisted internal magnetic field, DiBraccio and Gershman observed smooth, closed magnetic loops. Such loop-like plasmoids are typically formed as a spinning planet flings bits of its atmosphere to space. "Centrifugal forces take over, and the plasmoid pinches off," Gershman said. According to their estimates, plasmoids like that one could account for between 15% and 55% of atmospheric mass loss at Uranus, a greater proportion than either Jupiter or Saturn. It may well be the dominant way Uranus sheds its atmosphere to space.

How has plasmoid escape changed Uranus over time? With only one set of observations, it's hard to say. "Imagine if one spacecraft just flew through this room and tried to characterize the entire Earth," DiBraccio said. "Obviously it's not going to show you anything about what the Sahara or Antarctica is like."

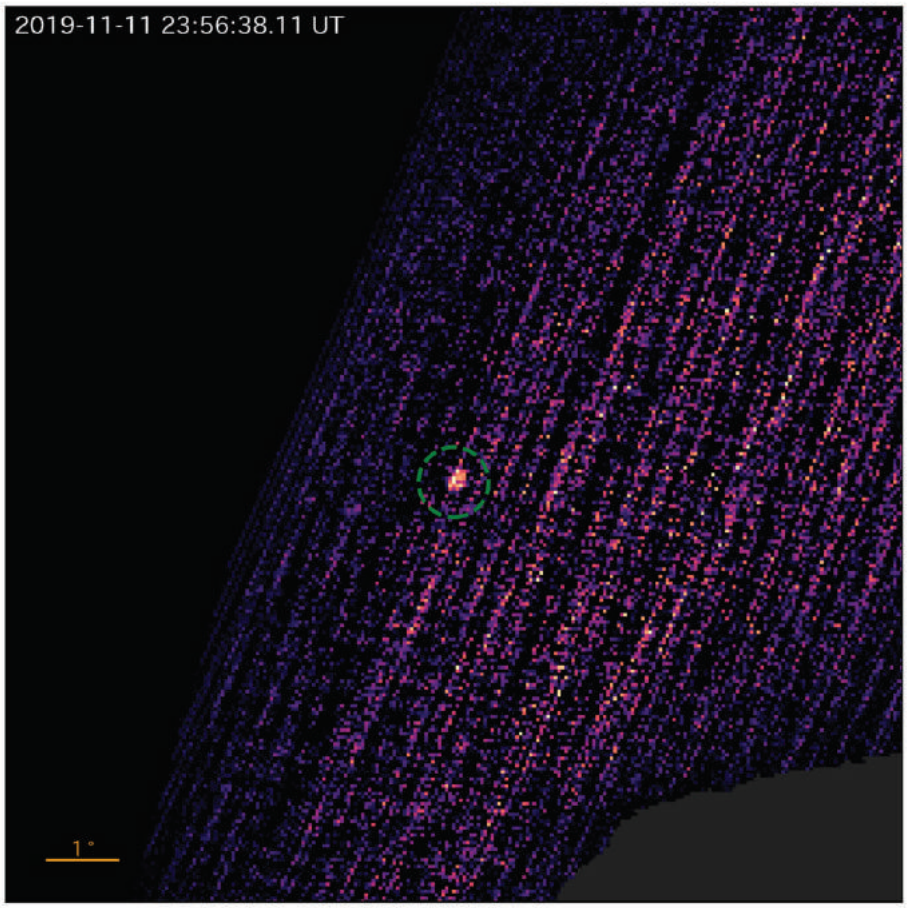
But the findings help focus new questions about the planet. The remaining mystery is part of the draw. "It's why I love planetary science," DiBraccio said. "You're always going somewhere you don't really know."

Original article by Miles Hatfield, NASA Goddard Space Flight Center, Greenbelt, Maryland.

NASA'S OSIRIS-REX STUDENTS CATCH UNEXPECTED GLIMPSE OF NEWLY DISCOVERED BLACK HOLE

REXIS, a shoebox-sized student instrument, was designed to measure the X-rays that Bennu emits in response to incoming solar radiation. X-rays are a form of electromagnetic radiation, like visible light, but with much higher energy. REXIS is a collaborative experiment led by students and researchers at the Massachusetts Institute of Technology (MIT) and Harvard University, who proposed, built, and operate the instrument.

On November 11, 2019, while the REXIS instrument was performing detailed science observations of Bennu, it captured X-rays radiating from a point off the asteroid's edge. "Our initial checks showed no previously cataloged object in that position in space," said Branden Allen, a Harvard research scientist and student supervisor who first



This image shows the X-ray outburst from the black hole MAXI J0637-043, detected by the REXIS instrument on NASA's OSIRIS-REx spacecraft. The image was constructed using data collected by the X-ray spectrometer while REXIS was making observations of the space around asteroid Bennu on November 11, 2019. The outburst is visible in the center of the image, and the image is overlaid with the limb of Bennu (lower right) to illustrate REXIS's field of view. Credit: NASA/Goddard/University of Arizona/MIT/Harvard.

spotted the source in the REXIS data.

The glowing object turned out to be a newly flaring black hole X-ray binary – discovered just a week earlier by Japan's MAXI telescope – designated MAXI J0637-430. NASA's Neutron Star Interior Composition Explorer (NICER) telescope also identified the X-ray blast a few days later. Both MAXI and NICER operate onboard NASA's International Space Station and detected the X-ray event from low-Earth orbit. REXIS, on the other hand, detected the same activity millions of miles from Earth while orbiting Bennu, the first such outburst ever detected from interplanetary space.

"The glowing object turned out to be a newly flaring black hole X-ray binary"

"Detecting this X-ray burst is a proud moment for the REXIS team. It means our instrument is performing as expected and to the level required of NASA science instruments," said Madeline Lambert, an MIT graduate student who designed the instrument's command sequences that serendipitously revealed the black hole.

X-ray blasts, like the one emitted from the newly discovered black hole, can only be observed from space since Earth's protective atmosphere shields our planet from X-rays. These X-ray emissions occur when a black hole pulls in matter from a normal star that is in orbit around it. As the matter spirals onto a spinning disk surrounding the black hole, an enormous amount of energy (primarily in the form of X-rays) is released in the process.

"We set out to train students how to build and operate space instruments," said MIT professor Richard Binzel, instrument scientist for the REXIS student experiment. "It turns out, the greatest lesson is to always be open to discovering the unexpected."

The main purpose of the REXIS instrument is to prepare the next generation of scientists, engineers, and project managers in the development and operations of spaceflight hardware. Nearly 100 undergraduate and graduate students have worked on the REXIS team since the mission's inception.

For more information on NASA's OSIRIS-REx mission, visit www.nasa.gov/osiris-rex.

Original article by Brittany Enos, University of Arizona.

osiris-rex

ANCIENT METEORITE SITE ON EARTH COULD REVEAL NEW CLUES ABOUT MARS' PAST

Scientists at the University of California Riverside (UCR) have devised new analytical tools to break down the enigmatic history of Mars' atmosphere – and whether life was once possible there. A paper detailing the work was published in late February in the journal Science Advances. It could help astrobiologists understand the alkalinity, pH, and nitrogen content of ancient waters on Mars, and by extension, the carbon dioxide composition of the planet's ancient atmosphere. Mars of today is too cold to have liquid water on its surface, a requirement for hosting life as we know it.

"The question that drives our interests isn't whether there's life on present-day Mars," said Tim Lyons, UCR distinguished professor of biogeochemistry. "We are driven instead by asking whether there was life on Mars billions of years ago, which seems significantly more likely. Overwhelming evidence exists that Mars had liquid water oceans roughly 4 billion years ago."

The central question astrobiologists ask is how that was possible. The Red Planet is farther from the Sun than Earth is, and billions of years ago the Sun generated less heat than it does today. "To have made the planet warm enough for liquid surface water, its atmosphere would likely have needed an immense amount of greenhouse gas, carbon dioxide specifically," explained Chris Tino, a UCR graduate student and co-first-author of the paper along with Eva Stüeken, a lecturer at the University of St. Andrews in Scotland.

Since sampling Mars' atmosphere from billions of years ago to learn its carbon dioxide content is impossible, the team concluded that a site on Earth whose geology and chemistry bear similarities to the martian surface might provide some of the missing pieces. They found it in southern Germany's Nordlinger Ries crater. Formed roughly 15 million years ago after being struck by a meteorite, Ries crater features layers of rocks and minerals better preserved than almost anywhere on Earth.

The Mars 2020 rover will land in a similarly structured, well-preserved ancient crater. Both places featured liquid water in their distant past, making their chemical compositions comparable.

A sample of suevite rock formed nearly 15 million years ago by the Ries Crater meteorite impact. Similarly impact-generated rocks exist on the rims of ancient crater lakes on Mars. Credit: NASA.

According to Tino, it's unlikely that ancient Mars had enough oxygen to have hosted complex life forms like humans or animals. However, some microorganisms could have survived if ancient martian water had both a neutral pH level and was highly alkaline. Those conditions imply sufficient carbon dioxide in the atmosphere – perhaps thousands of times more than what surrounds Earth today – to warm the planet and make liquid water possible.

While pH measures the concentration of hydrogen ions in a solution, alkalinity is a measure dependent on several ions and how they interact to stabilize pH. "Ries crater rock samples have ratios of nitrogen isotopes that can best be explained by high pH," Stüeken said. "What's more, the minerals in the ancient sediments tell us that alkalinity was also very high."

However, martian samples with mineral indicators for high alkalinity and nitrogen isotope data pointing to relatively low pH would demand extremely high levels of carbon dioxide in the past atmosphere. The resulting carbon dioxide estimates could help solve the long-standing mystery of how an ancient Mars located so far from a faint early Sun could have been warm enough for surface oceans and perhaps life. How such high levels could have been maintained and what might have lived beneath them remain important questions.

"Before this study, it wasn't clear that something as straightforward as nitrogen isotopes could be used to estimate the pH of ancient waters on Mars; pH is a key parameter in calculating the carbon dioxide in the atmosphere," Tino said. For more information, visit https://news.ucr.edu/articles/2020/02/13/ancient-meteorite-site-earth-could-reveal-new-clues-about-mars-past.

Portions of this article were provided by UCR.

CHINA'S FARSIDE MISSION REAWAKENS TO CONTINUE EXPLORATION

China's Chang'e-4 lander as viewed by the Yutu-2 rover. Credit: CNSA/CLEP..

On the farside of the Moon, China's Chang'e-4 lander and Yutu-2 rover have resumed work for the 15th lunar day after "sleeping" during the extremely cold night. According to the Xinhua News Agency the lander woke up at 6:57 a.m. Tuesday, February 18 (Beijing time), and the rover at 5:55 p.m. Monday, February 17. Reportedly, both were in normal working order.

The wheeled Yutu-2 (Jade Rabbit-2) rover has traveled more than 367 meters (1204 feet) with a plan to drive northwest and then southwest to continue its scientific exploration.

The Chang'e-4 mission was launched on December 8, 2018, making the first-ever soft landing within the Von Kármán crater, a large lunar impact feature that is located in the southern hemisphere on the farside of the Moon.

China's next Moon exploration mission is slated to be the Chang'e-5, a multi-staged effort to rocket lunar samples back to Earth later this year. According to Chinese news services, Chang'e-5 is comprised of four parts including the orbiter, ascender, lander, and Earth reentry module. If successful, this robotic spacecraft would attempt the first lunar sample return to Earth in over 40 years.

The former Soviet Union successfully executed three robotic sample return missions: Luna 16 returned a small sample (101 grams) from Mare Fecunditatis in September 1970; in February 1972, Luna 20 returned 55 grams of soil from the Apollonius highlands region; and Luna 24 retrieved 170.1 grams of lunar samples from the Moon's Mare Crisium (Sea of Crisis) for return to Earth in August 1976.

The last samples from the Moon to reach Earth came via the Apollo 17 mission in December 1972.

Portions of this article were provided by Leonard David's Inside Outer Space.

UCI ASTRONOMER AND COLLEAGUES CONFIRM EXISTENCE OF EXOPLANET ORBITING NEARBY STAR

Using the Habitable Zone Planet Finder (HPF) instrument, a team of scientists – including University of California Irvine (UCI) astronomer Paul Robertson – has confirmed that an object previously detected by the Kepler space telescope is an exoplanet, a planet orbiting a star outside our solar system. The team's findings were published recently in The Astronomical Journal.

Called G 9-40b, the body is about twice the size of Earth, slightly smaller than Neptune, and orbits a low-mass M-dwarf star only 100 light-years away. Kepler detected the planet by observing its transit across the star's front, with an expected dimming of light cast by the host.

Through precise measurements of infrared signals, the sophisticated HPF spectrograph was able to accurately identify G 9-40b as an exoplanet, ruling out the possibility of a close stellar neighbor or binary companion to the dwarf star. High-contrast adaptive optics imaging observations using the ShARCS camera on the 3-meter C. Donald Shane telescope at California's Lick Observatory showed that the host star was the true source of the transits.

The Hobby-Eberly Telescope at the McDonald Observatory in Texas. This telescope is home to the Habitable Zone Planet Finder instrument, which recently confirmed the existence of the exoplanet G 9-40b. Credit: Ethan Tweedie Photography.

"Kepler had outstanding measurement precision, but its spatial imaging resolution left open the possibility that the planet signal might be coming from an unresolved nearby star," said Corey Beard, a UCI physics and astronomy graduate student who led the analysis of the adaptive optics data. He said the complementary roles of the various instruments involved enabled the team to confirm the existence of the exoplanet with high confidence.

"The HPF's measurement precision for the smallest stars in the galaxy is really unprecedented," said Robertson, HPF project scientist and UCI assistant professor of physics and astronomy. "It opens up exciting new areas of exploration for planets orbiting these stars." He said his team hopes to further observe G 9-40b to gain an accurate measurement of its mass and determine whether it's a gas-rich planet like Neptune or a rocky planet like Earth or Mars.

Installed at the 10-meter Hobby-Eberly Telescope at Texas' McDonald Observatory, HPF was designed to detect and characterize planets in the habitable zone – the region around a star where a planet could sustain liquid water on its surface – around M dwarfs, the most common stars in the Milky Way.

For more information about this project, visit hpf.psu.edu/.

A YEAR OF SURPRISING SCIENCE FROM NASA'S INSIGHT MARS MISSION

A new understanding of Mars is beginning to emerge, thanks to the first year of NASA's InSight lander mission. Findings described in a set of six papers published on February 24 reveal a planet alive with quakes, dust devils, and strange magnetic pulses. Five of the papers were published in Nature. An additional paper in Nature Geoscience details the InSight spacecraft's landing site, a shallow crater nicknamed "Homestead Hollow" in a region called Elysium Planitia.

InSight is the first mission dedicated to looking deep beneath the martian surface. Among its science tools are a seismometer for detecting quakes, sensors for gauging wind and air pressure, a magnetometer, and a heat flow probe designed to take the planet's temperature. While the team continues to work on getting the probe into the martian surface as intended, the ultra-sensitive seismometer, called the Seismic Experiment for Interior Structure (SEIS), has enabled scientists to "hear" multiple trembling events from hundreds to thousands of miles away.

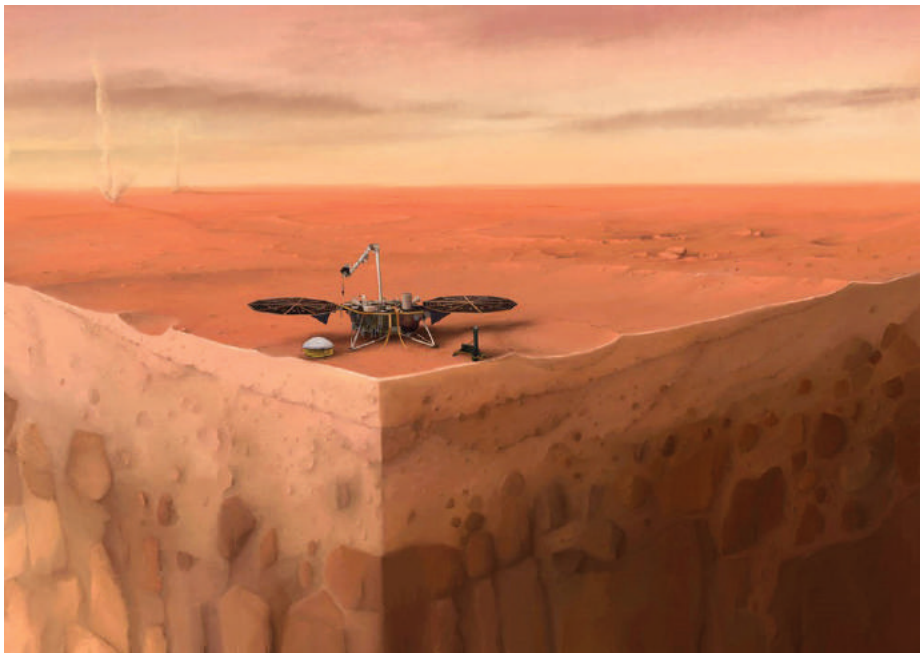
Seismic waves are affected by the materials they move through, giving scientists a way to study the composition of the planet's inner structure. Mars can help the team better understand how all rocky planets, including Earth, first formed.

Mars trembles more often – but also more mildly – than expected. SEIS has found more than 450 seismic signals to date, the vast majority of which are probably quakes (as opposed to data noise created by environmental factors, like wind). The largest quake was about magnitude 4.0 in size – not quite large enough to travel down below the crust into the planet's lower mantle and core. Those are "the juiciest parts of the apple" when it comes to studying the planet's inner structure, said Bruce Banerdt, InSight principal investigator at NASA's Jet Propulsion Laboratory (JPL).

Scientists are ready for more: It took months after InSight's landing in November 2018 before they recorded the first seismic event. By the end of 2019, SEIS was detecting about two seismic signals a day, suggesting that InSight just happened to touch down at a particularly quiet time. Scientists still have their fingers crossed for "the Big One."

Mars doesn't have tectonic plates like Earth, but it does have volcanically active regions that can cause rumbles. A pair of quakes was strongly linked to one such region, Cerberus Fossae, where scientists see boulders that may have been shaken down cliffsides. Ancient floods there carved channels nearly 1300 kilometers (800 miles) long. Lava flows then seeped into those channels within the past 10 million years – the blink of an eye in geologic time.

Some of these young lava flows show signs of having been fractured by quakes less than 2 million years ago. "It's just about the youngest tectonic feature on the planet," said planetary geologist Matt Golombek of JPL. "The fact that we're seeing evidence of shaking in this region isn't a surprise, but it's very cool."



In this artist's concept of NASA's InSight lander on Mars, layers of the planet's subsurface can be seen below and dust devils can be seen in the background. Credit: IPGP/Nicolas Sarter.

Billions of years ago, Mars had a magnetic field. It is no longer present, but it left ghosts behind, magnetizing ancient rocks that are now from 61 meters (200 feet) to several miles below ground. InSight is equipped with a magnetometer – the first on the surface of Mars to detect magnetic signals.

The magnetometer has found that the signals at Homestead Hollow are 10 times stronger than what was predicted based on data from orbiting spacecraft that study the area. The measurements of these orbiters are averaged over a couple of hundred miles, whereas InSight's measurements are more local.

"This site has more whirlwinds than any other place we've landed on Mars while carrying weather sensors"

Because most surface rocks at InSight's location are too young to have been magnetized by the planet's former field, "this magnetism must be coming from ancient rocks underground," said Catherine Johnson, a planetary scientist at the University of British Columbia and the Planetary Science Institute. "We're combining these data with what we know from seismology and geology to understand the magnetized layers below InSight. How strong or deep would they have to be for us to detect this field?"

In addition, scientists are intrigued by how these signals change over time. The measurements vary by day and night; they also tend to pulse around midnight. Theories are still being formed as to what causes such changes, but one possibility is that they're related to the solar wind interacting with the martian atmosphere.

InSight measures wind speed, direction, and air pressure nearly continuously, offering more data than previous landed missions. The spacecraft's weather sensors have detected thousands of passing whirlwinds, which are called dust devils when they pick up grit and become visible. "This site has more whirlwinds than any other place we've landed on Mars while carrying weather sensors," said Aymeric Spiga, an atmospheric scientist at Sorbonne University in Paris.

Despite all that activity and frequent imaging, InSight's cameras have yet to see dust devils. But SEIS can feel these whirlwinds pulling on the surface like a giant vacuum cleaner. "Whirlwinds are perfect for subsurface seismic exploration," said Philippe Lognonné of the Institut de Physique du Globe de Paris (IPGP), principal investigator of SEIS.

InSight has two radios: one for regularly sending and receiving data, and a more powerful radio designed to measure the "wobble" of Mars as it spins. This X-band radio, also known as the Rotation and Interior Structure Experiment (RISE), can eventually reveal whether the planet's core is solid or liquid. A solid core would cause Mars to wobble less than a liquid one would.

This first year of data is just a start. Watching over a full martian year (two Earth years) will give scientists a much better idea of the size and speed of the planet's wobble.

Original article by Andrew Good (JPL) and Alana Johnson (NASA Headquarters). For more information, visit mars.nasa.gov/insight/.

NASA SELECTS MISSION TO STUDY CAUSES OF GIANT SOLAR PARTICLE STORMS

A new NASA mission called SunRISE will study what drives solar particle storms — giant surges of solar particles that erupt off the Sun, as depicted in this illustration. Understanding how such storms affect interplanetary space can help protect spacecraft and astronauts. Credit: NASA.

NASA has selected a new mission to study how the Sun generates and releases giant space weather storms – known as solar particle storms – into planetary space. Not only will such information improve understanding of how our solar system works, but it ultimately can help protect astronauts traveling to the Moon and Mars by providing better information on how the Sun's radiation affects the space environment they must travel through.

The new mission, called the Sun Radio Interferometer Space Experiment (SunRISE), is an array of six CubeSats operating as one very large radio telescope. NASA has awarded $62.6 million to design, build, and launch SunRISE by no earlier than July 1, 2023.

NASA chose SunRISE in August 2017 as one of two Mission of Opportunity proposals to conduct an 11-month mission concept study. In February 2019, the agency approved a continued formulation study of the mission for an additional year. SunRISE is led by Justin Kasper at the University of Michigan in Ann Arbor and managed by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.

"We are so pleased to add a new mission to our fleet of spacecraft that help us better understand the Sun, as well as how our star influences the space environment between planets," said Nicky Fox, director of NASA's Heliophysics Division. "The more we know about how the Sun erupts with space weather events, the more we can mitigate their effects on spacecraft and astronauts."

The mission design relies on six solar-powered CubeSats – each about the size

> "We are so pleased to add a new mission to our fleet of spacecraft that help us better understand the Sun"

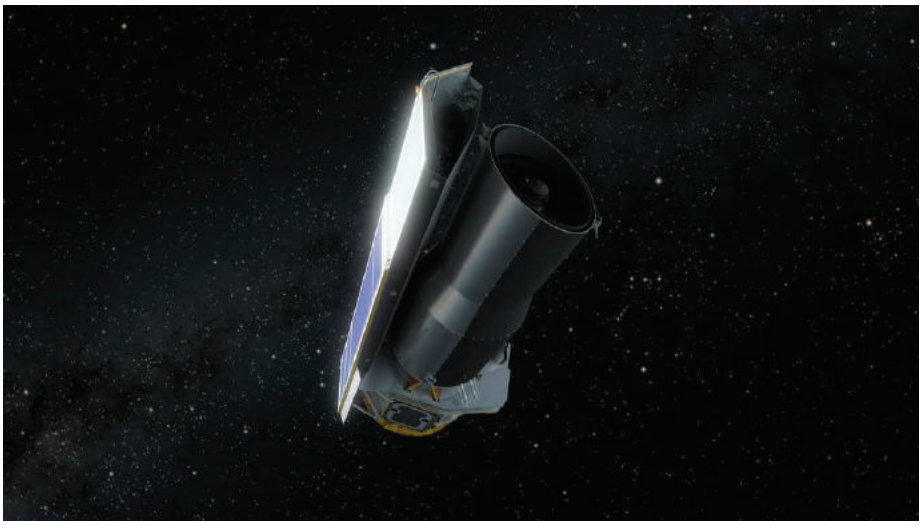
of a toaster oven — to simultaneously observe radio images of low-frequency emission from solar activity and share them via NASA's Deep Space Network. The constellation of CubeSats would fly within 10 kilometers (6 miles) of each other, above Earth's atmosphere, which otherwise blocks the radio signals SunRISE will observe. Together, the six CubeSats will create three-dimensional maps to pinpoint where giant particle bursts originate on the Sun and how they evolve as they expand outward into space. This, in turn, will help determine what initiates and accelerates these giant jets of radiation. The six individual spacecraft will also work together to map, for the first time, the pattern of magnetic field lines reaching from the Sun out into interplanetary space.

NASA's Missions of Opportunity maximize science return by pairing new, relatively inexpensive missions with launches on spacecraft already approved and preparing to go into space. SunRISE proposed an approach for access to space as a hosted rideshare on a commercial satellite provided by Maxar of Westminster, Colorado, and built with a Payload Orbital Delivery System (PODS). Once in orbit, the host spacecraft will deploy the six SunRISE spacecraft and then continue its prime mission.

Missions of Opportunity are part of the Explorers Program, which is the oldest continuous NASA program designed to provide frequent, low-cost access to space using principal investigator-led space science investigations relevant to the Science Mission Directorate's (SMD) astrophysics and heliophysics programs. The program is managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, for SMD, which conducts a wide variety of research and scientific exploration programs for Earth studies, space weather, the solar system, and the universe.

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

NASA'S SPITZER SPACE TELESCOPE ENDS MISSION OF ASTRONOMICAL DISCOVERY



NASA's Spitzer Space Telescope has concluded after more than 16 years of exploring the universe in infrared light. Credit: NASA/JPL-Caltech.

After more than 16 years studying the universe in infrared light, revealing new wonders in our solar system, our galaxy, and beyond, NASA's Spitzer Space Telescope's mission has come to an end. Mission engineers confirmed at 2:30 p.m. U.S. Pacific Standard Time (5:30 p.m. Eastern Standard Time) Thursday the spacecraft was placed in safe mode, ceasing all science operations. After the decommissioning was confirmed, Spitzer Project Manager Joseph Hunt declared the mission had officially ended.

Launched in 2003, Spitzer was one of NASA's four Great Observatories, along with the Hubble Space Telescope, the Chandra X-ray Observatory, and the Compton Gamma Ray Observatory. The Great Observatories program demonstrated the power of using different wavelengths of light to create a fuller picture of the universe.

"Spitzer has taught us about entirely new aspects of the cosmos and taken us many steps further in understanding how the universe works, addressing questions about our origins and whether or not are we alone," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate in Washington. "This Great Observatory has also identified some important and new questions and tantalizing objects for further study, mapping a path for future investigations to follow. Its immense impact on science certainly will last well beyond the end of its mission."

Among its many scientific contributions, Spitzer studied comets and asteroids in our own solar system and found a previously unidentified ring around

Saturn. It studied star and planet formation, the evolution of galaxies from the ancient universe to today, and the composition of interstellar dust. It also proved to be a powerful tool for detecting exoplanets and characterizing their atmospheres. Spitzer's best-known work may be detecting the seven Earth-sized planets in the TRAPPIST-1 system – the largest number of terrestrial planets ever found orbiting a single star – and determining their masses and densities.

"I think that Spitzer is an example of the very best that people can achieve"

In 2016, following a review of operating astrophysics missions, NASA made a decision to close out the Spitzer mission in 2018 in anticipation of the launch of the James Webb Space Telescope (JWST), which also will observe the universe in infrared light. When JWST's launch was postponed, Spitzer was granted an extension to continue operations until this year. This gave Spitzer additional time to continue producing transformative science, including insights that will pave the way for JWST, which is scheduled to launch in 2021.

"Everyone who has worked on this mission should be extremely proud today," Hunt said. "There are literally hundreds of people who contributed directly to Spitzer's success and thousands who used its scientific capabilities to explore the universe. We leave behind a powerful scientific and technological legacy."

Although it was not NASA's first space-based infrared telescope, Spitzer was the most sensitive infrared telescope in history when it launched, and it delivered a deeper and more far-reaching view of the infrared cosmos than its predecessors. Above Earth's atmosphere, Spitzer could detect some wavelengths that cannot be observed from the ground. The spacecraft's Earth-trailing orbit placed it far away from our planet's infrared emissions, which also gave Spitzer better sensitivity than was possible for larger telescopes on Earth.

Spitzer's prime mission came to an end in 2009, when the telescope exhausted its supply of the liquid helium coolant necessary for operating two of its three instruments: the Infrared Spectrograph (IRS) and the Multiband Imaging Photometer for Spitzer (MIPS). The mission was deemed a success, having achieved all of its primary science objectives and more. But Spitzer's story wasn't over. Engineers and scientists were able to keep the mission going using only two out of four wavelength channels on the third instrument, the Infrared Array Camera (IRAC). Despite increasing engineering and operations challenges, Spitzer continued to produce transformational science for another 10.5 years – far longer than mission planners anticipated.

During its extended mission, Spitzer continued to make significant scientific discoveries. In 2014, it detected evidence of asteroid collisions in a newly formed planetary system, providing evidence that such smash-ups might be common in early solar systems and crucial to the formation of some planets. In 2016, Spitzer worked with Hubble to image the most distant galaxy ever detected. From 2016 onward, Spitzer studied the TRAPPIST-1 system for more than 1000 hours. All of Spitzer's data are free and available to the public in the Spitzer data archive. Mission scientists say they expect researchers to continue making discoveries with Spitzer long after the spacecraft's decommissioning.

"I think that Spitzer is an example of the very best that people can achieve," said Spitzer Project Scientist Michael Werner. "I feel very fortunate to have worked on this mission, and to have seen the ingenuity, doggedness, and brilliance that people on the team showed. When you tap into those things and empower people to use them, then truly incredible things will happen."

View some of the amazing images showcasing some of Spitzer's greatest discoveries at www.jpl.nasa.gov/news/news.php?feature=7221.

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VIRTUAL EDUCATION AND PUBLIC ENGAGEMENT OPPORTUNITIES

Organizations across the country are curtailing education and public engagement programs.

Some are conducting online programs; contact your

- local museums and planetariums (informal.jpl.nasa.gov/museum/Connect)
- libraries (www.starnetlibraries.org/portfolio-items/nasa-my-library)
- Solar System Ambassadors (nasa.gov/ssa/directory.cfm), and
- amateur astronomy clubs (nightsky.jpl.nasa.gov) to determine how you can participate.

A variety of education and public engagement resources are available for use with audiences.

NASA at Home

e-Books, videos, virtual tours, and more.

www.nasa.gov/specials/nasaathome/index.html

NASA SMD Resources for Learners

It has a variety of SMD resources.

eospso.nasa.gov/sites/default/files/publications/NASA%20Science%20Resources.pdf

LPI's Cosmic Explorations Speaker Series

Archives of past presentations available for viewing.

bit.ly/2RlUvNC

LPI's Explore! Resources

Use Explore! activities to engage children and preteens in the wonders of lunar exploration; the planets Earth, Jupiter, and Mars; rockets; staying healthy in space; and more! https://www.lpi.usra.edu/education/explore/

Explore! how-to videos: bit.ly/3eeIjIz

NASA RESEARCH ANNOUNCEMENT: Science Activation Program Integration

The SMD Science Activation Program (SciAct) seeks to further enable NASA science experts and content into the learning environment more effectively and efficiently with learners of all ages. Proposers must propose and explain processes to integrate SMEs into the SciAct portfolio towards the overall outcome of more effectively and efficiently connecting with learners of all ages, and/or processes to broaden participation in SciAct offerings. Proposals are due **May 27, 2020**. For more information, visit: *bit.ly/2yOaGwS*.

NASA POSTDOCTORAL PROGRAM FELLOWSHIPS

The NASA Postdoctoral Program, or NPP, supports NASA's goal to expand scientific understanding of the Earth and the universe in which we live. Selected by a competitive peer-review process, NPP fellows complete one- to three-year fellowships that offer scientists and engineers unique opportunities to conduct research in fields of science relevant to NASA. Interested applicants may apply by one of three annual application deadlines: **March 1, July 1, and November 1**. For more information, visit: *npp.usra.edu*.

AMERICAN ASTRONOMICAL SOCIETY EDUCATION PRIZE

The AAS Education Prize is to recognize outstanding contributions to the education of the public, students and/or the next generation of professional astronomers. Nominations for AAS prizes must arrive in the Secretary's office by **June 30, 2020**. For more information, visit: *aas.org/grants-and-prizes/prize-nominations*.

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

IN MEMORIAM

Credit: University of Arizona

JOHANNES GEISS

1926–2020

Prof. Dr. Johannes Geiss, Honorary Director of the International Space Science Institute (ISSI) in Bern and External Scientific Member of the Max Planck Institute for Solar System Research (MPS), passed away in January. He was 93 years old.

Geiss was born on September 4, 1926, in Stolp in what was then Western Pomerania as the son of an estate manager. How different the world must have looked at that time, when his grandfather had to hitch the horse to a cart every two days in order to travel to the barber in the neighboring village for a shave. Who could have imagined that, not even 50 years later, his grandson would develop an experiment that would land on the Moon.

Geiss' first position as a physicist was at Fritz Houtermans' institute at the University of Bern. Houtermans wanted to apply mass spectrometry, with which Geiss had successfully been able to determine the isotopic composition of lead, to determine the age of meteoric matter. So, at the beginning of the 1950s, his glass mass spectrometer with him, he went to Bern, which would become the new center of his life, and by 1974 he was a naturalized citizen of Switzerland.

Geiss brought a breath of fresh air to an institute that was perhaps a little outdated at the time, and soon found enthusiastic companions to establish a group that would quickly make a name for itself in astrophysics. Periods spent abroad in Chicago with Harold Urey and as a young professor in Miami broadened and rounded out his education; in between, he habilitated in experimental physics, in particular extraterrestrial physics, at the University of Bern in 1957. He was appointed as an associate professor in 1960 and as a full professor in 1964. At the beginning of the 1960s, he had to take over management of the institute for the increasingly ill Houtermans, and was thus appointed director of the institute following Houtermans' death in 1966, a position which he held until his retirement in 1990.

Geiss was pulled to other places time and again in order to maintain and develop his ever-growing network. He spent the year before the Apollo 11 landing on the Moon at NASA in Houston in order to lobby for the ingeniously simple solar wind sail developed by him and his group. The solar wind would be captured with an aluminum foil during the astronauts' time on the surface of the Moon, as the solar wind arrives there unhindered because of the Moon's lack of an atmosphere and a magnetic field. The simplicity of the experiment and the excellent reputation of the Bernese mass spectrometer made him perfect for the job. But it took great tenacity, coupled with enthusiasm and a necessary bit of luck for the sail to fly with Apollo 11 in July 1969 and then an additional four times. Its analysis, in particular the ratio of the helium isotopes captured, corresponded to a measurement of the average density of the universe as a whole – a groundbreaking result for which he, together with Hubert Reeves, was awarded the Einstein Medal by the Albert Einstein Society in Bern in 2001.

In addition to isotope geochronology, Geiss' scientific interest was primarily focused on space plasmas. In addition to his groundbreaking experiments onboard the Apollo spacecraft, Geiss also investigated the composition of matter in the Earth's environment, the Sun, and interstellar gas. He was involved in numerous space missions such as the Ulysses deep-space probe, the Solar and Heliospheric Observatory (SOHO), and the Cassini/Huygens mission to study the saturnian system. Even after his retirement, Geiss remained a man of action in the field of space research. He played a major role in the founding of the International Space Science Institute in Bern, which he headed initially as founding director and then as honorary director until his death.

— Portions of text courtesy of the ***International Space Science Institute and the Max Planck Institute for Solar System Research***

Credit: University of Arizona.

ADAM SHOWMAN

1968–2020

Adam Showman, a Professor of Planetary Sciences at the University of Arizona's Lunar and Planetary Laboratory, passed away suddenly on March 16, 2020. Showman had a wide range of interests and expertise. Most notably he was an expert in both the atmospheres and interiors of planets. His atmospheric work concentrated on giant gaseous planets like Jupiter, Saturn, and many of the extrasolar planets that have been discovered, while most of his work on interiors dealt with the icy satellites that orbit the solar system's giant planets.

Showman was born in 1968, and received his B.S. in Physics from Stanford in 1991 and his Ph.D. in Planetary Sciences from the California Institute of Technology in 1999. He joined the staff of the Lunar and Planetary Laboratory at the University of Arizona in 2001 as an assistant professor. Showman was named full professor in 2012, and in 2018 he was named a Galileo Circle Fellow, one of the highest honors for faculty in the University of Arizona's College of Science.

During his career, Showman directly advised eleven graduate students and mentored many more across the disciplines of planetary science, atmospheric sciences, and geosciences. He was a renowned teacher who enjoyed explaining to his students the complicated details of planetary physics and hammering out ideas to solve research problems. He developed eight different courses in the planetary sciences, including two completely new graduate courses, and his early pioneering research on the atmospheric dynamics of exoplanets has been the paradigm of hot gas giant atmospheric circulation models ever since. Showman also made notable contributions to our understanding of atmospheric circulation in the four giant planets in our own solar system and of the geophysics of the Galilean satellites.

*— Text courtesy of **Renu Malhotra** (Lunar and Planetary Laboratory) and **Andrew P. Ingersoll** (Caltech)*

Credit: University of Pittsburgh.

WILLIAM A. CASSIDY

1928–2020

Emeritus Professor William A. Cassidy of the Department of Geology and Environmental Science at the University of Pittsburgh passed away on March 22, 2020. Cassidy is best known for creating the Antarctic Search for Meteorites (ANSMET) program in 1976, serving as its Principal Investigator for nearly 20 years.

Cassidy, a World War II veteran and Fulbright scholar, graduated from the University of New Mexico with a B.S. in geology and from Penn State University with a Ph.D. in geochemistry. He was very adventurous and loved to travel to strange places. After graduating from New Mexico, he gave himself a graduation present by attempting to drive a motorcycle the entire length of the Pan-American highway, which in places was little more than a cow path.

Cassidy was an expert in the geology of meteorite impact craters and traveled to many places in the world to study them, including Canada, South America, Africa, and Australia. He spent several summers in Argentina in the Campo del Cielo crater field, excavating a chain of impact craters that were made when a giant iron meteorite broke up in mid-air.

When he heard that a Japanese meteorologist had discovered some meteorites on a glacier in Antarctica, Cassidy realized that the thick, moving ice would be a natural collector and concentrator of meteorites. This realization led to the creation of ANSMET, and for many years, Cassidy led expeditions to Antarctica, discovering enough meteorites – including several from the Moon and Mars – to triple the world's collection. Because of those efforts, the Cassidy Glacier in Antarctica was named for him, as well as the mineral cassidyite and the asteroid 3382 Cassidy. In 1979, he was awarded the Antarctica Service Medal. His efforts in Antarctica were documented in his memoir, Meteorites, Ice, and Antarctica: A Personal Account, published by Cambridge University Press in 2003.

— Portions of text courtesy of the ***University of Pittsburgh***

VIRGINIA MIDDLE SCHOOL STUDENT EARNS HONOR OF NAMING NASA'S NEXT MARS ROVER

NASA's Thomas Zurbuchen and Lori Glaze congratulate Alexander Mather during a March 5, 2020, celebration at Lake Braddock Secondary School in Burke, Virginia. The seventh grader submitted the winning entry "Perseverance" to the agency's "Name the Rover" essay contest. Credit: NASA.

NASA's next Mars rover has a new name – Perseverance.

The name was announced on March 5, 2020 by Thomas Zurbuchen, associate administrator of the Science Mission Directorate, during a celebration at Lake Braddock Secondary School in Burke, Virginia. Zurbuchen was at the school to congratulate seventh grader Alexander Mather, who submitted the winning entry to the agency's "Name the Rover" essay contest, which received 28,000 entries from K-12 students from every U.S. state and territory.

"Alex's entry captured the spirit of exploration," said Zurbuchen. "Like every exploration mission before, our rover is going to face challenges, and it's going to make amazing discoveries. It's already surmounted many obstacles to get us to the point where we are today – processing for launch. Alex and his classmates are the Artemis Generation, and they're going to be taking the next steps into space that lead to Mars. That inspiring work will always require perseverance. We can't wait to see that nameplate on Mars."

Perseverance is the latest in a long line of Red Planet rovers to be named by school-age children, from Sojourner in 1997 to the Spirit and Opportunity rovers, which landed on Mars in 2004, to Curiosity, which has been exploring Mars since 2012. In each case, the name was selected following a nationwide contest.

The contest that resulted in Alex's winning entry of Perseverance began August 28, 2019. Nearly 4,700 volunteer judges – educators, professionals and space enthusiasts from around the country – reviewed submissions to help narrow the pool down to 155 semifinalists. Once that group was whittled down to nine finalists, the public had five days to weigh in on their favorites, logging more than 770,000 votes online, with the results submitted to NASA for consideration. The nine finalists also talked with a panel of experts, including Lori Glaze, director of NASA's Planetary Science Division; NASA astronaut Jessica Watkins; rover driver Nick Wiltsie at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California; and Clara Ma, who, as a sixth grade student in 2009, named Curiosity.

Perseverance currently is undergoing final assembly and checkout at NASA's Kennedy Space Center in Flo.rida.

For more information about the mission, go to: mars.nasa.gov/mars2020/.

NASA HONORS TUSKEGEE AIRMAN DURING BLACK HISTORY MONTH PROGRAM

Credits: Eddie Kyle Photography/Edward Kyle.

As part of its celebration of Black History Month, NASA honored retired Air Force Col. Charles McGee at a ceremony Wednesday, February 5, in the James Webb Auditorium at NASA Headquarters. McGee, who served as a pilot with the Tuskegee Airmen during World War II – known at the time as the "Red Tails" – was a career officer in the Air Force and also served during the Korean and Vietnam wars, having flown 409 combat missions during his 30 years of service. Of the 355 Tuskegee pilots who flew in combat, McGee is one of only nine surviving. McGee received an honorary promotion to the rank of brigadier general, as authorized by the National Defense Authorization Act for Fiscal Year 2020, which President Trump signed into law in December, the same month McGee celebrated his 100th birthday.

McGee is joined by NASA astronaut Alvin Drew, also a retired Air Force colonel, who logged more than 612 hours in space on space shuttle Endeavor on the STS-118 mission in 2007 and space shuttle Discovery on STS-133 in 2011. The two share their experiences on what it means to be a trailblazer and to inspire others to follow their dreams.

The event also featured a vocal performance by the Jubilee Singers of All Souls Church, Unitarian, in Washington. The event was sponsored by the NASA Headquarters chapter of Blacks in Government.

NASA ADDS SHANNON WALKER TO FIRST OPERATIONAL CREWED SPACEX MISSION

Shannon Walker looking out of the international space station's cupola at the Caribbean view beneath on November 25, 2010. Credit: NASA.

NASA has assigned astronaut Shannon Walker to the first operational crewed flight of the SpaceX Crew Dragon spacecraft on a mission to the International Space Station.Walker will join NASA astronauts Michael Hopkins and Victor Glover, Jr., as well as Soichi Noguchi of the Japan Aerospace Exploration Agency (JAXA), for a six-month expedition aboard the unique space laboratory.

This mission will be the first in a series of regular, rotational flights to the station following NASA's certification of the new crewed system following completion and validation of SpaceX's test flight with astronauts, known as Demo-2. This test is expected to take place in mid-to-late May as part of NASA's Commercial Crew Program.

Pending the successful Demo-2 test, Walker, Glover, Hopkins, and Noguchi will launch aboard Crew Dragon on SpaceX's Falcon 9 rocket from Launch Pad 39A at NASA's Kennedy Space Center in Florida. That launch is targeted for later this year.

Walker was born in Houston and began her career at NASA's Johnson Space Center in Houston in 1987 as a robotics flight controller for the space shuttle with Rockwell Space Operations Co. She became a NASA employee in 1995,

working on robotics and avionics hardware for the station with the program's international partners. She also coordinated on-orbit problem resolution in the Mission Evaluation Room at Johnson and in Moscow and served as acting manager of the On-Orbit Engineering Office before NASA selected her for the 2004 astronaut class. As an astronaut, she spent 163 days as a flight engineer aboard the space station for Expeditions 24 and 25 in 2010. Walker earned a bachelor's degree in physics and a master's and doctorate in space physics, all from Rice University in Houston.

NASA already assigned Glover and Hopkins to the first operation SpaceX crewed mission in August 2018. This will be the first spaceflight for Glover and the second for Hopkins, who lived aboard the space station from September 2013 to March 2014 as part of Expeditions 37 and 38.

It will be the third spaceflight for Noguchi, who was a space shuttle crew member on the STS-114 mission in 2005 and a space station crew member from December 2009 to June 2010 as part of Expeditions 22 and 23.

NASA's Commercial Crew Program is working with the American aerospace industry as companies develop and operate a new generation of spacecraft and launch systems capable of carrying crews to low-Earth orbit and to the space station. Commercial transportation to and from the station will provide expanded utility, additional research time and broader opportunities for discovery on the orbital outpost.

The station is a critical testbed for NASA to understand and overcome the challenges of long-duration spaceflight. As commercial companies focus on providing human transportation services to and from low-Earth orbit, NASA is free to focus on building spacecraft and rockets for deep space missions.

Get more information on NASA's Commercial Crew Program at: www.nasa.gov/commercialcrew.

NASA ADMINISTRATOR NAMES DIRECTOR FOR OHIO CENTER

Marla Pérez-Davis Credit: NASA.

NASA Administrator Jim Bridenstine named Marla Pérez-Davis director of the agency's Glenn Research Center in Cleveland. Pérez-Davis has been serving as the acting director of Glenn since Oct. 1, 2019.

"I appreciate both the scope of responsibility Marla has taken on and the estimable abilities she brings to the table as a longtime member of the Ohio community," said NASA Administrator Jim Bridenstine. "I look forward to working with her in her new position as we move forward to achieving NASA's, and the nation's, ambitious Moon to Mars exploration goals."

As Glenn's director, Pérez-Davis will lead a center that has a decades-long tradition of excellence in aeronautics and spaceflight, with more than 3,200 civil service and contractor employees and an annual budget of approximately $933 million.

Prior to this appointment, Pérez-Davis was the deputy director of Glenn, sharing responsibility with the center director for planning, organizing, and managing the agency-level programs and projects assigned to the center.

Her prior leadership positions include serving as deputy director of the center's Research and Engineering Directorate, where she was responsible for leading, planning, coordinating, and managing all phases of Glenn's research and engineering activities to accomplish NASA missions.

Since joining Glenn in 1983, Pérez-Davis has held a number of other key positions, including director of the Aeronautics Research Office; chief of the Project Liaison and Integration Office; and chief of the Electrochemistry Branch. She also participated in the NASA Administrator's Fellowship Program and served her tenure at the University of Puerto Rico-Mayaguez Campus, where she developed and implemented initiatives leading to K-12 teacher's professional development and other outreach activities in Puerto Rico.

Pérez-Davis, a native of Puerto Rico, earned her bachelor's degree from the University of Puerto Rico, a master's degree from the University of Toledo and a doctorate from Case Western Reserve University in chemical engineering. In 2006, she completed NASA's Senior Executive Service Candidate Development Program and the Office of Personnel Management Program. She is the recipient of numerous NASA awards including the NASA Outstanding Leadership Medal and the prestigious Presidential Rank Award for Meritorious Executives.

For information about NASA's missions, programs, and activities, visit: www.nasa.gov.

NASA SELECTS FOUR POSSIBLE MISSIONS TO STUDY THE SECRETS OF THE SOLAR SYSTEM

Artist concept of the solar system. Credit: NASA.

NASA has selected four Discovery Program investigations to develop concept studies for new missions. Although they're not official missions yet and some ultimately may not be chosen to move forward, the selections focus on compelling targets and science that are not covered by NASA's active missions or recent selections. Final selections will be made next year.

NASA's Discovery Program invites scientists and engineers to assemble a team to design exciting planetary science missions that deepen what we know about the solar system and our place in it. These missions will provide frequent flight opportunities for focused planetary science investigations. The goal of the program is to address pressing questions in planetary science and increase our understanding of our solar system.

"These selected missions have the potential to transform our understanding of some of the solar system's most active and complex worlds," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate. "Exploring any one of these celestial bodies will help unlock the secrets of how it, and others like it, came to be in the cosmos."

Each of the four nine-month studies will receive $3 million to develop and mature concepts and will conclude with a Concept Study Report. After evaluating the concept studies, NASA will continue development of up to two missions towards flight.

The proposals were chosen based on their potential science value and feasibility of development plans following a competitive peer-review process.

The selected proposals are:

DAVINCI+ (Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging Plus)

DAVINCI+ will analyze Venus' atmosphere to understand how it formed, evolved and determine whether Venus ever had an ocean. DAVINCI+ plunges through Venus' inhospitable atmosphere to precisely mea-

sure its composition down to the surface. The instruments are encapsulated within a purpose-built descent sphere to protect them from the intense environment of Venus. The "+" in DAVINCI+ refers to the imaging component of the mission, which includes cameras on the descent sphere and orbiter designed to map surface rock-type. The last U.S.-led, in-situ mission to Venus was in 1978. The results from DAVINCI+ have the potential to reshape our understanding of terrestrial planet formation in our solar system and beyond. James Garvin of NASA's Goddard Space Flight Center in Greenbelt, Maryland, is the principal investigator. Goddard would provide project management.

Io Volcano Observer (IVO)

IVO would explore Jupiter's moon, Io, to learn how tidal forces shape planetary bodies. Io is heated by the constant crush of Jupiter's gravity and is the most volcanically active body in the solar system. Little is known about Io's specific characteristics, such as whether a magma ocean exists in its interior. Using close-in flybys, IVO would assess how magma is generated and erupted on Io. The mission's results could revolutionize our understanding of the formation and evolution of rocky, terrestrial bodies, as well as icy ocean worlds in our solar system, and extrasolar planets across the universe. Alfred McEwen of the University of Arizona in Tucson is the principal investigator. The Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland would provide project management.

TRIDENT

Trident would explore Triton, a unique and highly active icy moon of Neptune, to understand pathways to habitable worlds at tremendous distances from the Sun. NASA's Voyager 2 mission showed that Triton has active resurfacing—generating the second youngest surface in the solar system – with the potential for erupting plumes and an atmosphere. Coupled with an ionosphere that can create organic snow and the potential for an interior ocean, Triton is an exciting exploration target to understand how habitable worlds may develop in our solar system and others. Using a single fly-by, Trident would map Triton, characterize active processes, and determine whether the predicted subsurface ocean exists. Louise Prockter of the Lunar and Planetary Institute/Universities Space Research Association in Houston is the principal investigator. NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, would provide project management.

VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy)

VERITAS would map Venus' surface to determine the planet's geologic history and understand why Venus developed so differently than the Earth. Orbiting Venus with a synthetic aperture radar, VERITAS charts surface elevations over nearly the entire planet to create three-dimensional reconstructions of topography and confirm whether processes, such as plate tectonics and volcanism, are still active on Venus. VERITAS would also map infrared emissions from the surface to map Venus' geology, which is largely unknown. Suzanne Smrekar of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, is the principal investigator. JPL would provide project management.

The concepts were chosen from proposals submitted in 2019 under NASA Announcement of Opportunity (AO) NNH19ZDA010O, Discovery Program. The selected investigations will be managed by the Planetary Missions Program Office at NASA's Marshall Space Flight Center in Huntsville, Alabama, as part of the Discovery Program. The Discovery Program conducts space science investigations in the Planetary Science Division of NASA's Science Mission Directorate, guided by NASA's agency priorities and the Decadal Survey process of the National Academy of Sciences.

Established in 1992, NASA's Discovery Program has supported the development and implementation of over 20 missions and instruments. These selections are part of the ninth Discovery Program competition.

For more information about NASA's planetary science, visit: www.nasa.gov/solarsystem.

NASA SELECTS PROPOSALS FOR STUDENT AERONAUTICS, SPACE PROJECTS

In partnership with NASA's Space Grant project and Arizona Space Grant Consortium will allow students to participate in designing, building, and flying entry-level balloon payloads.

NASA awarded funds to 52 proposals aimed at attracting and retaining more students from institutions of higher education in science, technology, engineering, and mathematics programs. Awardees plan to use the funds to increase diversity and inclusion in STEM fields. Each selected submission aligns with goals of both the NASA mission directorates and the agency's Office of STEM Engagement to enable contributions to NASA's work; build a diverse, skilled future STEM workforce;

and strengthen understanding of STEM through powerful connections at NASA.

One awardee, the Arizona Space Grant Consortium, will provide funding for the Arizona STEM Challenges to Educate New Discoverers (ASCEND) program, which will allow students to participate in designing, building, and flying entry-level balloon payloads. Through each payload and launch, students will collect and study data while building excitement for careers in STEM. The ASCEND program will promote NASA and Space Grant to underrepresented student populations.

Nebraska Space Grant Consortium will continue offering project-based learning opportunities to students from the University of Nebraska-Lincoln. As part of the program, participating college students will be able to compete in the Lunabotic challenge at NASA's Kennedy Space Center in Florida. Working in teams, students will be tasked with creating an operational robot to demonstrate techniques and technology for mining minerals on the Moon – a real-world problem NASA must solve in the agency's Moon to Mars exploration initiative and its Artemis program.On the East Coast, the Georgia Space Grant Consortium will bring internship opportunities to students from West Georgia Technical College and Atlanta Metropolitan State College. Both colleges will offer two local-industry internships during the fall and spring semesters. Students from Atlanta Metropolitan State College enrolled in the Engineering Transfer associate degree program will be eligible to apply, as well.

This month, the NASA Space Grant Consortium celebrates its 30th anniversary of inspiring the next generation of explorers. NASA Space Grant Consortia operates in all 50 states, the District of Columbia and the Commonwealth of Puerto Rico. In addition, NASA partners with more than 1,000 affiliates, including colleges, universities, industry, museums, science centers, nonprofit organizations, and state and local agencies, to enrich science and engineering education, research and public outreach efforts for NASA's aeronautics and space projects.

The National Space Grant College and Fellowship Project is managed by NASA's Office of STEM Engagement. Through NASA's higher education program and funding, the agency continues its tradition of investing in STEM education with the goal of developing authentic learning opportunities that are relevant to NASA's mission. These investments develop the skills needed to achieve the nation's exploration goals through a robust, diverse STEM workforce.

Student teams working on entry-level balloon pay-loads.

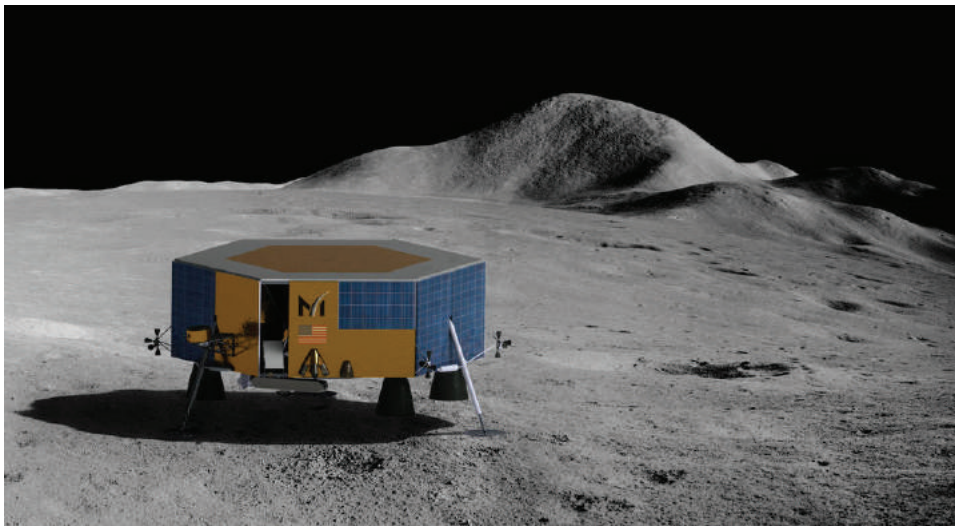
For more information about the awards and proposals funded, visit: go.nasa.gov/2ujeqEB.

NASA AWARDS CONTRACT TO DELIVER SCIENCE, TECH TO MOON AHEAD OF HUMAN MISSIONS

The payloads, which include instruments to assess the composition of the lunar surface, test precision landing technologies, and evaluate the radiation on the Moon, are being delivered under NASA's Commercial Lunar Payload Services (CLPS) initiative as part of the agency's Artemis program. NASA has selected Masten Space Systems of Mojave, California, to deliver and operate eight payloads – with nine science and technology instruments – to the Moon's South Pole in 2022, to help lay the foundation for human expeditions to the lunar surface beginning in 2024.

As the country and the world face the challenges of the COVID-19 pandemic, NASA is leveraging virtual presence and communications tools to safely make progress on these important lunar exploration activities, and to award this lunar surface delivery as it was scheduled prior to the pandemic.

"Under our Artemis program, we are going to the Moon with all of America," said NASA Administrator Jim Bridenstine. "Commercial industry is critical to making our vision for lunar exploration a reality. The science and technology we are sending to the lunar surface ahead of our crewed missions will help us understand the lunar environment better than we ever have before. These CLPS deliveries are on the cutting edge of our work to do great science and support human exploration of the Moon. I'm happy to welcome another of our innovative companies to the group that is ready to start taking our payloads to the Moon as soon as possible."



Masten's XL-1 lunar lander will deliver science and technology payloads to the Moon's South Pole in 2022. Credit: Masten Space Systems.

The $75.9 million award includes end-to-end services for delivery of the instruments, including payload integration, launch from Earth, landing on the Moon's surface, and operation for at least 12 days. Masten Space Systems will land these payloads on the Moon with its XL-1 lander.

"The Moon provides great scientific value, and these payloads will advance what we know and help define and improve the science astronauts can do," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate (SMD). "Our commercial Moon delivery efforts are seeking to demonstrate how frequent and affordable access to the lunar surface benefits both science and exploration."

The payloads that will be delivered have been developed predominantly from the two recent NASA Provided Lunar Payloads (NPLP) and Lunar Surface Instrument and Technology Payloads (LSITP) solicitations.

The nine instruments to be delivered are:

- **Lunar Compact Infrared Imaging System (L-CIRiS)** will deploy a radiometer – a device that measures infrared wavelengths of light – to explore the Moon's surface composition, map its surface temperature distribution, and demonstrate the instrument's feasibility for future lunar resource utilization activities.
- **Linear Energy Transfer Spectrometer (LETS)** is a sensor that will measure the radiation environment on the Moon's surface. The payload also is being flown on a CLPS flight to the Moon in 2021.
- **Heimdall** is a flexible camera system for conducting lunar science on commercial vehicles. This innovation includes a single digital video recorder and four cameras: a wide-angle descent imager, a narrow-angle regolith imager, and two wide-angle panoramic imagers. This camera system is intended to model the properties of the Moon's regolith – the soil and other material that make up the top layer of the lunar surface – and characterize and map geologic features. Other goals for this instrument include characterizing potential landing or trafficability hazards.
- **MoonRanger** is a small robotic rover that weighs less than 30 pounds and will demonstrate communications and mapping technologies. It will demonstrate the ability to move quickly across long distances on the lunar surface with autonomous navigation and without the ability to communicate with Earth in real time. It is a technology that could enable exploration of destinations that are far from lunar landing sites. The MoonRanger will carry the **Neutron Spectrometer System**, which will measure the concentration of hydrogen in the Moon's regolith – a possible indication of the existence of buried water.
- **Mass Spectrometer Observing Lunar Operations (MSolo)** is a device to measure potentially accessible resources on the Moon's surface. It will identify gases coming off a lander during touchdown on the lunar surface to help scientists understand what elements are coming from the lunar surface and which ones are introduced by a lander itself.
- **Near-Infrared Volatile Spectrometer System (NIRVSS)** is a tool to measure surface composition and temperature. The instrument will characterize the variability of the lunar soils and detect volatiles such as methane, carbon dioxide, ammonia and water.
- **Laser Retroreflector Array (LRA)** is a series of eight small mirrors to measure distance and support landing accuracy. It requires no power or communications from the lander and can be detected by future spacecraft orbiting or landing on the Moon.
- **Sample Acquisition, Morphology Filtering, and Probing of Lunar Regolith (SAMPLR**) is a robotic arm that will collect samples of lunar regolith and demonstrate the use of a robotic scoop that can filter and isolate particles of different sizes. The sampling technology makes use of a flight spare from the Mars Exploration Rover project.

Find more information about the agency's Commercial Lunar Payload Services project at: www.nasa.gov/clps.

NASA AWARDS LAUNCH SERVICES CONTRACT FOR THE PSYCHE MISSION

NASA has selected SpaceX of Hawthorne, California, to provide launch services for the agency's Psyche mission. The Psyche mission currently is targeted to launch in July 2022 on a Falcon Heavy rocket from Launch Complex 39A at Cape Canaveral Air Force Station in Florida.

The total cost for NASA to launch Psyche and the secondary payloads is approximately $117 million, which includes the launch service and other mission- related costs.

The Psyche mission will journey to a unique metal-rich asteroid, also named Psyche, which orbits the Sun between Mars and Jupiter. The asteroid is considered unique, as it appears to largely be made of the exposed nickel-iron core of an early planet – one of the building blocks of our solar system.

Deep within rocky, terrestrial planets, including Earth, scientists infer the presence of metallic cores, but these lie unreachably far below the planet's rocky mantles and crusts. Because we cannot see or measure Earth's core directly, the mission to Psyche offers a unique window into the violent history of collisions and accretion that created terrestrial planets.

The launch of Psyche will include two secondary payloads: Escape and Plasma Acceleration and Dynamics Explorers (EscaPADE), which will study the Martian atmosphere, and Janus, which will study binary asteroids.

NASA's Launch Services Program at Kennedy Space Center in Florida will manage the SpaceX launch service. The mission is led by Arizona State University. NASA's Jet Propulsion Laboratory is responsible for the mission's overall management, system engineering, integration, testing and mission operations. Maxar Space Solutions is providing a high-power solar electric propulsion spacecraft chassis.

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

NASA AWARDS ARTEMIS CONTRACT FOR GATEWAY LOGISTICS SERVICES

Credit: SpaceX

NASA has selected SpaceX of Hawthorne, California, as the first U.S. commercial provider under the Gateway Logistics Services contract to deliver cargo, experiments and other supplies to the agency's Gateway in lunar orbit. The award is a significant step forward for NASA's Artemis program that will land the first woman and next man on the Moon by 2024 and build a sustainable human lunar presence.

At the Moon, NASA and its partners will gain the experience necessary to mount a historic human mission to Mars.

SpaceX will deliver critical pressurized and unpressurized cargo, science experiments and supplies to the Gateway, such as sample collection materials and other items the crew may need on the Gateway and during their expeditions on the lunar surface.

"This contract award is another critical piece of our plan to return to the Moon sustainably," said NASA Administrator Jim Bridenstine. "The Gateway is the cornerstone of the long-term Artemis architecture and this deep space commercial cargo capability integrates yet another American industry partner into our plans for human exploration at the Moon in preparation for a future mission to Mars."

NASA is planning multiple supply missions in which the cargo spacecraft will stay at the Gateway for six to 12 months at a time. These firm-fixed price, indefinite delivery/indefinite quantity contracts for logistics services guarantee two missions per logistics services provider with a maximum total value of $7 billion across all contracts

as additional missions are needed.

"Returning to the Moon and supporting future space exploration requires affordable delivery of significant amounts of cargo," said SpaceX President and Chief Operating Officer Gwynne Shotwell. "Through our partnership with NASA, SpaceX has been delivering scientific research and critical supplies to the International Space Station since 2012, and we are honored to continue the work beyond Earth's orbit and carry Artemis cargo to Gateway."

The Gateway Logistics Services contract enables NASA to order missions for as long as 12 years with a 15-year performance period and provides the ability to add new competitive providers. These missions will support NASA's plans for sustainable exploration with both international and commercial partners, while developing the experience and capabilities necessary to send humans to Mars.

"This is an exciting new chapter for human exploration," said Mark Wiese, Deep Space Logistics manager at NASA's Kennedy Space Center in Florida. "We are bringing the innovative thinking of commercial industry into our supply chain and helping ensure we're able to support crews preparing for lunar surface expeditions by delivering the supplies they need ahead of time."

Charged with returning to the Moon in the next four years, NASA's Artemis program will reveal new knowledge about the Moon, Earth and our origins in the solar system. The Gateway is a vital part of NASA's deep space exploration plans, along with the Space Launch System (SLS) rocket, Orion spacecraft, and human landing system that will send astronauts the Moon. One standard logistics service mission is anticipated for each Artemis SLS/Orion crewed mission to the Gateway. Gaining new experiences on and around the Moon will prepare NASA to send the first humans to Mars in the coming years, and the Gateway will play a vital role in this process.

"We're making significant progress moving from our concept of the Gateway to reality," said Dan Hartman, Gateway program manager at NASA's Johnson Space Center in Houston. "Bringing a logistics provider onboard ensures we can transport all the critical supplies we need for the Gateway and on the lunar surface to do research and technology demonstrations in space that we can't do anywhere else. We also anticipate performing a variety of research on and within the logistics module."

For more information about NASA's Moon to Mars exploration plans, visit: www.nasa.gov/moontomars.

NASA SELECTS EARLY-STAGE TECHNOLOGY CONCEPTS FOR NEW, CONTINUED STUDY

Among the selections are 16 new concepts and seven studies that previously received at least one NIAC award. A full list of the 2020 Phase I, II and III selections can be found here.

"NIAC is an innovative program that encourages researchers – and the agency – to think outside of the box for solutions that could overcome challenges facing future science and exploration missions," said Walt Engelund, deputy associate administrator for programs within NASA's Space Technology Mission Directorate (STMD). "We're excited about the new concepts and to see how additional time and resources advances the research selected for follow-on Phase II and III studies."

Credits: NASA JPL/Slava Turyshev

A mission concept to image Earth-like planets outside of the solar system was selected for a Phase III study. Slava Turyshev, a researcher at NASA's Jet Propulsion Laboratory in Pasadena, California, will receive a $2 million grant to further mature the concept and related technologies.

During his Phase I and Phase II NIAC research, Turyshev outlined the feasibility of a solar gravity lens to enable enhanced viewing of planets orbiting other stars, known as exoplanets. He also developed a mission architecture that uses multiple small spacecraft and solar sail technology to propel them to their target destination 50 billion miles from Earth.

"This is only the third study selected for Phase III funding in the history of the program," said NIAC Program Executive Jason Derleth. "We're excited by its potential to bring us closer to imaging an exoplanet in detail, at a resolution comparable to the well-known Apollo 8 Earthrise photo."

The selected Phase I and II studies will explore the overall viability of a technology and develop them into mission concepts. Areas researchers will study include mapping asteroids and other small bodies in the solar system with hopping probes, making on-demand pharmaceuticals in space, and extracting water on the Moon. Several of the concepts could inform capabilities relevant to NASA's Artemis program, which will land the first woman and

next man on the Moon in 2024 and establish a sustainable presence on and around the Moon by 2028.

NASA selected the proposals through a peer-review process that evaluates innovation and technical viability. All projects are still in the early stages of development, with most requiring a decade or more of technology maturation, and are not official NASA missions.

NIAC supports visionary research ideas through multiple progressive phases of study. Phase I studies receive $125,000 and are nine-month efforts. Eligible recipients of Phase I awards can submit proposals for a follow-on Phase II study. Selected Phase II researchers receive $500,000 grants to further develop their concepts for up to two years. Phase III is designed to strategically transition NIAC concepts with the highest potential impact for NASA other government agencies or commercial partners. Phase III researchers receive $2 million grants to develop and mature their mission concept over two years.

NIAC is funded by STMD, which is responsible for developing the new cross-cutting technologies and capabilities needed by the agency to achieve its current and future missions.

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

NASA SELECTS PROPOSALS TO STUDY VOLATILE STARS, GALAXIES, COSMIC COLLISIONS

NASA has selected proposals for four missions that would study cosmic explosions and the debris they leave behind, as well as monitor how nearby stellar flares may affect the atmospheres of orbiting planets.

Following detailed evaluations, the agency intends to select two proposals in 2021 to be the next astrophysics missions under the Explorers Program. The selected missions will be targeted for launch in 2025.

"These promising proposals under the Explorers Program bring out some of the most creative, innovative ways to help uncover the secrets of the universe," said Thomas Zurbuchen, associate administrator of the agency's Science Mission Directorate in Washington. "From studying stars and planets outside our solar system to seeking answers to the largest cosmic mysteries, I look forward to the breakthrough science from these modest size missions."

Two astrophysics Small Explorer (SMEX) missions and two Missions of Opportunity (MO) proposals were competitively selected, based on potential science value and feasibility of development plans. Excluding the cost of launch, SMEX mission costs are capped at $145 million each, and MO costs are capped at $75 million each.

Each SMEX proposal will receive $2 million to conduct a nine-month mission concept study. The selected proposals are:

The Extreme-ultraviolet Stellar Characterization for Atmospheric Physics and Evolution (ESCAPE) Mission

- ESCAPE would study nearby stars, watching for rapid, strong ultraviolet flares. It aims to determine how likely such flares are to strip the atmosphere from a rocky planet orbiting the star, affecting conditions for habitability.
- Principal investigator: Kevin France at the University of Colorado at Boulder.

The Compton Spectrometer and Imager (COSI)

- COSI would scan our Milky Way galaxy, measuring gamma rays from radioactive elements produced during stellar explosions to map the recent history of star death and element production. It would also measure polarization, to improve our understanding of how distant energetic cosmic explosions produce gamma rays.
- Principal investigator: John Tomsick at the University of California, Berkeley.

MO proposals will each receive $500,000 to conduct a nine-month implementation concept study. The selected proposals are:

The Gravitational-wave Ultraviolet Counterpart Imager Mission

- The Gravitational-wave Ultraviolet Counterpart Imager consists of two independent small satellites, each scanning the sky in a different ultraviolet band. It would detect the light from hot gas in the explosion that follows a burst of gravitational waves caused by merging neutron stars or a neutron star merging with a black hole. Between these events, the mission would map the sky in ultraviolet light, finding other bright objects such as exploding stars.
- Principal investigator: Stephen (Brad) Cenko at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

LEAP – A LargE Area burst Polarimeter

- Mounted on the International Space Station, LEAP would study the energetic jets launched during the explosive death of a massive star, or the merger of compact objects such as neutron stars. LEAP's measurements of polarization in gamma-ray bursts could distinguish between competing theories for the nature of the jets, which move out at close to the speed of light. LEAP would complement NASA's Imaging X-ray Polarimetry Explorer (IXPE), scheduled to launch in 2021.
- Principal investigator: Mark McConnell at the University of New Hampshire in Durham.

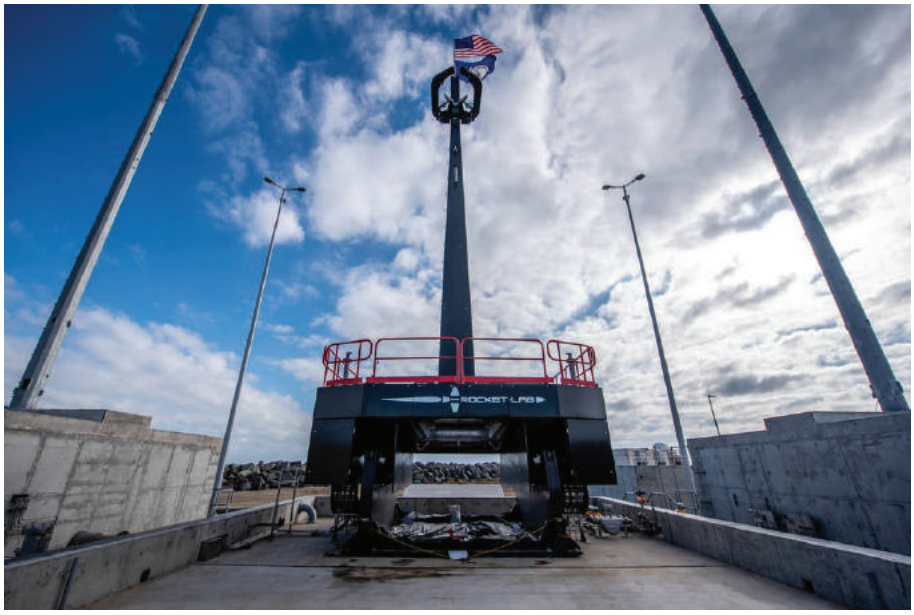
"Each of these missions would take the next steps in some of the hottest areas of astrophysics today," said Paul Hertz, Astrophysics Division director at NASA Headquarters. "With the high science rewards for low dollar amounts, Explorers missions successfully fill the scientific gaps in our current fleet of space observatories."

The Explorers Program, managed by Goddard, is the oldest continuous NASA program designed to provide frequent, low-cost access to space using principal investigator-led space science investigations relevant to the Science Mission Directorate's astrophysics and heliophysics programs.

Since the launch in 1958 of Explorer 1, which discovered Earth's radiation belts, the Explorers Program has launched more than 90 missions, including the Uhuru and Cosmic Background Explorer (COBE) missions that led to Nobel Prizes for their investigators.

For information about the Explorers Program visit: explorers.gsfc.nasa.gov/index.html.

NASA AWARDS CONTRACT TO LAUNCH CUBESAT TO MOON FROM VIRGINIA

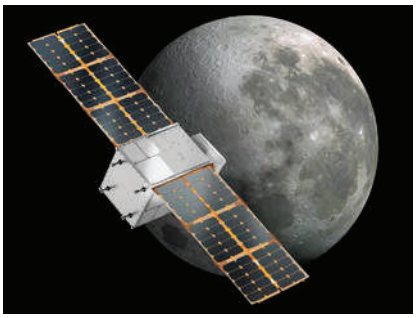


Credit: Rocket Lab.

NASA has selected Rocket Lab of Huntington Beach, California, to provide launch services for the Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) CubeSat.

Rocket Lab, a commercial launch provider licensed by the Federal Aviation Administration, will launch the 55-pound CubeSat aboard an Electron rocket from NASA's Wallops Flight Facility in Virginia. After launch, the company's Photon platform will deliver CAPSTONE to a trans-lunar injection. The engine firing will allow the CubeSat to break free of Earth's gravity and head to the Moon. Then, CAPSTONE will use its own propulsion system to enter a cislunar orbit, which is the orbital area near and around the Moon. The mission is targeted for launch in early 2021 and will be the second lunar mission to launch from Virginia.

Following a three-month trip to the Moon, CAPSTONE will enter a near rectilinear halo orbit, which is a highly elliptical orbit over the Moon's poles, to verify its characteristics for future missions and conduct a navigation demonstration with NASA's Lunar Reconnaissance Orbiter. CAPSTONE will serve as a pathfinder for the lunar spaceship Gateway, a key component of NASA's Artemis program.



Credit: NASA

The firm-fixed-price launch contract is valued at $9.95 million. In September, NASA awarded a $13.7 million contract to Advanced Space of Boulder, Colorado, to develop and operate the CubeSat.

After a final design review this month, Advanced Space and Tyvak Nano-Satellite Systems Inc. of Irvine, California, will start building and testing the spacecraft.

CAPSTONE is managed by NASA's Small Spacecraft Technology program within the agency's Space Technology Mission Directorate. Advanced Exploration Systems within NASA's Human Exploration and Operations Mission Directorate supports the launch and mission operations.

To learn more about NASA's Launch Services Program, visit: www.nasa.gov/centers/kennedy/launchingrockets/index.html.

NASA COMMEMORATES 50TH ANNIVERSARY OF APOLLO 13, "A SUCCESSFUL FAILURE"

Credit: NASA

As NASA marks the 50th anniversary of the Apollo 13 mission – which has become known as "a successful failure" that saw the safe return of its crew in spite of a catastrophic explosion – the agency is sharing a variety of resources, recognizing the triumph of the mission control team and the astronauts, and looking at how those lessons learned can be applied to its lunar Artemis program.

"Our goal 50 years ago was to save our valiant crew after sending them around the Moon and return them safely to Earth," said NASA Administrator Jim Bridenstine. "Our goal now is to return to the Moon to stay, in a sustainable way. We are working hard to ensure that we don't need to respond to this kind of emergency in Artemis, but to be ready to respond to any problems we don't anticipate."

The crew of Apollo 13 consisted of Commander James (Jim) Lovell Jr., Command Module Pilot John Swigert Jr. and Lunar Module Pilot Fred Haise Jr. Their Saturn V rocket launched at 2:13 p.m. EST on April 11, 1970, from Launch Pad 39A at NASA's Kennedy Space Center in Florida. The command module was named Odyssey, and the lunar module was named Aquarius.

While en route to the Moon on April 13, an oxygen tank in the Apollo service module ruptured. The lunar landing and moonwalks, which would have been executed by Lovell and Haise, were aborted as a dedicated team of flight controllers and engineering experts in the Apollo Mission Control Center devoted their efforts to developing a plan to shelter the crew in the lunar module as a "lifeboat" and retain sufficient resources to bring the spacecraft and its crew back home safely. Splashdown occurred in the Pacific Ocean at 1:07 p.m. April 17, after a flight that lasted five days, 22 hours and 54 minutes.

A wealth of new content and programming, historic documents, still and video imagery are available online, including previously unreleased conversations

between the crew of Apollo 13 and the recently restored Apollo Mission Control Center in Houston. This dialogue includes the now-famous exchange between Lovell and mission control during which Lovell utters the phrase, "Hey Houston, we've had a problem here."

A group of flight controllers gathers around the console of Glenn S. Lunney (seated, nearest camera), Shift 4 flight director, in the Mission Operations Control Room (MOCR) of Mission Control Center (MCC), located in Building 30 at the Manned Spacecraft Center (MSC). Their attention is drawn to a weather map of the proposed landing site in the South Pacific Ocean. Among those looking on is Dr. Christopher C. Kraft, deputy director, MSC, standing in black suit, on right. When this photograph was taken, the Apollo 13 lunar landing mission had been canceled, and the problem-plagued Apollo 13 crew members were in trans-Earth trajectory attempting to bring their crippled spacecraft back home. Credit: NASA.

Among the resources NASA made available are:

Apollo 13 on NASA TV

NASA TV is commemorating the anniversary with multiple videos and interviews, anchored by an original special program, "Apollo 13: Home Safe". The 30-minute program features an interview with Lovell, a conversation with Haise and Flight Directors Gene Kranz and Glynn Lunney, and engineer Hank Rotter, in the restored Apollo mission control room mixed with archival footage from the mission. In addition, NASA TV will air replays of historic mission footage and "pop-up" mission factoids at the exact times the events happened 50 years ago.

Apollo 13 Views of the Moon in 4K

This video, from the Scientific Visualization Studio at NASA's Goddard Space Flight Center in Greenbelt, Maryland, uses data gathered from NASA's Lunar Reconnaissance Orbiter spacecraft to recreate some of the stunning views of the Moon the Apollo 13 astronauts saw on their perilous journey around the farside of the Moon. These visualizations, in 4K resolution, depict many different views of the lunar surface, starting with earthset and sunrise and concluding with the time Apollo 13 reestablished radio contact with mission control.

Houston, We Have A Podcast

Listen as Lovell and Haise remember the fateful mission from their perspective 50 years later and reflect on the highlights of their expansive careers and share wisdom gained from their famous mission on its 50th anniversary. Houston, We Have A Podcast is the official podcast of NASA's Johnson Space Center, in Houston.

Apollo 13 In Real Time

This searchable Apollo 13 website is a NASA-funded project designed by NASA contractor Ben Feist that provides viewers with access to all of the photographs, film, transcripts and audio from the mission. Visitors can replay the mission in real time or scroll through to find highlights. The site includes more than 17,000 hours of audio recorded from the various positions at mission control. It also includes video from NASA press conferences as they occurred, as well as newly audio-synched, previously silent, mission control footage.

Most of the Apollo 13 flight control team audio tapes were digitized in cooperation with the University of Texas, Dallas. Five additional tapes were found with the help of the National Archives and were digitized earlier this year by NASA.

Apollo 13 In-Flight Video Recordings

These TV transmissions are film recordings of television transmissions, or kinescopes, transferred onto broadcast videotape, then converted to digital files and posted to Johnson's Internet Archive collection.

Apollo 13 Imagery Collections

NASA makes imagery available in many formats and resolutions, and NASA's Image and Video Library contains many items related to Apollo 13. Apollo 13 images also are available on the Apollo Lunar Surface Journal, a volunteer-created site managed by NASA's History Office.

Apollo 13 Presentation

Download and adapt these presentation slides about Apollo 13 to your audience and setting. The notes section for each slide contains the image source and explanations.

Additional Apollo Resources

Additional Apollo audio and video resources are available for download in the highest resolutions available in this publicly curated collection on the Internet Archive. Additional resources related to all the Apollo missions are available at NASA's Apollo 50th Anniversary website.

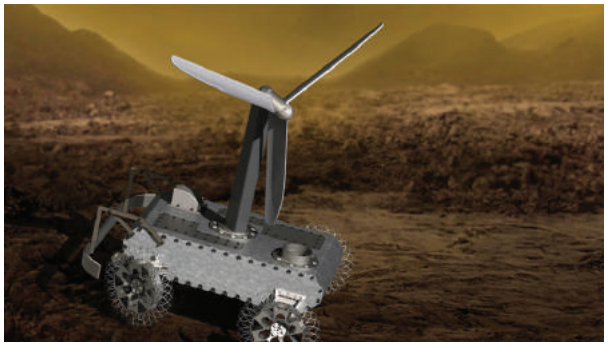
NASA WANTS YOUR HELP DESIGNING A VENUS ROVER CONCEPT

NASA's Jet Propulsion Laboratory in Pasadena, California, under a grant from the NASA Innovative Advanced Concepts program, is running a public challenge to develop an obstacle avoidance sensor for a possible future Venus rover. The "Exploring Hell: Avoiding Obstacles on a Clockwork Rover" challenge is seeking the public's designs for a sensor that could be incorporated into the design concept.

Venus is an extreme world. With a surface temperature in excess of 840 degrees Fahrenheit and a surface pressure 90 times that of Earth, Venus can turn lead into a puddle and crush a nuclear-powered submarine with ease. While many missions have visited our sister planet, only about a dozen have made contact with the surface of Venus before quickly succumbing to the oppressive heat and pressure.

Exploring and studying different geologic units across the surface of Venus could help us understand the planet's evolution, and could contribute to a better understanding of Earth's climate.

Powered by wind, AREE is intended to spend months, not minutes, exploring the Venus landscape. AREE could collect valuable, long-term longitudinal scientific data. As the rover explores the planet, it must also detect obstacles in its path, such as rocks, crevices and steep terrain. And NASA is crowdsourcing help for that sensor design. The challenge's winning sensor will be incorporated into the rover concept and could potentially one day be the mechanism by which a rover detects and navigates around obstructions.



An illustration of a concept for a possible wind-powered Venus rover. Credit: NASA/JPL-Caltech.

The difficulty of this challenge is in designing a sensor that does not rely on electronic systems. Current state-of-the-art electronics fail at just over 250 degrees Fahrenheit and would easily succumb to the extreme Venus environment. That is why NASA is turning to the global community of innovators and inventors for a solution.

Participants will have an opportunity to win a first-place prize of $15,000. Second place wins $10,000; and third place, $5,000. JPL is working with the NASA Tournament Lab to execute the challenge on the heroX crowdsourcing platform. Submissions will be accepted through May 29, 2020.

For more information about the challenge and how to enter, visit: *www.herox.com/VenusRover*.

THOUSANDS APPLY TO JOIN NASA'S ARTEMIS GENERATION, #BEANASTRONAUT

More than 12,000 people have applied to join NASA's next class of astronauts, demonstrating strong national interest to take part in America's plans to explore the Moon and take humanity's next giant leap – human missions to Mars.

Applications were received from every U.S. state, the District of Columbia, and four U.S. territories. However, the process is just beginning for NASA's Astronaut Selection Board, which will assess the applicants' qualifications and invite the most qualified candidates to the agency's Johnson Space Center in Houston for interviews and medical tests before making a final selection. NASA expects to introduce the new astronaut candidates in the summer of 2021.

Thousands of Americans apply to be the next Artemis generation astronauts. Credit: NASA.

"We've entered a bold new era of space exploration with the Artemis program, and we are thrilled to see so many incredible Americans apply to join us," said NASA Administrator Jim Bridenstine. "The next class of Artemis Generation astronauts will help us explore more of the Moon than ever before and lead us to the Red Planet."

The application for the newest class of astronauts opened March 2 and closed March 31. The number of people who applied to be an astronaut represents the second-highest number of applications NASA has ever received,

surpassed only by the record of 18,300 set by the most recent class of astronauts who graduated in January.

For this round of applications, NASA increased the education requirement for applicants from a bachelor's degree to a master's degree in a science, technology, math, or engineering field. In addition, the application period was shortened from two months to one.

"We're able to build such a strong astronaut corps at NASA because we have such a strong pool of applicants to choose from," said Anne Roemer, manager of the Astronaut Selection Board and director of human resources at Johnson. "It's always amazing to see the diversity of education, experience and skills that are represented in our applicants. We are excited to start reviewing astronaut applications to identify the next class of astronaut candidates."

Since the 1960s, NASA has selected 350 people to train as astronaut candidates for its increasingly challenging missions to explore space. With 48 astronauts in the active astronaut corps, more will be needed to serve as crew aboard spacecraft bound for multiple destinations and propel exploration forward as part of Artemis missions and beyond.

Once selected, the astronaut candidates will go through approximately two years of initial skills training, such as spacewalking, robotics, and spacecraft systems, as well as expeditionary behavior skills, such as leadership, followership, and teamwork. After completing training, the new astronauts could launch on American rockets and spacecraft — developed for NASA's Commercial Crew Program — to live and work aboard the International Space Station, 250 miles above Earth. There they will take part in experiments that benefit life at home and prepare us for the Moon and Mars.

This new class also may launch aboard NASA's powerful new Space Launch System rocket and Orion spacecraft for Artemis missions to the Moon. Beginning in 2024, NASA will send the first woman and next man to the lunar surface and will establish sustainable lunar exploration by 2028. Gaining insights from new experiences on and around the Moon will prepare NASA to send the first humans to Mars in the 2030s.

For more information about NASA astronauts, visit: www.nasa.gov/astronauts.

NASA PSYCHE MISSION LAUNCHES FREE ONLINE CLASS ON BUILDING EFFECTIVE TEAMS, COVERING TEAM CULTURE, DIVERSITY, BIAS, AND INCLUSIVITY

Course on building effective teams covers team culture, diversity, bias, and inclusivity

IImagine a team of scientific experts representing 15 distinct institutions, all highly regarded in their fields with a support team of at least 350. Now imagine that team working on a finely tuned mission to space, an exploration like nothing before, a trip to study a unique metal asteroid orbiting the Sun between Mars and Jupiter.

Now that's teamwork.

NASA's Psyche mission is being led by Arizona State University. NASA's Jet Propulsion Laboratory is responsible for mission management, operations, and navigation. The spacecraft's solar-electric propulsion chassis will be built by SSL with a payload that includes an imager, magnetometer, and a gamma-ray spectrometer.

The mission's scientific goals and objectives are vast and include giving scientists the opportunity to learn more about Earth's own metallic core. For more details: Psyche: Mission to a Metal World.

Teaching NASA's Global Mindset

It would be difficult to find a more apt example of a project that requires people with a Global Mindset, people who know how to work as a team, team members who are able to work well with people who are unlike themselves.

"Every endeavor is a human endeavor, and going to space is truly about the team," said Psyche Mission principal investigator Lindy Elkins-Tanton, a planetary scientist, professor with expertise in planet formation and evolution, and Director of ASU's School of Earth and Space Exploration.

The NASA Psyche Mission is scheduled to launch in 2022 and the Psyche spacecraft won't reach the metallic asteroid until 2026.

This month, the program launched a free online course for people around the world to learn how to work successfully on a team. The lessons include interviews from experts at ASU and NASA. And the course features Thunderbird's Mansour Javidan, Garvin Distinguished Professor and Director

of Najafi Global Mindset Institute.

"For a successful mission, we want to build the very best teams and we are so fortunate to have one of the world's most prominent experts on teams, Mansour Javidan, help us with this course," said Elkins-Tanton.

Team Building and Team Diversity

Called "The Inclusive Mindset: Tools for Building Positive Team Culture," the course is part of the Psyche Mission Innovation Toolkit. Students will learn about team building and team diversity. And the only prerequisite to enroll is an interest in the behind-the-scenes work that goes into running a successful team.

"Today's organizations are increasingly encouraging and supporting workforce diversity," said Javidan. "So, it is critical for students, employees, and managers to learn the tools that will help them work effectively in diverse teams. Such training can improve the efficiency of the team and the quality of its work, while reducing stress and misunderstanding."

This course is designed to help learners understand the unique challenges of a diverse team and provides intuitive tools to help them address these challenges and take actions to be more successful in working with others. It also provides both self- and team-assessment instruments to help learners gain a deeper understanding of their own – and their team's – strengths and weaknesses.

Javidan teaches these concepts and the essential skills of global leadership in depth in Thunderbird's Global Mindset for Strategic Leadership program.

Learning Teamwork NASA-Style

Global Mindset is a set of individual characteristics, which help you do a better job of working with people who are different than you. Students who take the NASA course will take away an understanding of core individual qualities and attributes that would enable global business success, in addition to being vital on a space mission.

As Javidan describes it: "Over the past 20 years companies in many countries have been looking for opportunities outside their own country. What they have found is that sometimes things are not as easy as they thought. Sometimes they experience challenges that surprise them."

"Many executives and managers who are successful in their home market face challenges outside their home market," he explains. "What separates those who are successful from those who aren't? In what way can we help managers succeed across countries? Through research, we were able to identify individual characteristics that impacted success working with people from other parts of the world. The combination of those characteristics is called Global Mindset."

The course is divided into seven modules that cover topics of team culture, diversity, bias, and inclusivity, as well as developing an inclusive mindset while building and maintaining a successful team. During the course, enrolled learners can create their own online portfolio – called an "ePortfolio" – of their work and reflections. Participants who complete the course receive a downloadable and printable certificate of completion.

For more information about the Psyche Mission courses, see Inclusive Mindset: Tools for Building Positive Team Culture.

NEW NASA PODCAST HELPS LISTENERS EXPLORE OUR "CURIOUS UNIVERSE"

NASA's newest podcast is taking listeners on an adventure to explore the wonders of Earth and help unravel the mysteries of the universe.

NASA's Curious Universe explores the wild and wonderful places on our home planet and beyond. Host Padi Boyd transports listeners into the world of NASA's missions, projects and people. Each episode is an invitation to an adventure with a NASA expert, such as astronaut Nick Hague and astrophysicist Michelle Thaller.

The show, which launches Monday, April 6, visits a wide range of tour stops along NASA's journeys in science and spaceflight. Listeners will traverse the Amazon rainforest, dive into an astronaut training pool, and peer inside a lab where "space crafters" sew for NASA missions. The premiere episode debuted April 13, honoring 50 years of Earth Day. New episodes are released every Monday.

NASA's Curious Universe is for everyone and doesn't require any prior knowledge of NASA or its missions. First-time explorers welcome!

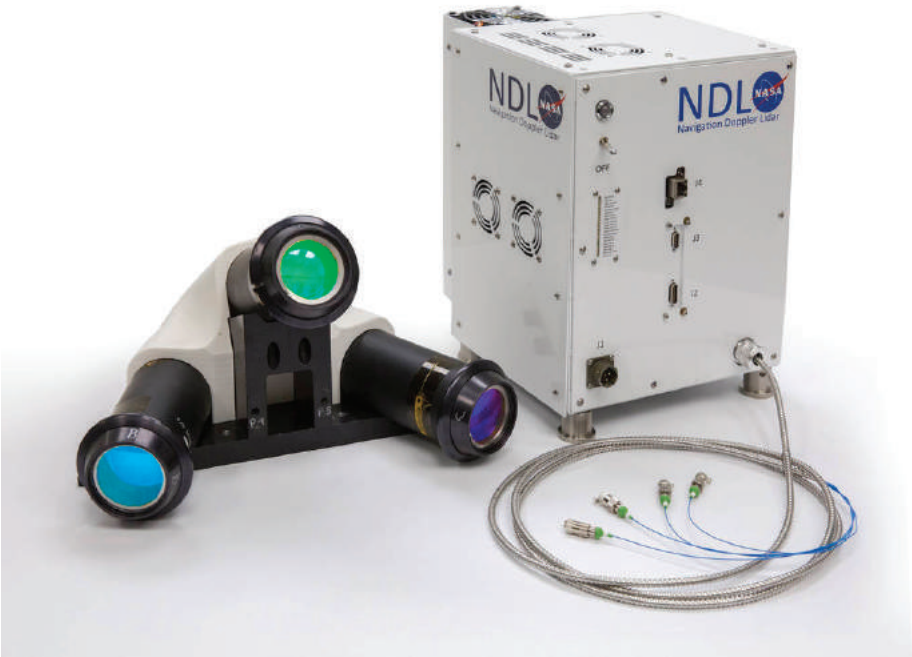
Find the NASA's Curious Universe trailer now on Apple Podcasts, Google Podcasts, and Soundcloud.

NASA's Curious Universe is the latest addition to NASA's podcast portfolio,

which includes Houston, We Have a Podcast, On a Mission and Gravity Assist, among others.

Discover all of NASA's podcasts at: nasa.gov/podcasts.

NEW SPINOFF PUBLICATION SHARES HOW NASA INNOVATIONS BENEFIT LIFE ON EARTH



Navigational Doppler Lidar is an instrument developed at NASA's Langley Research Center in Hampton, Virginia to land spacecraft safely, but it could help self-driving cars successfully navigate rush-hour traffic. Credit: NASA.

As NASA pushes the frontiers of science and human exploration, the agency also advances technology to modernize life on Earth, including drones, self-driving cars and other innovations.

NASA's diverse missions spur the creation and improvement of thousands of new products that make life better for people around the world. Dozens of the latest examples are featured in the newest edition of NASA's Spinoff publication, including several from NASA's Jet Propulsion Laboratory in Southern California, and many illustrating how NASA is working to shape the coming revolution of autonomous vehicles on the roads and in the air.

In this issue of Spinoff, readers will learn about Langley's contributions to:

- A special 3D imager with a global shutter flash lidar that's helping NASA sample an asteroid and could soon help cars safely navigate the road.
- Navigational Doppler Lidar, an instrument developed to land spacecraft safely, that could help self-driving cars successfully navigate rush-hour traffic.
- A weight-estimating software that is helping design urban air taxis.
- Unique sensors that are improving aerodynamic design and aircraft performance.
- A new laser that enables precise measurements for weather forecasting.
- A swarming technology that will let drones work cooperatively to monitor crops and infrastructure and could improve military training.
- And a new software that can help reduce uncertainty in complex systems used to validate autonomous systems for planes and drones. It can also predict how drug molecules might behave in the body.

The publication also includes a "Spinoffs of Tomorrow" section, which highlights 20 NASA technologies available for license, including a nanosensor array that can diagnose illness by scent, a drought assessment and prediction system, and a computer monitoring system that alerts when hackers try to infiltrate.

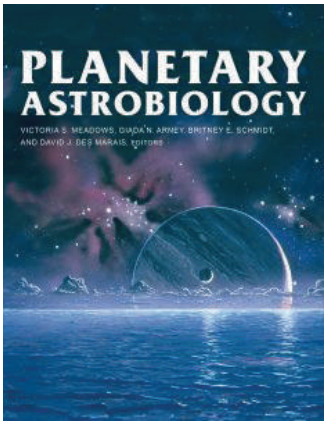
Spinoff highlights the many successes of the agency's Technology Transfer program within STMD, which is charged with finding the widest possible applications for NASA technology through partnerships and licensing agreements with industry, ensuring that NASA's investments in its missions and research find additional applications that benefit the nation and the world.

Print and digital versions of the latest issue of Spinoff are available at: https://spinoff.nasa.gov.

An iPad version, including shortened versions of the stories, multimedia and interactive features, is also available for download in the iTunes store.

For more information about NASA's Technology Transfer program, visit: *technology.nasa.gov*.

NEW AND NOTEWORTHY

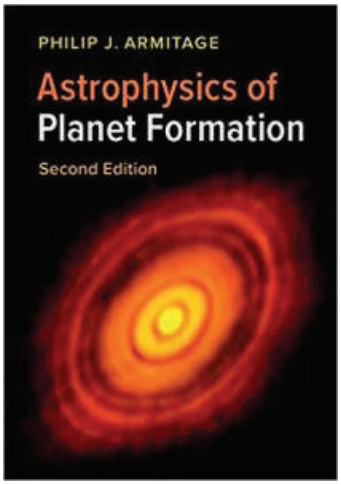


PLANETARY ASTROBIOLOGY

Edited by Victoria Meadows, David J. Des Marais, Giada Arney, and Britney Schmidt

University of Arizona Press, 2020, 504 pp., Hardcover. $75.00 uapress.arizona.edu

Are we alone in the universe? How did life arise on our planet? How do we search for life beyond Earth? These profound questions excite and intrigue broad cross sections of science and society. Answering these questions is the province of the emerging, strongly interdisciplinary field of astrobiology. Life is inextricably tied to the formation, chemistry, and evolution of its host world, and multidisciplinary studies of solar system worlds can provide key insights into processes that govern planetary habitability, informing the search for life in our solar system and beyond. Planetary Astrobiology brings together current knowledge across astronomy, biology, geology, physics, chemistry, and related fields, and considers the synergies between studies of solar systems and exoplanets to identify the path needed to advance the exploration of these profound questions. Planetary Astrobiology represents the combined efforts of 50 international experts consolidated into 19 chapters and provides an accessible, interdisciplinary gateway for new students and seasoned researchers who wish to learn more about this expanding field. Readers are brought to the frontiers of knowledge in astrobiology via results from the exploration of our own solar system and exoplanetary systems. The overarching goal of Planetary Astrobiology is to enhance and broaden the development of an interdisciplinary approach across the astrobiology, planetary science, and exoplanet communities, enabling a new era of comparative planetology that encompasses conditions and processes for the emergence, evolution, and detection of life.



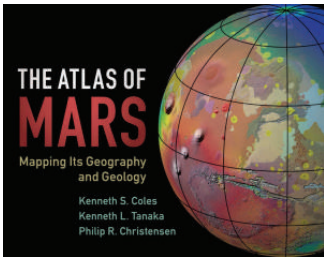
ASTROPHYSICS OF PLANET FORMATION, SECOND EDITION

By Philip J. Armitage

Cambridge University Press, 2020, 342 pp., Hardcover. $79.99. www.cambridge.org

Concise and self-contained, this textbook gives a graduate-level introduction to the physical processes that shape planetary systems, covering all stages of planet formation. Writing for readers with undergraduate backgrounds in physics, astronomy, and planetary science, Armitage begins with a description of the structure and evolution of protoplanetary disks, moves on to the formation of planetesimals, rocky, and giant planets, and concludes by describing the gravitational and gas dynamical evolution of planetary systems. He provides a self-contained account of the modern theory of planet formation and, for more advanced readers, carefully selected references to the research literature, noting areas where research is ongoing. The second edition has been thoroughly revised to include observational results from NASA's Kepler mission, ALMA observations and the JUNO mission to Jupiter, new theoretical ideas including pebble accretion, and an up-to-date understanding in areas such as disk evolution and planet migration.

Note: Product descriptions are taken from publishers' websites. LPI is not responsible for factual content.

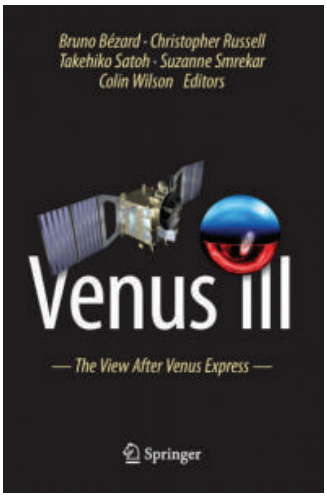


THE ATLAS OF MARS: Mapping Its Geography and Geology

By Kenneth S. Coles, Kenneth L. Tanaka, and Philip R. Christensen

Cambridge University Press, 2019, 300 pp., Hardcover. $49.99. www.cambridge.org

Planetary scientist and educator Ken Coles has teamed up with Ken Tanaka from the United States Geological Survey's Astrogeology team, and Phil Christensen, Principal Investigator of the Mars Odyssey orbiter's THEMIS science team, to produce this all-purpose reference atlas, The Atlas of Mars. Each of the 30 standard charts includes a full-page color topographic map at 1:10,000,000 scale, a THEMIS daytime infrared map at the same scale with features labeled, a simplified geologic map of the corresponding area, and a section describing prominent features of interest. The atlas is rounded out with extensive material on Mars' global characteristics, regional geography and geology, a glossary of terms, and an indexed gazetteer of up-to-date martian feature names and nomenclature. This is an essential guide for a broad readership of academics, students, amateur astronomers, and space enthusiasts, replacing the NASA atlas from the 1970s.

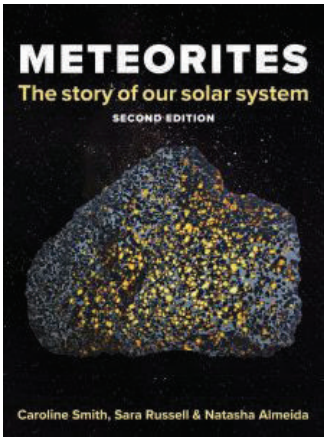


VENUS III: The View After Venus Express

Edited by Bruno Bézard, Christopher Russell, Takehiko Satoh, Suzanne Smrekar, and Colin Wilson

Springer, 2020, 533 pp., Hardcover. $179.99. www.springer.com

The Venus Express spacecraft, which was launched in November 2005 and ceased activity in December 2014, has brought about a new wealth of data on Venus' atmosphere, surface, and space environment. Following the completion of this landmark mission, an overview of the current state of scientific understanding of Venus has been assembled into a single collection. The 10 papers in this book, written by an international team of specialists, are the products of this effort. They review our knowledge of Venus' interior structure, surface composition, and atmosphere in terms of thermal structure, dynamics, composition, chemistry, clouds, aeronomy, and interaction with the solar wind. Additionally, they identify the questions and measurements that remain open for study in ongoing and future research and exploration efforts. The resulting volume is primarily intended for students and researchers of planetary science. This book is a follow-up to the pioneering book Venus, published in 1983, and its successor volume Venus II, published in 1997, both of which stood at their respective times as the most authoritative single-volume works available on the planet.



METEORITES: The Story of Our Solar System, Second Edition

By Caroline Smith, Sara Russell, and Natasha Almeida

Firefly Books, 2019, 128 pp., Paperback. $24.95. www.fireflybooks.com

Leading experts in the field provide a compelling introduction to the space rocks that enter Earth's atmosphere at speeds ranging from 25,000 mph to 160,000 mph. Scientists estimate that about 48.5 tons of meteoritic material falls on Earth each day. These messengers from space give us a unique insight into the nature of the material that was present when our solar system formed. Many of the specimen meteorites in this second edition were re-photographed to improve quality, and the optical microscopy shots were updated. There is also much new information on discoveries and developments in the study of meteorites, including meteorite falls and craters, and new information on ones previously covered; use of weather radar to detect and analyze meteorites, such as the 28,000-mph January 18, 2018, Michigan "fireball"; how astrophysicists determine if a meteorite comes from Mars, and information about the martian meteorites found to date; and updated information on the results of the European Space Agency's Rosetta Mission in which a controlled impact was successfully completed into Comet 67P after investigating it with a probe for more than two years.

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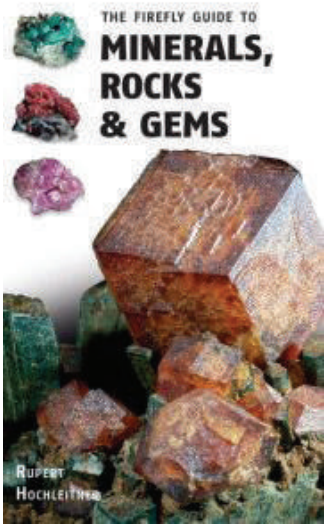
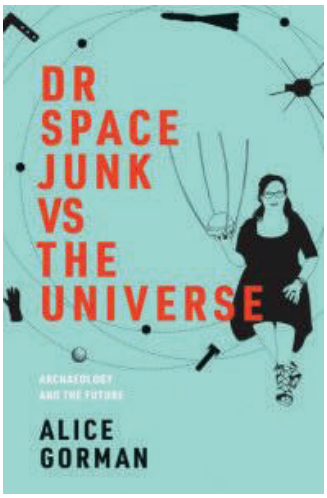


THE FIREFLY GUIDE TO MINERALS, ROCKS AND GEMS

By Rupert Hochleitner

Firefly Books, 2019, 256 pp., Paperback, $19.95. www.fireflybooks.com

The Firefly Guide to Minerals, Rocks and Gems is designed for easy and reliable identification of minerals, rocks, and gems. The identification process begins with the stone's streak color, which is how the book is organized: blue, red, yellow, brown, green, black, and white. Using a sequence of straightforward questions and answers — aided by over 1000 photographs and drawings — the book narrows down the possibilities among 350 minerals, rocks, and gems to reach the conclusive classification. Identification is then further narrowed down with respect to crystal form, hardness, luster, density, cleavage, break, and tenacity. Each rock's main photograph shows the general or typical view, and identification tips about features are noted in the margins of the respective page. Similar stones are presented for comparison, and tips are provided that can eliminate imposters. Drawings show the mineral's crystal shape, and the chemical formula reveals the elements from which the mineral is composed. There is also information about where the stone is typically found and some of the ways that humans have utilized it. Packed with beautiful photographs of Earth's many minerals, rocks, and gems, this book is perfect for amateur mineralogists and collectors.



DR. SPACE JUNK VS. THE UNIVERSE: Archaeology and the Future

By Alice Gorman

MIT Press, 2019, 304 pp., Hardcover. $27.95. mitpress.mit.edu

Alice Gorman is a space archaeologist: She examines the artifacts of human encounters with space. These objects, left behind on Earth and in space, can be massive (dead satellites in eternal orbit) or tiny (discarded zip ties around a defunct space antenna). They can be bold (an American flag on the Moon) or hopeful (messages from Earth sent into deep space). They raise interesting questions: Why did Elon Musk feel compelled to send a red Tesla into space? What accounts for the multiple rocket-themed playgrounds constructed after the Russians launched Sputnik? Gorman — affectionately known as "Dr. Space Junk" — takes readers on a journey through the solar system and beyond, deploying space artifacts, historical explorations, and even the occasional cocktail recipe in search of the ways that we make space meaningful. Engaging and erudite, Gorman recounts her background as a (non-space) archaeologist and how she became interested in space artifacts. She shows us her own piece of space junk, a fragment of the fuel tank insulation from Skylab, the NASA spacecraft that crash-landed in Western Australia in 1979. She explains that the conventional view of the space race as "the triumph of the white, male American astronaut" seems inadequate. What really interests her, she says, is how everyday people engage with space. To an archaeologist, objects from the past are significant because they remind us of what we might want to hold on to in the future.

LEGO® INTERNATIONAL SPACE STATION

Produced by LEGO®

864 pieces. $69.99. www.lego.com

Build and display this spectacular LEGO® International Space Station (ISS). Packed with authentic ISS details, including a posable Canadarm2 and two rotating joints that coincide with eight adjustable "solar panels," this 864-piece set is a wonderful gift idea for space enthusiasts, adult LEGO® fans, or any experienced builder. This model comes with a display stand, a buildable mini NASA space shuttle, and three mini cargo spacecrafts, plus two astronaut microfigures to create a striking centerpiece in any room. Illustrated instructions are included, plus a 148-page booklet with fascinating ISS facts and information about the LEGO® fan who created this space model kit and its LEGO® designer. The finished model measures over 7 inches (20 centimeters) high, 12 inches (31 centimeters) long, and 19 inches (49 centimeters) wide. For ages 16 and up.

Note: Product descriptions are taken from publishers' websites. LPI is not responsible for factual content.

MARS SPACE STATION

Produced by Playmobil

$79.99. www.playmobil.us

This Mars Space Station from Playmobil comes with two astronauts, a robot, a functioning double-laser shooter, lots of equipment and accessories, and various light and sound effects. This set can be combined with Playmobil's Mission Rocket with Launch Site and Satellite Meteoroid Laser (each sold separately) for added fun! Two AAA batteries are required. For ages 6 to 10.

GIANT INFLATABLE SOLAR SYSTEM

Produced by Learning Resources

$49.99. www.learningresources.com

Demonstrate rotation, revolution, and orbit in three dimensions with this durable, washable solar system set. Teach the position, order, size, and shape of the planets and the Sun. This set is also great for creating an out-of-this-world playroom or bedroom. Each colorful planet (and Sun) inflates easily, and loops are included for easy hanging. This unique solar system set turns any room into an intergalactic experience! The set includes eight planets with hanging hooks, Pluto, the Sun, Earth's Moon, a convenient foot pump, an activity guide with fun planet facts, and a repair kit. Inflatables measure 5 inches (13 centimeters) to 23 inches (58 centimeters) in diameter. For ages 5 to 9.

DISCOVER SPACE 100-PIECE JIGSAW PUZZLE

Produced by Crocodile Creek

$24.99. store.crocodilecreek.com

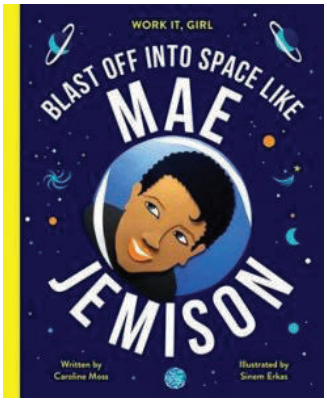
This 100-piece floor jigsaw puzzle is a perfect for little ones to learn about space and the solar system. The three-foot puzzle also comes with 21 put-together icons that match up to planets, the solar system, the Sun, and astronauts. Also included is a guide book that has details about each of the icons featured on the puzzle and in the figures. All of Crocodile Creek's puzzles are printed with soy-based ink on recycled cardboard. For ages 5 and up.

SUPER COOL SPACE FACTS: A Fun, Fact-Filled Space Book for Kids

By Bruce Betts

Rockridge Press, 2019, 124 pp., Paperback. $9.99. Available on Amazon.com

Take an exciting, fact-filled journey that goes where all great space books for kids should – to our solar system and beyond! Super Cool Space Facts is bursting with information about stormy planets, exploding stars, weird black holes, amazing landers, and more. Blast past other space books for kids with galaxies of wonder – launch into learning with awesome and easy-to-digest facts about everything from asteroids hurtling through space to astronauts on the International Space Station; entertaining information – fill your outer space adventure with the jokes, big word alerts, and fascinating mysteries of the universe all space books for kids should have; and full-color photos – see how cool space is with incredible pictures of stars, galaxies, planets, constellations, and more. Super Cool Space Facts brings you out-of-this-world fun. It's a must-have title for anyone interested in space books for kids. For ages 6 to 9.



BLAST OFF INTO SPACE LIKE MAE JEMISON

By Caroline Moss

Frances Lincoln Children's Books, 2020, 64 pp., Hardcover. $15.99. www.quartoknows.com

In this imaginatively illustrated book from the "Work It, Girl" series, discover how Mae Jemison became the first African American woman in space in this true story of her life. Then, learn 10 key lessons from her work you can apply to your own life. When Mae Jemison was a little girl, she loved science, dancing, and dinosaurs. She watched the Apollo Moon landings and wondered why none of the astronauts were women – and she just didn't buy the answers she was given. Brightly-colored photo illustrations of 3-D cut paper artwork featuring inspiring quotes from this amazing woman bring her story to vivid life. Learn how to work it as you lay the foundations for your own successful career. For ages 8 to 12.

Note: Product descriptions are taken from publishers' websites. LPI is not responsible for factual content.

CALENDAR

2020 Upcoming Events

May | June | July | August | September | October | November | December

May

Atmospheres and Exospheres of Terrestrial Planets, Satellites, and Exoplanets

May 3–8

Vienna, Austria

meetingorganizer.copernicus.org/EGU2020/abstractsubmission/36525

Planet Mars V

May 3–8

Les Houches, France

www.cosmos.esa.int/web/planet-mars-5/home

Stars and Planets in the Ultraviolet: A Cross-Community Symposium

May 4–6

Tempe, AZ

na.eventscloud.com/website/9538/

Women in Space Conference

May 6–8

Saint-Hubert, Quebec

www.womeninspacecon.com/

17th AIP Thinkshop on Protoplanetary Disk Chemodynamics

May 11–15

Potsdam, Germany

thinkshop.aip.de/17

Sixth International Planetary Dunes Workshop

May 12–13

Virtual

www.hou.usra.edu/meetings/dunes2020/

8th European Lunar Symposium

May 12–14

Padua, Italy

els2020.arc.nasa.gov/

Workshop on Observatory for the Outer Heliosphere, Heliosheath, and Interstellar Space

May 21–22

Boulder, Colorado

lasp.colorado.edu/home/mop/resources/hosted-meetings/outer-heliosphere-workshop/

June

23rd Meeting of the Small Bodies Assessment Group

June 1-2

Laurel, Maryland

www.lpi.usra.edu/sbag/meetings/

Towards Other Earths III: From Solar System to Exoplanets

June 1–5

Lamego, Portugal

www.iastro.pt/toe3/

Planet Formation: From Dust Coagulation to Final Orbit Assembly

June 1–26

Garching, Germany

www.munich-iapp.de/planetformation

Mercury: 2020 (RESCHEDULED)

June 2–4

Orléans, France

mercury2020.ias.u-psud.fr/main_1st.php

GAIA and TESS: Tools for Understanding of the Local Universe

June 5-15

Brno, Czech Republic

gate.physics.muni.cz/

7th Mars Atmosphere Modelling and Observations Conference

June 8–11

Paris, France

www-mars.lmd.jussieu.fr/paris2020/

17th International Planetary Probe Workshop

June 8–12

Monterey, California

www.ippw2020.org/

The 11th Joint Planetary and Terrestrial Mining Sciences Symposium and Space Resources Roundtable (POSTPONED)

June 9–11

Ottawa, Canada

www.ptmss.ca/

Global Space Exploration Conference

June 9–11

St. Petersburg, Russia

www.iafastro.org/events/global-series-conferences/glex-2020/

Asteroids, Comets, Meteors Conference

June 14–19

Flagstaff, Arizona

www.hou.usra.edu/meetings/acm2020/

SPICE Training Class at ESACTraining Class at ESAC (CANCELED)

June 16–18

Madrid, Spain

www.cosmos.esa.int/web/spice/training

2020 Annual Meeting of Planetary Geologic Mappers (CANCELED)

June 16–18

Denver, Colorado

www.hou.usra.edu/meetings/pgm2020/

PREPARING FOR SOFIA-HIRMES SCIENCE: The Missing Link Between JWST and Herschel

June 22–24

Baltimore, Maryland

www.hirmes.org/2020-workshop

Planetary Science Informatics and Data Analytics Conference (CANCELED)

June 22–24

Madrid, Spain

www.cosmos.esa.int/web/psida-2020

Cosmic Explorations: At the Intersection of Science, Space, Art, and Culture

- June 22–25
- Pasadena, California
- cosmicexplorations.org/

The Planetary CubeSats/SmallSats Symposium

- June 25–26
- Greenbelt, Maryland
- cubesats.gsfc.nasa.gov/symposium.html

European Astronomical Society Annual Meeting

- June 29 – July 3
- Leiden, the Netherlands
- eas.unige.ch//EAS_meeting/

July

NASA Exploration Science Forum

- July 8–10
- Virtual
- lunarscience.arc.nasa.gov/nesf2020/

Data Analysis for Planetary Science (DAPS-CBW 2020)

- July 20–31
- Antofagasta, Chile
- cospar.das.uchile.cl/

Exoplanets III

- July 27–31
- Heidelberg, Germany
- hdconfsys.zah.uni-heidelberg.de/exoplanets3/index.php

August

11th Planetary Crater Consortium Meeting

- August 5–7
- Honolulu, Hawai‘i
- www.hou.usra.edu/meetings/crater2020/

83rd Annual Meeting of The Meteoritical Society (POSTPONED)

August 9–14

Glasgow, Scotland

www.metsoc2020.com/

Experimental Analysis of the Outer Solar System II

August 11–13

Fayetteville, Arkansas

www.hou.usra.edu/meetings/exoss2020/

43rd COSPAR Scientific Assembly

August 15–23

Sydney, Australia

www.cospar-assembly.org

Formation and Evolution of Planetary Systems and Habitable Planets

August 19–26

Torun, Poland

eai.faj.org.pl

September

Planetary Science: The Young Solar System

September 6–12

Quy Nhon, Vietnam

www.icisequynhon.com/conferences/2020/planetary_science

Ocean Worlds 5

September 8–9

Woods Hole, Massachusetts

www.hou.usra.edu/meetings/oceanworlds2020/

Annual Meeting of the Lunar Exploration Analysis Group

September 14–16

Houston, Texas

www.hou.usra.edu/meetings/leag2020/

NASA Astrobiology Graduate Conference (AbGradCon)

September 14–18

Tokyo, Japan

www.abgradcon.org/

Comet-Like Activity of Small Bodies in the Solar System

September 22–25

Tatranska Lomnica, Slovakia

www.cometactivity2020.eu

Europlanet Science Congress

September 27–October 2

Granada, Spain

www.epsc2020.eu/

From Clouds to Planets II: The Astrochemical Link

September 28–October 2

Berlin, Germany

events.mpe.mpg.de/event/12/

October

Martian Geological Enigmas: From the Late Noachian Epoch to the Present Day

October 5–7

Houston, Texas

www.hou.usra.edu/meetings/martianenigmas2020/

71st International Astronautical Congress 2020

October 12–16

Dubai, United Arab Emirates

www.iafastro.org/events/iac/iac-2020/

International Symposium on Artificial Intelligence, Robotics, and Automation in Space

October 18–21

Pasadena, California

www.hou.usra.edu/meetings/isairas2020/

GSA Annual Meeting

October 25–28

Montreal, Quebec, Canada

community.geosociety.org/gsa2020/home

52nd Meeting of the Division for Planetary Sciences of the American Astronomical Society

October 25–30
Spokane, Washington
dps.aas.org/meetings/current

November

Apophis T-9 Years: Knowledge Opportunities for the Science of Planetary Defense (RESCHEDULED)

November 9–10
Nice, France
www.hou.usra.edu/meetings/apophis2020/

Astrobiology 2020

November 9–13
Vredefort Dome, South Africa
astrobiology.uj.ac.za/

36th International Geological Congress (IGC) (NEW DATES)

November 9–14
New Delhi, India
www.36igc.org/

Hera Workshop

November 11–13
Nice, France
www.cosmos.esa.int/web/hera-community-workshop

18th Meeting of the Venus Exploration Group (VEXAG)

November 16–18
Pasadena, California
www.lpi.usra.edu/vexag/meetings/vexag-18/

Magnetism and Accretion

November 16–20
Cape Town, South Africa
ma2020.saao.ac.za/

3rd Annual Interstellar Probe Exploration Workshop

November 17–19

Baltimore, Maryland/Washington, D.C. Area

www.hou.usra.edu/meetings/interstellarprobe2020/

5th International Workshop on Instrumentation for Planetary Missions 2020

November 18–20

Tokyo, Japan

www2.rikkyo.ac.jp/web/ipm2020/

Modeling, Observing, and Understanding Flows and Magnetic Fields in the Earth's Core and in the Sun

November 30–December 4

Cambridge, United Kingdom

www.newton.ac.uk/event/dytw03

December

AGU Fall Meeting

December 7–11

San Francisco, California

www.agu.org/