NASA'S AMES RESEARCH CENTER:
Contributions to Flight and Planetary Science

James Anderson, NASA Ames Historian

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Note from the Editors: This issue's lead article is the ninth in a series of reports describing the history and current activities of the planetary research facilities funded by NASA and located nationwide. This issue features NASA's Ames Research Center, which has led NASA in conducting world-class research and development in aeronautics, exploration technology, and science since 1939. — Paul Schenk and Renée Dotson

Aerial image of NASA Ames Research Center. Credit: NASA.

This year marks the 80th anniversary of NASA's Ames Research Center, situated in the heart of California's Silicon Valley. Before the advent of both NASA and Silicon Valley, Ames was already evolving as a special place where state-of-the-art facilities and world-class talent melded to produce cutting-edge research in aerodynamics, thermodynamics, and simulation.

Basic and applied research have been cornerstones of Ames since it was founded in 1939 as an expansion of the facilities that the National Advisory Committee for Aeronautics (NACA) established at Langley Memorial Aeronautical Laboratory, now NASA's Langley Research Center. Ames has always had a cadre of theorists, engineers, machinists, and computers (from humans to supercomputers) that have collaborated to solve the most urgent and interesting problems related to flight.

Flight, of course, requires some kind of an atmosphere. When taken metaphorically, an atmosphere provides an artful organizing theme to tie together all the different facets of research and the independent, expert, and sometimes eccentric, characters of the researchers themselves who have made Ames what it is over the years — the "atmosphere" of Ames as a place. When taken literally, an atmosphere is that immense, life-sustaining, gaseous ocean at the bottom of which we live and find refuge from the hazards of the space beyond Earth. After all, the first "A" in NASA is "Aeronautics," and there is no way to get from Earth to space without passing through our atmosphere, just as there is no way to land on another world without passing through its own, however tenuous, otherworldly atmosphere. Atmospheres and the need to understand and adapt our technology to their structures, their behaviors, and their underlying physics have permeated much of the work at Ames.

Even though atmospheres are far from the whole story, the diverse areas of expertise at Ames today, from entry systems and aerosciences to cost-effective space missions, intelligent and adaptive systems, advanced computing and IT systems, air traffic management, astrobiology, life science, and space and Earth science, have sometimes evolved in concert with one another and, at other times, independently of one another. The interests of research leaders and their teams often accounted for the disciplinary shifts between the research fields.

When NASA succeeded the NACA in 1958, planetary science was hardly a leading justification for that shift, but NASA would soon develop strength in the field, and Ames played an integral role from the beginning. What follows are some key highlights from Ames' past and present that have made — and continue to make — Ames the indispensable node it is within NASA and throughout the expanded networks of planetary science and space technology.

Ames Before NASA

Before NASA, there was supersonic flight. And before supersonic flight, there were problems affecting aircraft that ranged from icing to engine buffeting, all of which resulted from interactions with the aircraft and our atmosphere.

Icing studies were already underway at Langley and the leader of that effort, Lewis Rodert, brought that research to Ames and conducted it out of the first research building to open here. Aircraft were modified to collect data pertinent to the issue, and the results informed early solutions in thermal deicing that were built into a number of Allied aircraft during the war. Rodert would win the Collier Trophy for this research.

After the war, Rodert moved on to the NACA's third laboratory, now NASA's Glenn Research Center. Further pursuing the icing research into evermore refined and practical applications was not the cutting-edge theoretical work that was already dominant, and would continue to dominate, the work at Ames. There were also limitations to what sorts of icing conditions could be produced in wind tunnels.

Things getting cold proved to be a much less persistent issue of interest than having to deal with things getting hot and turbulent. Before the end of the war, there were already plans for expanding supersonic tunnel design. Ames had a supersonic tunnel with a 1 × 3-foot (30 × 91-centimeter) test section, but newer tunnels would be required to accommodate larger models and to get around other limitations that the dimensions imposed.

The new supersonic tunnel that was built proved incapable, initially, of operating in the transonic

H. Julian "Harvey" Allen in 1957 in front of the 8 × 7-foot (244 × 213-centimeter) Supersonic Wind Tunnel test section. A blunt body model mounted in the test section is ready for testing. Credit: NACA.

regime. Charles Hall, a longtime Ames researcher who will reappear in this story, led the modifications to the 6 × 6-foot (183 × 183-centimeter) supersonic tunnel to make it operational continuously from Mach 0.65 to Mach 2.2. The tunnel enabled basic research that resulted in the development of innovations such as the conical camber and improved understanding of vortex flows.

Even before NASA, however, Ames was not simply a world-class collection of wind tunnels. A complimentary and exceedingly practical, quick, and economical method of research was employed to collect transonic data that helped validate the supersonic area rule, a theory developed at Ames by Robert T. Jones, the American inventor of the swept wing. That method involved simply dropping models, often full scale, with their instrumentation from aircraft aloft. Rocket-boosted model tests would have been more expensive and time-consuming.

As the 1950s progressed, plenty of rockets were being tested for their flight properties, and re-entry conditions proved to be a major obstacle to protecting the intended nuclear warhead cargo. The pointed nose cone shapes that worked so well aerodynamically at certain speeds could not withstand the thermodynamic heating that resulted from re-entry speeds at higher Mach numbers.

To solve the re-entry problem, a counterintuitive solution was proposed and developed by Ames' most eccentric character and Smith DeFrance's succeeding director, the chief of the Ames Theoretical Aerodynamics Section, H. Julian "Harvey" Allen. Allen's blunt body concept addressed the fact that at re-entry speeds, thermodynamics became more important than aerodynamics. A blunt tip changed the bow shock wave in a way that shifted the heat away from the body's surface out into the surrounding atmosphere, be it a capsule containing a warhead or, eventually, an astronaut.

Ames in the Apollo Era

The blunt body concept has remained an enduring innovation, as the concept continues to be applied to entry probe design today. Throughout the 1960s, the Mercury, Gemini, and Apollo capsule shapes were all tested in Ames' facilities and refined as a result. In addition to thermal protection system research and heat shield testing, Ames also developed navigation systems, designed flight simulators, built magnetometers deployed on the Moon, and analyzed lunar samples to look for signs of life.

Along with Johnson Space Center, Ames was the only other NASA facility to analyze Apollo 11 samples in 1969. The Lunar Biological Laboratory contained a clean room — an integral part of the semiconductor industry — that was specifically designed and built to look for signs of life in the lunar samples. The Ames scientists in the Life Detection Systems Branch comprised a team of chemists, biologists, and microbiologists (about a third of whom were women) who tested 300 different environments using 10 petri dishes for each environment.

Those 3000 petri dishes were monitored for any signs of life. Of course, no signs of life have ever been detected, but the experience gained in Vance Oyama's lab would later inform the Viking mission to Mars. For Viking, the biology team would be led by Ames' Harold P. Klein, and Oyama served as the principal investigator for the gas exchange experiment.

Apollo benefitted from Ames' expertise without redefining Ames as a center. As the Apollo-era budgets ebbed, the Center continued to advance the state-of-the-art in the cutting-edge fields that had pre-dated Apollo, while branching out into life sciences and the space sciences.

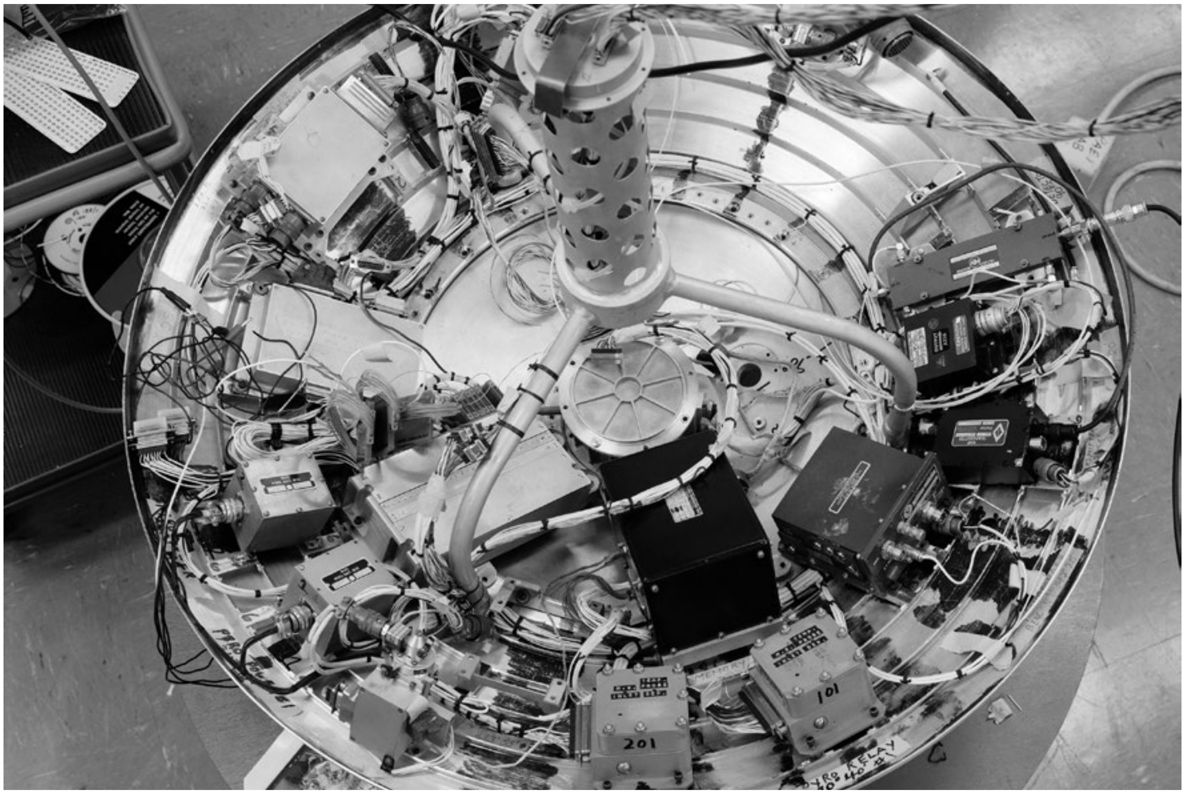
The Planetary Atmosphere Experiments Test (PAET)

Validation of the blunt body concept and stability testing of various re-entry capsule designs took place in the Ames hypervelocity free flight facility. Prototypes for the facility had been constructed in 1958 and 1961, achieving re-entry speeds with models launched into a counter-flow of gas in a shock tunnel.

One of the leaders of that research and technological development, Alvin Seiff, had designed a supersonic free flight tunnel at Ames that opened in 1948. By the 1960s, Seiff and David Reese, the Assistant Chief of the Vehicle Environment Division, had been considering how an entry probe could be used to determine atmospheric structure.

Seiff's key insight was to invert the whole approach to hypervelocity aerodynamic research. Rather than determining the aerodynamics of a body traveling through known atmospheric conditions, how could a body of known aerodynamics be used to determine the atmospheric conditions? The solution would open up other worlds, literally, to the study of their atmospheres during probe entry. The result was the Planetary Atmosphere Experiments Test (PAET), a project that Reese managed through its design, development, and fabrication at Ames.

The PAET probe was outfitted



A view looking down into the top of the completed Planetary Atmosphere Experiments Test (PAET) engineering model showing the details of the assembly's components and wiring harness. Credit: Charlie Lonzo.

with accelerometers, pressure and temperature sensors, a mass spectrometer, and a radiometer. The radiometer measured emission from the shock layer of the probe. Once fabrication of the PAET spacecraft was complete, it was loaded onboard a plane in May 1971 and sent to Wallops Station in Virginia for launch.

PAET launched from Wallops on Sunday, June 20, and splashed down near Bermuda within 15 minutes. Its entry speed was 6.6 kilometers per second (4 miles per second), high enough to require the rocket boost supplied by NASA's Scout rocket. The Scout was NASA's only solid rocket with orbital capability at the time, so the days of dropping a test probe from an airplane or even a high-altitude balloon like so many previous and successful aerodynamics tests would not have sufficed. The launch had been delayed two days because of antenna issues that the USS Vanguard sustained after encountering rough seas during its participation providing telemetry for an earlier Mariner launch. All the PAET's systems functioned as designed and the payload continued to send data for over an hour as it floated, but it sank before the USS Vanguard arrived to retrieve it. Retrieval would have been a nice benefit, but it was never a requirement for the mission.

Not only did the mission give practical feedback about the behavior of the instruments under true atmospheric entry conditions, but the data the PAET returned overlaid beautifully with meteorological data from conventional soundings. Especially successful was the atmosphere structure determination, which returned a temperature profile accurate to within 1°C (less than 2°F) over long stretches of the 80 kilometers (50 miles) in altitude from which it started recording.

PAET proved that a probe could enter an atmosphere while collecting data at planetary re-entry speeds, transmit that data before impact — but after emerging from the communications blackout phase of entry — and that researchers could then use that data to reconstruct an atmospheric profile. This validation on Earth led to its application in the planetary atmospheric entries carried out by Pioneer Venus, multiple Mars entries starting with both Viking landers, the Galileo probe to Jupiter, and the Huygens probe to Saturn's moon Titan.

In concert with such practical, economical, and scientifically rich instrumentation at Ames was the equally important theoretical research into planetary atmospheres. Of the many talented scientists in the field, James Pollack deserves special recognition.

James Pollack

Pollack spent over 20 years at Ames until succumbing to a form of cancer at age 55. A researcher whose work embodied the connections to be drawn and the insights to be gained through the study of atmospheres and planetary science — and their humbling and profound influence on our understanding of Earth — Pollack was involved with every major

Dr. James Pollack of the Ames Theoretical Studies Branch. Credit: Wade Sisler.

planetary mission from Mariner 9 through Cassini, which launched three years after Pollack passed away in 1994.

He was the "P" in the famous "TTAPS" paper, "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," published in Science in 1983. At the time, Pollack was the chief scientist of the Ames Climate Office, a position he held from 1978 to 1984. For the publication, fellow Ames scientists Brian Toon and Thomas Ackerman contributed their expertise on cloud microphysics, climate, and radiation. Richard Turco, working for defense contractor R&D Associates, was the lead author. Carl Sagan was the "S."

Pollack had met Sagan at the University of California, Berkeley, when he was completing a master's degree in physics while Sagan worked as a postdoctoral researcher. Their overlapping interests sparked a collaboration that would continue for the rest of their lives. After completing his master's degree, Pollack became Sagan's first graduate student at Harvard, where he completed his doctorate. Sagan's own thesis had focused on Venus and, while at Harvard, Pollack's doctoral thesis investigated the greenhouse effect in Venus' atmosphere.

They were close collaborators and at the same time polar opposites in many respects. Sagan became a wildly popular communicator of science and pursued a broad array of research interests over the course of his career, while Pollack maintained a dedicated focus to planetary science and became renowned only within particular segments of the scientific community.

By the late 1960s, Pollack was looking forward to returning to northern California when Raymond Reynolds, the chief of the Theoretical Studies Branch, hired Pollack, who then began his career at Ames in 1970. Reynolds and Pollack both shared interests in the greenhouse effect and the atmosphere of Jupiter.

Pollack contributed to a number of fields within planetary science over his career. He advanced and refined models of greenhouse heating using data returned from Mariner 5 and Venera 4. He studied aerosols and their effect on the climate, developed numerical models for the physics underlying planetary formation of the gas giants, and contributed to the general circulation model that would become the Mars Global Climate Model.

He developed a reputation for seeing the big picture, and for providing cogent insights and suggestions to his colleagues. While not a computer scientist, Pollack supported the computer coding work through incredibly detailed handwritten notes to the programmers. His relationship with his own desktop workstation produced an amusing anecdote. Apparently unaware that his e-mail messages could be deleted, years of messages took up enough disk space that it led to trouble with his computer account. It's worth considering the photo of Pollack at the computer in light of such a story, seeing someone completely at ease with physical theory, numerical theory, and even the associated algorithms, while remaining endearingly clueless about clearing out an inbox.

Pollack put the Ames supercomputers to work. Drawing upon his earlier work on Venus and the greenhouse effect, Pollack further developed radiative transfer algorithms that astronomer Allen Grossman and physicist Harold Graboske had applied to the evolution of low mass stars.

Pollack also drew upon Ames' strength in airborne astronomy. Continuing the study of the clouds of Venus in early 1971, Pollack connected with Fred Witteborn, chief of the Astrophysics Branch at Ames. This led to airborne observations of Venus onboard an Ames Learjet in the summer of 1972 using an infrared telescope. The observations indicated that

Artist's concept of Pioneer 10 crossing the asteroid belt. Credit: Rick Guidice.

the venusian atmosphere contained sulfuric acid in high concentrations.

It was an exciting time for planetary science. Pioneer 10 had launched in the spring of 1972, followed by Pioneer 11, both of which were managed at Ames. And with the success of the PAET and the lobbying efforts of Ames' Director Hans Mark, NASA transferred the program that would become Pioneer Venus to Ames from Goddard. Charlie Hall, the manager of Pioneers 10 and 11, led that program as well, which sent two separate vehicles — an orbiter and a bus containing four entry probes — to the planet, both of which launched in 1978.

Pioneers 10 and 11

From 1965 to 1968, as human spaceflight attracted much of the attention that NASA received, a series of spin-stabilized satellites, identical in their basic design, carried various combinations of instruments into heliocentric orbit that measured solar wind and cosmic rays, magnetic fields, and cosmic dust. Those economical spacecraft, Pioneers 6 through 9, were managed at Ames and became the first spacebased solar weather monitoring network.

The next two missions to receive numerical designations, Pioneers 10 and 11, were also spin-stabilized and became the first two of only five spacecraft that have been sent on trajectories that have, or eventually will have, carried them out of the solar system. Pioneer 10 became the first to cross the orbit of Mars, pass through the asteroid belt, and reach the planet Jupiter. There, in 1973, its suite of instruments powered by radioisotope thermoelectric generators sent back the first data and images from the vicinity of the gas giant before its slingshot around the planet carried it out on its historic path. Pioneer 11 soon followed and was sent even closer around Jupiter and on to Saturn. Pioneers 10 and 11 certainly lived up to their name, beginning the so-called "grand tour" of the outer planets, which culminated with the breathtaking imagery that Voyagers 1 and 2 would capture of not just Jupiter and Saturn, but also Uranus and Neptune, before eventually overtaking the Pioneers on their respective journeys.

Underscoring the momentous nature of the spacecraft leaving our solar system, Sagan spearheaded the effort to have the Pioneer plaques affixed to the craft. The amount of information about humanity carried onboard such a craft would soon be increased even more with the creation of the Voyager records.

The Pioneers were both scientific

Pioneer 10 interstellar plaque positioned on the spacecraft. Credit: NASA.

and cultural achievements. The manager of the Pioneers, Charlie Hall, was known for conducting stand-up meetings because "people don't talk so long when their feet get tired." That reason was mentioned in Jupiter Odyssey, a 1974 documentary film about Pioneer that was but one example of how Pioneer was recognized in media.

The intersection between media and science was particularly evident in the Pioneer Image Converter System (PICS), developed by L. Ralph Baker of the University of Arizona. PICS allowed for a real-time display of the spin-scan images returned from the photopolarimeter and included a video signal. That signal, after creation of a synthetic green image of Jupiter from the scientifically more interesting red and blue channels that were simultaneously recorded by Pioneer 10, could be broadcast over television. In recognition, the San Francisco chapter of the National Academy of Television Arts and Sciences presented the Governors' Award to Ames "for its outstanding contributions to the Science of television technology for its work on Pioneer 10 and the Jupiter remote telecast December 3, 1973." So in addition to the scientific laurels Pioneer received, it also collected an Emmy.

From Airborne Science to Virtual Institutes

In 2015, as the New Horizons probe was passing by Pluto, Pluto passed between the line of sight from Earth to a distant star. This occultation was visible from the Southern Hemisphere and was captured by the Stratospheric Observatory for Infrared Astronomy (SOFIA), the only observatory in existence capable of positioning itself anywhere around the globe and above the vast majority of water in our atmosphere, a necessary capability for conducting infrared astronomy.

SOFIA is only the most recent example in a long line of airborne and infrared astronomy that dates back to at least the 1960s. While the advent of planetary spacecraft in the 1960s was a major development in planetary science, the concurrent developments in airborne capabilities have been indispensable, too.

Airborne science at Ames has looked both up into deep space and down to our planet below, enabling decades of research open to scientists from around the world. SOFIA's predecessor, the Kuiper Airborne Observatory (KAO), was enabled because of the success that earlier platforms had achieved. And the success of the KAO led to its ultimate retirement in order to support the development of SOFIA.

Airborne observations were also a part of the Stardust mission's re-entry. Stardust had passed through the tail of Comet Wild 2, collecting dust samples (as well as cosmic dust samples along the way), and returned those samples to Earth at the fastest re-entry speed of any spacecraft, almost twice the re-entry speed of the PAET.

Those samples, and the science surrounding their study, are indicative of the broader, interdisciplinary, and cross-pollinating nature of research that the figurative atmosphere of Ames provides. From lunar science to astrobiology, Ames has led the development of "virtual institutes," which bring together researchers across disciplinary, geographical, and organizational separations that have historically restricted the flow of scientific communication and hindered collaboration.

Ames Today

In September of this year, astronomers using data from the Hubble Space Telescope detected water vapor in the atmosphere of exoplanet K2-18b. This exoplanet is one of thousands now known to exist in our galaxy thanks to the Kepler spacecraft, a mission for which Ames' Bill Borucki served as the principal investigator.

Meanwhile, other promising developments are underway much closer to home. Over this summer, more than 200 employees of the U.S. Geological Survey (USGS) have been moving in at Ames in the NASA Research Park section of the campus. Both NASA and the USGS share a mandate to observe, study, and understand Earth.

This new co-location of scientific talent should enable some potentially very significant occasions for cooperation. There are opportunities for jointly developed tools for future satellite missions, as well as opportunities to enhance scientific returns through connecting USGS ground station data collection capabilities with spacebased observations, just as airborne observations have helped calibrate spacebased observations in the past.

And just as the PAET probe proved a capability on Earth for use on other worlds, so too may the resulting collaborative efforts between these agencies result in future methods and technologies that could be deployed throughout the solar system. It is only with the help of agencies such as NASA and the National Oceanic and Atmospheric Administration (NOAA) that the USGS can get into our atmosphere above ground level. Once up there, there are plenty of opportunities to study biology and geology aloft, which will only enrich work in other fields like astrobiology and the study of extremophiles.

Additionally, two NASA spacecraft currently in development — the Mars Helicopter Scout, which will accompany the Mars 2020 rover, and Dragonfly, a rotorcraft octocopter that will fly to various landing points on Titan — are the firsts of their kind that will take airborne science to other worlds. Ames is playing a role in each of these missions.

As we just celebrated the 50th anniversary of Apollo, its legacy is still with us. The Moon remains a promising and exciting source for scientific research today and Apollo samples are still contributing to that research. Just this year, NASA announced nine teams that have been selected to receive pristine samples returned from Apollo that have been stored untouched at Johnson Space Center. The Ames team will study their sample to investigate how exposure to the environment of space affects the surface of the Moon, often called "space weathering." Since lunar science is so intimately tied to our understanding of how Earth formed, this research and the USGS co-location could present a unique opportunity for refining our understanding of Earth's cosmic history while advancing the science and technology that supports Earth-monitoring.

Ultimately, our knowledge of Earth is a subset of planetary science. The enduring value of Ames as a Center is due in no small part to its ability to forge connections that support cutting-edge research and the development of our understanding of our place in the cosmos.

Suggested Further Reading

For the most recent overview of Ames history, see:

Bugos G. E. (2014) Atmosphere of Freedom: 75 Years at the NASA Ames Research Center. NASA SP-2014-4314, National Aeronautics and Space Administration, NASA History Office, Washington DC.

For a more detailed account of James Pollack's work and reminiscences from colleagues who worked with him, see:

Marlaire R. D. (2017) James B. Pollack and NASA's Planetary Missions: A Tribute. NASA SP-2017-632, National Aeronautics and Space Administration, Washington DC.

FROM THE DESK OF **LORI GLAZE**

REFLECTIONS ON NASA'S AMES RESEARCH CENTER

Lori S. Glaze

Director, NASA's Planetary Science Division, October 2019

As I reflect on the 80th anniversary of NASA's Ames Research Center, I cannot help being reminded of the very word chosen to depict the center's core value: Research. Originally founded in 1939 to conduct important wind-tunnel research for aircraft structures, Ames' excellence in basic and applied research establishes it as a key player in conducting world-class research and development in aeronautics, exploration technology, and science for the past four decades. Providing leadership in robotic lunar exploration and astrobiology, Ames laid the groundwork for some of the Agency's top-level priorities, missions, and programs.

Through human and robotic exploration, our understanding of the Moon fundamentally changed, and Ames is a prominent author of that story. Managed by Ames and selected as part of the Discovery Program, the Lunar Prospector was a transformative mission that successfully launched into low polar orbit of the Moon in January of 1998 onboard the American-made Athena II rocket. The Lunar Prospector allowed scientists to construct a detailed map of the lunar surface, and neutron spectrometer data helped lead to one of planetary science's most exciting discoveries — the presence of water ice in the polar craters of the Moon.

The Lunar Crater Observation and Sensing Satellite (LCROSS) launched in tandem with the Lunar Reconnaissance Orbiter (LRO) onboard an Atlas V rocket in June 2009 as part of the shared Lunar Precursor Robotic Program — America's first mission to the Moon in more than 10 years. Assembled and tested at Ames, LCROSS continued the legacy of Lunar Prospector's search for water ice in the permanently shadowed craters near the Moon's poles. Both LRO and LCROSS forever changed the way we think about the Moon and effectively set the stage for the Agency's priorities of returning to the Moon in a sustainable way with the Artemis program.

Earlier this year, NASA proudly handpicked nine teams to be entrusted with opening one of the remaining pristine samples

returned from Apollo. These samples — considered national treasures —have been stored and untouched at Johnson Space Center for years, until now. Ames houses one of the teams selected to expound our concept of space weathering and advance our understanding of how exposure to the space environment affects the lunar surface. This important research not only helps NASA prepare for future expeditions to the Moon, but also gives us further insight into our home planet's cosmic history and origin.

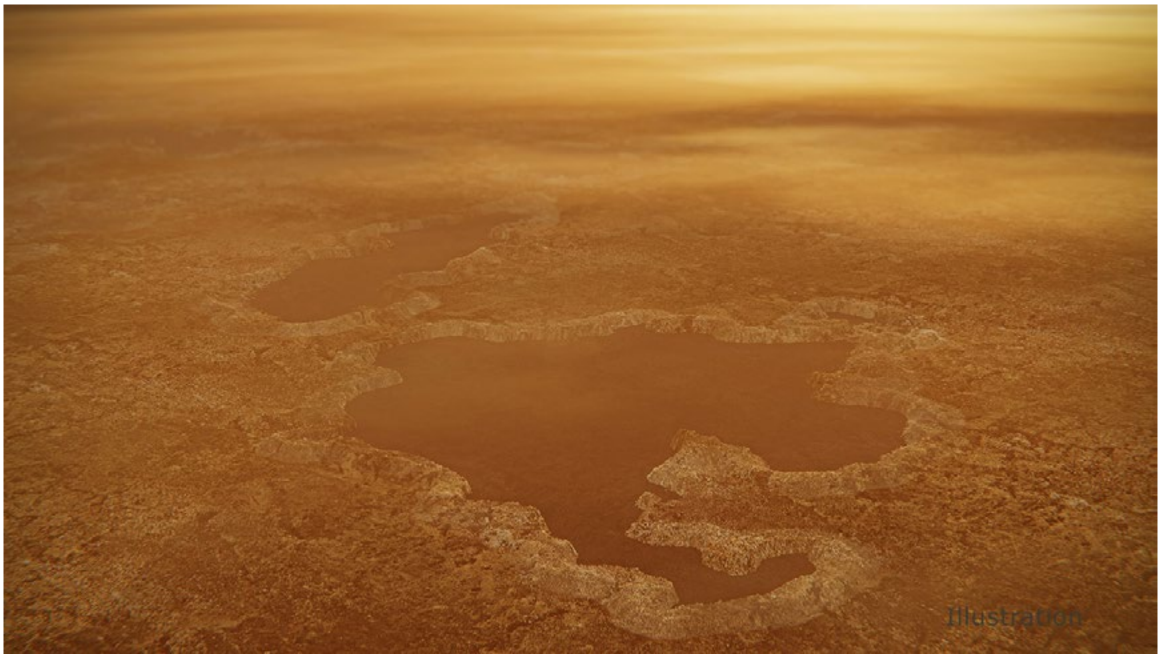
As we look beyond our Earth-

Moon system, Ames has been integral in NASA's robotic exploration of planets with atmospheres, as well as missions needing to re-enter Earth's atmosphere. The unique and innovative Thermal Protection System (TPS) consisting of Phenolic Impregnated Carbon Ablator (PICA) tiles developed at Ames in the 1980s enabled technology for flagship missions like the Mars Curiosity Rover. Ames' Arc Jet Complex is an invaluable resource to test missions with heatshields expected to encounter heating and pressure conditions similar to those experienced by a spacecraft during atmospheric re-entry. More recently, NASA's Heatshield for Extreme Entry Environment Technology (HEEET) Project is perfecting a new, three-dimensional, woven TPS technology, directly contributing to science missions recommended in the Planetary Science Decadal Survey. These technologies are necessary for future missions requiring protection from extremely intense atmospheric pressure and heating, advancing our technology today for the missions of tomorrow. Moreover, the Entry Systems and Technology division at Ames is aiding NASA in strengthening commercial partnerships with collaborative and reimbursable Space Act Agreements, further echoing that science and space exploration is a collaborative and unifying effort.

For the last 20 years, the NASA Astrobiology Institute (NAI) helped establish and advance the field of astrobiology, doing important work in furthering our understanding of the origin, evolution, distribution, and future of life in the universe. Following the leadership of the NAI, the field of astrobiology grew and expanded into a multi-disciplinary endeavor advancing knowledge of the types of environments able to support life as well as exploring techniques for how we might recognize life on another body. Similarly, Ames pushed the boundaries in NASA's fundamental space biology program, which is responsible for hundreds of science payloads flown into space. These science demonstrations directly furthered our understanding of biology and helped illuminate paths for creating countermeasures for longer-duration human spaceflight, helping guide NASA as it looks forward to the Moon and Mars.

The past 80 years of Ames accomplishments are a source of great pride, and I am filled with excitement when thinking about the future. Ames is continuing its legacy of excellence in lunar exploration by making important contributions to the Science Mission Directorate's Lunar Discovery and Exploration Program (LDEP) by managing the Volatiles Investigating Polar Exploration Rover (VIPER), leading the mission's science, systems engineering, real-time rover surface operations, and software efforts. This unprecedented rover will allow scientists to take an up-close look at the Moon's south pole, and for the first time ever, analyze and sample the water ice known to be present because of important findings from the Lunar Prospector and LCROSS. Additionally, Ames' Near InfraRed Volatiles Spectrometer System (NIRVSS) onboard VIPER is critical to analyzing regolith and ice samples in the area where the first woman and next man will land under the Artemis program. This mission epitomizes the research and innovation at the very core of Ames, and I cannot wait to see what great science it will uncover. I thank all of the staff at Ames, past and present, for your contributions to NASA and planetary science, and I look forward to the scientific mysteries we will uncover through the hard work, excellence, and research at Ames.

New Models Suggest Titan Lakes Are Explosion Craters



This artist's concept of a lake at the north pole of Saturn's moon Titan illustrates raised rims and rampart-like features such as those seen by NASA's Cassini spacecraft around the moon's Winnipeg Lacus. Credit: NASA/JPL-Caltech.

Using radar data from NASA's Cassini spacecraft, recently published research presents a new scenario to explain why some methane-filled lakes on Saturn's moon Titan are surrounded by steep rims that reach hundreds of feet high. The model suggests that explosions of warming nitrogen created basins in the moon's crust.

Titan is the only planetary body in our solar system other than Earth known to have stable liquid on its surface. Instead of water raining down from clouds and filling lakes and seas as on Earth, on Titan it is methane and ethane — hydrocarbons that we think of as gases but that behave as liquids in Titan's frigid climate.

Most existing models that lay out the origin of Titan's lakes show liquid methane dissolving the moon's bedrock of ice and solid organic compounds, carving reservoirs that fill with the liquid. This may be the origin of a type of lake on Titan that has sharp boundaries. On Earth, bodies of water that formed similarly, by dissolving surrounding limestone, are known as karstic lakes.

The new, alternative model for some of the smaller lakes (tens of kilometers/miles across) turns that theory upside down: It proposes pockets of liquid nitrogen in Titan's crust warmed, turning into explosive gas that blew out craters, which then filled with liquid methane. The new theory explains why some of the smaller lakes near Titan's north pole, like Winnipeg Lacus, appear in radar imaging to have very steep rims that tower above sea level — rims difficult to explain with the karstic model.

The radar data were gathered by the Cassini Saturn Orbiter during its last close flyby of Titan, as the spacecraft prepared for its final plunge into Saturn's atmosphere two years ago. An international team of scientists led by Giuseppe Mitri of Italy's Università d'Annunzio became convinced that the karstic model was inconsistent with what they saw in these images.

"The rim goes up, and the karst process works in the opposite way," Mitri said. "We were not finding any explanation that fit with a karstic lake basin. In reality, the morphology was more consistent with an explosion crater, where the rim is formed by the ejected material from the crater interior. It's totally a different process."

The work meshes with other Titan climate models showing the moon may be warm compared to how it was in earlier Titan "ice ages."

Over the last half-billion or billion years on Titan, methane in its atmosphere has acted as a greenhouse gas, keeping the moon relatively warm — although still cold by Earth standards. Scientists have long believed that the moon has gone through epochs of cooling and warming, as methane is depleted by solar-driven chemistry and then resupplied.

In the colder periods, nitrogen dominated the atmosphere, raining down and cycling through the icy crust to collect in pools just below the surface, said Cassini scientist and study co-author Jonathan Lunine of Cornell University in Ithaca, New York.

"These lakes with steep edges, ramparts and raised rims would be a signpost of periods in Titan's history when there was liquid nitrogen on the surface and in the crust," he noted. Even localized warming would have been enough to turn the liquid nitrogen into vapor, causing it to expand quickly and blow out a crater.

"This is a completely different explanation for the steep rims around those small lakes, which has been a tremendous puzzle," said Cassini Project Scientist Linda Spilker of JPL. "As scientists continue to mine the treasure trove of Cassini data, we'll keep putting more and more pieces of the puzzle together. Over the next decades, we will come to understand the Saturn system better and better."

For more about Titan, please visit: https://solarsystem.nasa.gov/missions/cassini/overview/

NASA Mission Selects Final Four Site Candidates for Asteroid Sample Return

After months grappling with the rugged reality of asteroid Bennu's surface, the team leading NASA's first asteroid sample return mission has selected four potential sites for the Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) spacecraft to "tag" its cosmic dance partner.

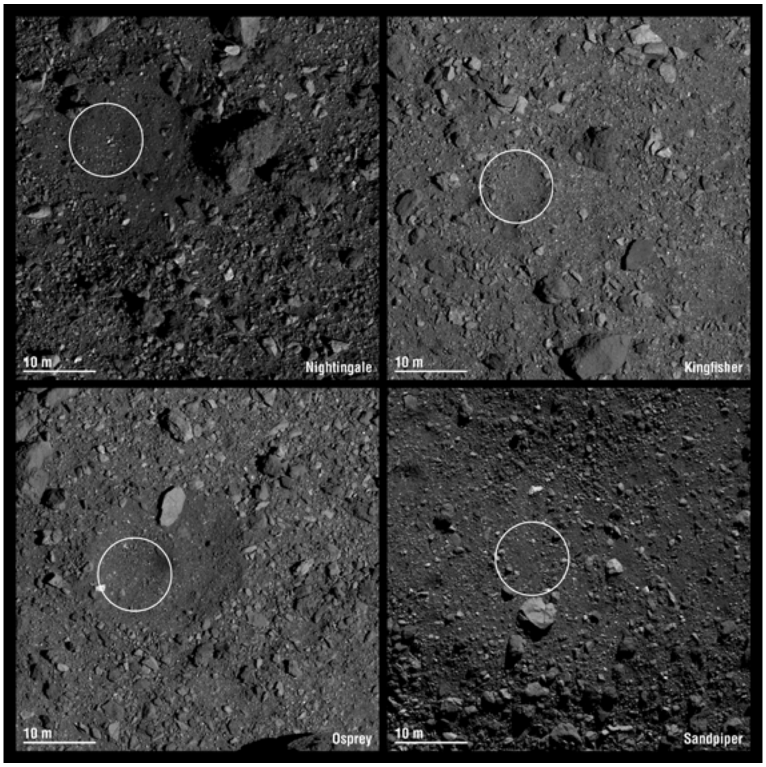
Since its arrival in December 2018, the OSIRIS-REx spacecraft has mapped the entire asteroid in order to identify the safest and most accessible spots for the spacecraft to collect a sample. These four sites now will be studied in further detail in order to select the final two sites — a primary and backup — in December.

The team originally had planned to choose the final two sites by this point in the mission. Initial analysis of Earth-based observations suggested the asteroid's surface likely contains large "ponds" of fine-grained material. The spacecraft's earliest images, however, revealed Bennu has an especially rocky terrain. Since then, the asteroid's boulder-filled topography has created a challenge for the team to identify safe areas containing sampleable material, which must be fine enough — less than 2.5 cm (1 in.) in diameter – for the spacecraft's sampling mechanism to ingest it.

"We knew that Bennu would surprise us, so we came prepared for whatever we might find," said Dante Lauretta, OSIRIS-REx principal investigator at the University of Arizona, Tucson. "As with any mission of exploration, dealing with the unknown requires flexibility, resources, and ingenuity. The OSIRIS-REx team has demonstrated these essential traits for overcoming the unexpected throughout the Bennu encounter."

The original mission schedule intentionally included more than 300 days of extra time during asteroid operations to address such unexpected challenges. In a demonstration of its flexibility and ingenuity in response to Bennu's surprises, the mission team is adapting its site selection process. Instead of down-selecting to the final two sites this summer, the mission will spend an additional four months studying the four candidate sites in detail, with a particular focus on identifying regions of fine-grain, sampleable material from upcoming, high-resolution observations of each site. The boulder maps that citizen science counters helped create through observations earlier this year were used as one of many pieces of data considered when assessing each site's safety. The data collected will be key to selecting the final two sites best suited for sample collection.

In order to further adapt to Bennu's ruggedness, the OSIRIS-REx team has made other adjustments to its sample site



The final four candidate sample collection sites on asteroid Bennu are designated Nightingale, Kingfisher, Osprey and Sandpiper. Each circle has a 5-m (16.4-ft.) radius. Credit: NASA/ Goddard/University of Arizona.

identification process. The original mission plan envisioned a sample site with a radius of 25 m (82 ft.). Boulder-free sites of that size don't exist on Bennu, so the team has instead identified sites ranging from 5–10 m (16–33 ft.) in radius. In order for the spacecraft to accurately target a smaller site, the team reassessed the spacecraft's operational capabilities to maximize its performance. The mission also has tightened its navigation requirements to guide the spacecraft to the asteroid's surface, and developed a new sampling technique called "Bullseye TAG," which uses images of the asteroid surface to navigate the spacecraft all the way to the actual surface with high accuracy. The mission's performance so far has demonstrated that the new standards are within its capabilities.

"Although OSIRIS-REx was designed to collect a sample from an asteroid with a beach-like area, the extraordinary in-flight performance to date demonstrates that we will be able to meet the challenge that the rugged surface of Bennu presents," said Rich Burns, OSIRIS-REx project manager at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "That extraordinary performance encompasses not only the spacecraft and instruments, but also the team who continues to meet every challenge that Bennu throws at us."

The four candidate sample sites on Bennu are designated Nightingale, Kingfisher, Osprey, and Sandpiper — all birds native to Egypt. The naming theme complements the mission's two other naming conventions — Egyptian deities (the asteroid and spacecraft) and mythological birds (surface features on Bennu).

The four sites are diverse in both geographic location and geological features. While the amount of sampleable material in each site has yet to be determined, all four sites have been evaluated thoroughly to ensure the spacecraft's safety as it descends to, touches, and collects a sample from the asteroid's surface.

Nightingale is the northern-most site, situated at 56° north latitude on Bennu. There are multiple possible sampling regions in this site, which is set in a small crater encompassed by a larger crater 140 m (459 ft.) in diameter. The site contains mostly fine-grained, dark material and has the lowest albedo, or reflection, and surface temperature of the four sites.

Kingfisher is located in a small crater near Bennu's equator at 11° north latitude. The crater has a diameter of 8 m (26 ft.) and is surrounded by boulders, although the site itself is free of large rocks. Among the four sites, Kingfisher has the strongest spectral signature for hydrated minerals.

Osprey is set in a small crater, 20 m (66 ft.) in diameter, which is also located in Bennu's equatorial region at 11° north latitude. There are several possible sampling regions within the site. The diversity of rock types in the surrounding area suggests that the regolith within Osprey may also be diverse. Osprey has the strongest spectral signature of carbon-rich material among the four sites.

Sandpiper is located in Bennu's southern hemisphere, at 47° south latitude. The site is in a relatively flat area on the wall of a large crater 63 m (207 ft.) in diameter. Hydrated minerals are also present, which indicates that Sandpiper may contain unmodified water-rich material.

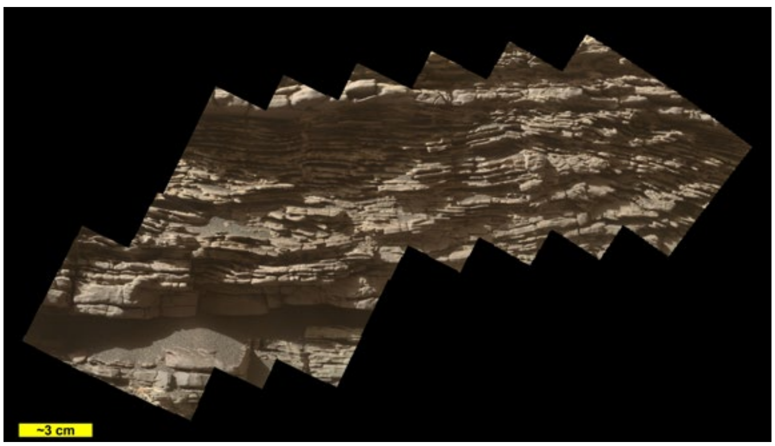
This fall, OSIRIS-REx will begin detailed analyses of the four candidate sites during the mission's reconnaissance phase. During the first stage of this phase, the spacecraft will execute high passes over each of the four sites from a distance of 1.29 kilometers (0.8 miles) to confirm they are safe and contain sampleable material. Close-up imaging also will map the features and landmarks required for the spacecraft's autonomous navigation to the asteroid's surface.

The team will use the data from these passes to select the final primary and backup sample collection sites in December.

The second and third stages of reconnaissance will begin in early 2020 when the spacecraft will perform passes over the final two sites at lower altitudes and take even higher resolution observations of the surface to identify features, such as groupings of rocks that will be used to navigate to the surface for sample collection. OSIRIS-REx sample collection is scheduled for the latter half of 2020, and the spacecraft will return the asteroid samples to Earth on September 24, 2023.

For more about OSIRIS-REx and asteroid sample return, please visit: https://www.asteroidmission.org/

New Finds for Mars Rover, Seven Years After Landing



This mosaic of images shows layers of ancient sediment on a boulder-sized rock called "Strathdon," as seen by the Mars Hand Lens Imager (MAHLI) camera on the end of the robotic arm on NASA's Curiosity rover. Credit: NASA/JPL-Caltech/MSSS.

NASA's Curiosity rover has come a long way since touching down on Mars seven years ago. It has traveled a total of 21 kilometers (13 miles) and ascended 368 meters (1207 feet) to its current location.

The rover is far from done, having just drilled its 22nd sample from the Martian surface. It has a few more years before its nuclear power system degrades enough to significantly limit operations. After that, careful budgeting of its power will allow the rover to keep studying the Red Planet.

Curiosity is now halfway through a region scientists call the "clay-bearing unit" on the side of Mount Sharp, inside Gale Crater. Billions of years ago, there were streams and lakes within the crater. Water altered the sediment deposited within the lakes, leaving behind lots of clay minerals in the region. That clay signal was first detected from space by NASA's Mars Reconnaissance Orbiter (MRO) a few years before Curiosity launched.

"This area is one of the reasons we came to Gale Crater," said Kristen Bennett of the U.S. Geological Survey, one of the co-leads for Curiosity's clay-unit campaign. "We've been studying orbiter images of this area for 10 years, and we're finally able to take a look up close."

Rock samples that the rover has drilled here have revealed the highest amounts of clay minerals found during the mission. But Curiosity has detected similarly high amounts of clay on other parts of Mount Sharp, including in areas where MRO didn't detect clay. That led scientists to wonder what is causing the findings from orbit and the surface to differ.

The science team is thinking through possible reasons as to why the clay minerals here stood out to MRO. The rover encountered a "parking lot full of gravel and pebbles" when it first entered the area, said the campaign's other co-lead, Valerie Fox of Caltech. One idea is that the pebbles are the key: Although the individual pebbles are too small for MRO to see, they may collectively appear to the orbiter as a single clay signal scattered across the area. Dust also settles more readily over flat rocks than it does over the pebbles; that same dust can obscure the signals seen from space. The pebbles were too small for Curiosity to drill into, so the science team is looking for other clues to solve this puzzle.

Curiosity exited the pebble parking lot back in June and started to encounter more complex geologic features. It stopped to take a 360° panorama at an outcrop called "Teal Ridge." More recently, it took detailed images of "Strathdon," a rock made of dozens of sediment layers that have hardened into a brittle, wavy heap. Unlike the thin, flat layers associated with lake sediments Curiosity has studied, the wavy layers in these features suggest a more dynamic environment. Wind, flowing water or both could have shaped this area.

Both Teal Ridge and Strathdon represent changes in the landscape. "We're seeing an evolution in the ancient lake environment recorded in these rocks," said Fox. "It wasn't just a static lake. It's helping us move from a simplistic view of Mars going from wet to dry. Instead of a linear process, the history of water was more complicated."

Curiosity is discovering a richer, more complex story behind the water on Mount Sharp — a process Fox likened to finally being able to read the paragraphs in a book — a dense book, with pages torn out, but a fascinating tale to piece together.

For more about Mars and Curiosity, please visit: https://mars.nasa.gov/msl/

Newly Discovered Comet Is Likely Interstellar Visitor

Comet C/2019 Q4 as imaged by the Canada-France-Hawaii Telescope on Hawaii's Big Island on Sept. 10, 2019. Credit: Canada-France-Hawaii Telescope.

A newly discovered comet has excited the astronomical community this week because it appears to have originated from outside the solar system. The object — designated C/2019 Q4 (Borisov) — was discovered on August 30, 2019, by Gennady Borisov at the MARGO observatory in Nauchnij, Crimea. The official confirmation that comet C/2019 Q4 is an interstellar comet has not yet been made, but if it is interstellar, it would be only the second such object detected. The first, 'Oumuamua, was observed and confirmed in October 2017.

The new comet, C/2019 Q4, is still inbound toward the Sun, but it will remain farther than the orbit of Mars and will approach no closer to Earth than about 300 million kilometers (190 million miles).

After the initial detections of the comet, Scout system, which is located at NASA's Jet Propulsion Laboratory in Pasadena, California, automatically flagged the object as possibly being interstellar. Davide Farnocchia of NASA's Center for Near-Earth Object Studies at JPL worked with astronomers and the European Space Agency's Near-Earth Object Coordination Center in Frascati, Italy, to obtain additional observations. He then worked with the NASA-sponsored Minor Planet Center in Cambridge, Massachusetts, to estimate the comet's precise trajectory and determine whether it originated within our solar system or came from elsewhere in the galaxy.

The comet is currently 420 million kilometers (260 million miles) from the Sun and will reach its closest point, or perihelion, on December 8, 2019, at a distance of about 300 million kilometers (190 million miles).

"The comet's current velocity is high, about 93,000 mph [150,000 kph], which is well above the typical velocities of objects orbiting the Sun at that distance," said Farnocchia. "The high velocity indicates not only that the object likely originated from outside our solar system, but also that it will leave and head back to interstellar space."

Currently on an inbound trajectory, comet C/2019 Q4 is heading toward the inner solar system. On October 26, it will pass through the ecliptic plane — the plane in which Earth and the other planets orbit the Sun — from above, at roughly a 40° angle.

C/2019 Q4 was established as being cometary due to its fuzzy appearance, which indicates that the object has a central icy body that is producing a surrounding cloud of dust and particles as it approaches the Sun and heats up. Its location in the sky (as seen from Earth) places it near the Sun — an area of sky not usually scanned by the large ground-based asteroid surveys or NASA's asteroid-hunting NEOWISE spacecraft.

C/2019 Q4 can be seen with professional telescopes for months to come. "The object will peak in brightness in mid-December and continue to be observable with moderate-size telescopes until April 2020," said Farnocchia. "After that, it will only be observable with larger professional telescopes through October 2020."

Observations completed by Karen Meech and her team at the University of Hawaii indicate the comet nucleus is somewhere between 2–16 kilometers (1.2–10 miles) in diameter. Astronomers will continue to collect observations to further characterize the comet's physical properties (size, rotation, etc.) and also continue to better identify its trajectory.

For more about asteroids and near Earth objects, please visit: https://www.jpl.nasa.gov/asteroidwatch/

Gaia Untangles the Starry Strings of the Milky Way

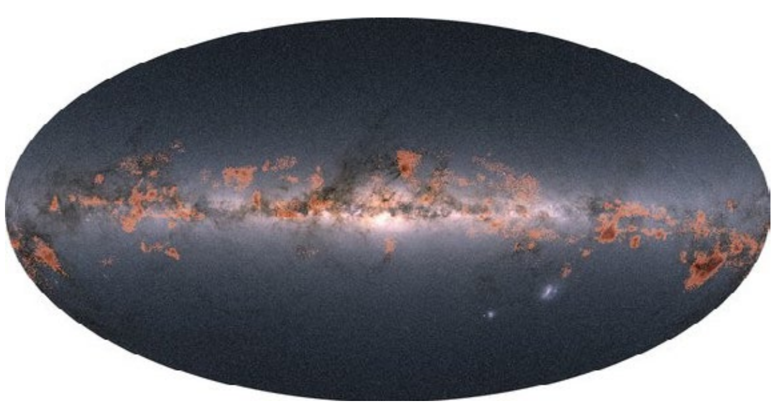
Rather than leaving home young, as expected, stellar siblings prefer to stick together in long-lasting, string-like groups, finds a new study of data from ESA's Gaia spacecraft.

Exploring the distribution and past history of the starry residents of our galaxy is especially challenging as it requires astronomers to determine the ages of stars. This is not at all trivial, as average stars of a similar mass but different ages look very much alike.

To figure out when a star formed, astronomers must instead look at populations of stars thought to have formed at the same time — but knowing which stars are siblings poses a further challenge, since stars do not necessarily hang out long in the stellar cradles where they formed.

"To identify which stars formed together, we look for stars moving similarly, as all of the stars that formed within the same cloud or cluster would move in a similar way," says Marina Kounkel of Western Washington University, and lead author of the study.

"We knew of a few such co-moving star groups near the solar system, but Gaia enabled us to explore the Milky Way in great detail out to far greater distances, revealing many more of these groups."



This image shows a view of stellar families — clusters and co-moving groups of stars in the Milky Way — identified using data from the second data release of ESA's Gaia mission. Families younger than 30 million years are highlighted in orange, on top of an all-sky view based on Gaia observations. The most massive among these familial groups of stars may keep moving together through the galaxy in long, string-like configurations for billions of years after their birth. Credit: ESA/Gaia/DPAC.

Kounkel used data from Gaia's second release to trace the structure and star formation activity of a large patch of space surrounding the solar system, and to explore how this changed over time. This data release, provided in April 2018, lists the motions and positions of over one billion stars with unprecedented precision.

The analysis of the Gaia data, relying on a machine learning algorithm, uncovered nearly 2000 previously unidentified clusters and co-moving groups of stars up to about 3000 light years from us — roughly 750 times the distance to Proxima Centauri, the nearest star to the Sun. The study also determined the ages for hundreds of thousands of stars, making it possible to track stellar families and uncover their surprising arrangements.

"Around half of these stars are found in long, string-like configurations that mirror features present within their giant birth clouds," adds Kounkel.

"We generally thought young stars would leave their birth sites just a few million years after they form, completely losing ties with their original family, but it seems that stars can stay close to their siblings for as long as a few billion years."

The strings also appear to be oriented in particular ways with respect to our galaxy's spiral arms, something that depends upon the ages of the stars within a string. This is especially evident for the youngest strings, comprising stars younger than 100 million years, which tend to be oriented at right angles to the spiral arm nearest to our solar system.

The astronomers suspect that the older strings of stars must have been perpendicular to the spiral arms that existed when these stars formed, which have now been reshuffled over the past billion years.

"The proximity and orientation of the youngest strings to the Milky Way's present-day spiral arms shows that older strings are an important fossil record of our galaxy's spiral structure," says co-author Kevin Covey, also of Western Washington University.

"The nature of spiral arms is still debated with the verdict on them being stable or dynamic structures not settled yet. Studying these older strings will help us understand if the arms are mostly static, or if they move or dissipate and re-form over the course of a few hundred million years — roughly the time it takes for the Sun to orbit around the galactic center a couple of times."

For more about Gaia, please visit: http://www.esa.int/Our_Activities/Space_Science/Gaia

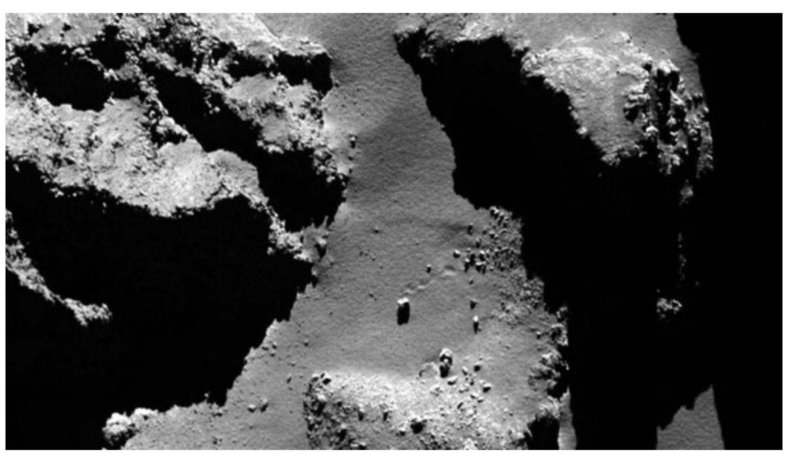
Comet's Collapsing Cliffs and Bouncing Boulders

Scientists analyzing the treasure trove of images taken by ESA's Rosetta mission have turned up more evidence for curious bouncing boulders and dramatic cliff collapses.

Rosetta operated at Comet 67P/Churyumov-Gerasimenko between August 2014 and September 2016, collecting data on the comet's dust, gas and plasma environment, its surface characteristics and its interior structure.

As part of the analysis of some 76,000 high-resolution images captured with its OSIRIS camera, scientists have been looking for surface changes. In particular, they are interested in comparing the period of the comet's closest approach to the Sun — known as perihelion — with that after this most active phase, to better understand the processes that drive surface evolution.

Loose debris is seen all over the comet, but sometimes boulders have been caught in the act of being ejected into space, or rolling across the surface. A new example of a bouncing boulder was recently identified in the smooth neck region that connects the comet's two lobes, an area that underwent a lot of noticeable large-scale surface changes over the course of the mission. There, a boulder about 10 meters wide (32.8 feet wide) has apparently fallen from the nearby cliff, and bounced several times across the surface without breaking or leaving



Example of a boulder having moved across the surface of Comet 67P/Churyumov-Gerasimenko's surface, captured in Rosetta's OSIRIS imagery. Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA.

"footprints" in the loosely consolidated surface material.

"We think it fell from the nearby 50 m-high [98.4 ft.-high] cliff, and is the largest fragment in this landslide, with a mass of about 230 tonnes [253.5 tons]," said Jean-Baptiste Vincent of the DLR Institute for Planetary Research, who presented the results at the 2019 EPSC-DPS conference in Geneva. "So much happened on this comet between May and December 2015 when it was most active, but unfortunately because of this activity we had to keep Rosetta at a safe distance. As such we don't have a close enough view to see illuminated surfaces with enough resolution to exactly pinpoint the 'before' location of the boulder."

Studying boulder movements like these in different parts of the comet helps determine the mechanical properties of both the falling material and the surface terrain on which it lands. The comet's material is in general very weak compared with the ice and rocks we are familiar with on Earth. Boulders on Comet 67P/C-G are around one hundred times weaker than freshly packed snow.

Another type of change has also been witnessed in several locations around the comet: the collapse of cliff faces along lines of weakness, such as the dramatic capture of the fall of a 70 m-wide (229.7 ft.-wide) segment of the Aswan cliff observed in July 2015. But Ramy El-Maarry and Graham Driver of Birkbeck, University of London, may have found an even larger collapse event, linked to a bright outburst seen on September 12, 2015 along the northern-southern hemisphere divide.

"This seems to be one of the largest cliff collapses we've seen on the comet during Rosetta's lifetime, with an area of about 2000 square meters [6561.7 square feet] collapsing," said El-Maarry, also speaking at EPSC-DPS.

During perihelion passage, the southern hemisphere of the comet was subjected to high solar input, resulting in increased levels of activity and more intensive erosion than elsewhere on the comet.

"Inspection of before and after images allow us to ascertain that the scarp was intact up until at least May 2015, for when we still have high enough resolution images in that region to see it," says Driver, an undergraduate student working with El-Maarry to investigate Rosetta's vast image archive.

"The location in this particularly active region increases the likelihood that the collapsing event is linked to the outburst that occurred in September 2015."

Looking in detail at the debris around the collapsed region suggests that other large erosion events have happened here in the past. El-Maarry and Driver found that the debris includes blocks of variable size ranging up to tens of meters, substantially larger than the boulder population following the Aswan cliff collapse, which is mainly comprised of boulders a few meters diameter.

"This variability in the size distribution of the fallen debris suggests either differences in the strength of the comet's layered materials, and/or varying mechanisms of cliff collapse," adds El-Maarry.

Studying comet changes like these not only gives insight into the dynamic nature of these small bodies on short timescales, but the larger scale cliff collapses provide unique views into the internal structure of the comet, helping to piece together the comet's evolution over longer timescales.

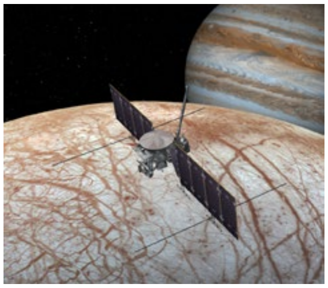
"Rosetta's datasets continue to surprise us, and it's wonderful the next generation of students are already making exciting discoveries," adds Matt Taylor, ESA's Rosetta project scientist.

For more information about Rosetta, please visit: http://www.esa.int/Our_Activities/Space_Science/Rosetta

Mission to Jupiter's Icy Moon Confirmed

An icy ocean world in our solar system that could tell us more about the potential for life on other worlds is coming into focus with confirmation of the Europa Clipper mission's next phase. The decision allows the mission to progress to completion of final design, followed by the construction and testing of the entire spacecraft and science payload.

"We are all excited about the decision that moves the Europa Clipper mission one key step closer to unlocking the mysteries of this ocean world," said Thomas Zurbuchen, associate administrator for the Science Mission Directorate at NASA Headquarters in Washington. "We



This artist's rendering shows NASA's Europa Clipper spacecraft, which is being developed for a launch sometime in the 2020s. This view shows the spacecraft configuration as of early 2016. Credit: NASA/JPL-Caltech.

are building upon the scientific insights received from the flagship Galileo and Cassini spacecraft and working to advance our understanding of our cosmic origin, and even life elsewhere."

The mission will conduct an in-depth exploration of Jupiter's moon Europa and investigate whether the icy moon could harbor conditions suitable for life, honing our insights into astrobiology. To develop this mission in the most cost-effective fashion, NASA is targeting to have the Europa Clipper spacecraft complete and ready for launch as early as 2023. The agency baseline commitment, however, supports a launch readiness date by 2025.

For more about the Europa Clipper mission, please visit: https://www.jpl.nasa.gov/missions/europa-clipper/

Unexpected Periodic Flares May Shed Light on Black Hole Accretion

ESA's X-ray space telescope XMM-Newton has detected never-before-seen periodic flares of X-ray radiation coming from a distant galaxy that could help explain some enigmatic behaviors of active black holes.

XMM-Newton, the most powerful X-ray observatory, discovered some mysterious flashes from the active black hole at the core of the galaxy GSN 069, about 250 million light years away. On December 24, 2018, the source was seen to suddenly increase its brightness by up to a factor of 100, then dim back to its normal levels within one hour and light up again nine hours later.

"It was completely unexpected," says Giovanni Miniutti, of the Centro de Astrobiología in Madrid, Spain, lead author of a new paper published in the journal Nature.

"Giant black holes regularly flicker like a candle but the rapid, repeating changes seen in GSN 069 from December onwards are something completely new."

Further observations, performed with XMM-Newton as well as NASA's Chandra X-ray observatory in the following couple of months, confirmed that the distant black hole was still keeping the tempo, emitting nearly periodic bursts of X-rays every nine hours. The researchers are calling the new phenomenon quasi-periodic eruptions or QPEs.

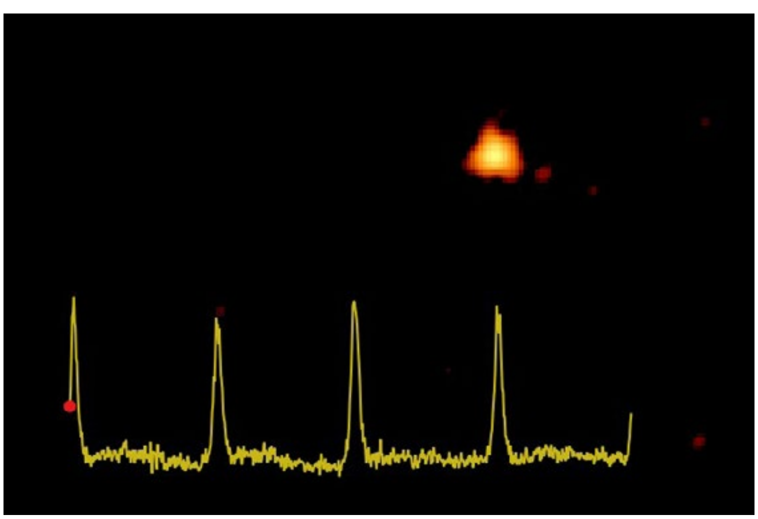
"The X-ray emission comes from material that is being accreted into the black hole and heats up in the process," explains Miniutti.

"There are various mechanisms in the accretion disc that could give rise to this type of quasi-periodic signal, potentially linked to instabilities in the accretion flow close to the central black hole.

"Alternatively, the eruptions could be due to the interaction of the disc material with a second body — another black hole or perhaps the remnant of a star previously disrupted by the black hole."

Although never before observed, Miniutti and colleagues think periodic flares like these might actually be quite common in the Universe.

It is possible that the phenomenon had not been identified before



An X-ray view of the active black hole at the core of distant galaxy GSN 069, about 250 million light years away, based on data from ESA's XMM-Newton X-ray observatory. The upper part shows an actual observation, and the graph in the lower part shows variations of the X-ray brightness of the source relative to its 'dormant' level. The black hole undergoes never-before-seen flashes — dubbed 'quasi-periodic eruptions', or QPEs — every nine hours. Credit: ESA/XMM-Newton; G. Miniutti & M. Giustini (CAB, CSIC-INTA, Spain).

because most black holes at the cores of distant galaxies, with masses millions to billions of times the mass of our Sun, are much larger than the one in GSN 069, which is only about 400,000 times more massive than our Sun.

The bigger and more massive the black hole, the slower the fluctuations in brightness it can display, so a typical supermassive black hole would erupt not every nine hours, but every few months or years. This would make detection unlikely as observations rarely span such long periods of time.

And there is more. Quasi-periodic eruptions like those found in GSN 069 could provide a natural framework to interpret some puzzling patterns observed in a significant fraction of active black holes, whose brightness seems to vary too fast to be easily explained by current theoretical models.

"We know of many massive black holes whose brightness rises or decays by very large factors within days or months, while we would expect them to vary at a much slower pace," says Miniutti.

"But if some of this variability corresponds to the rise or decay phases of eruptions similar to those discovered in GSN 069, then the fast variability of these systems, which appears currently unfeasible, could naturally be accounted for. New data and further studies will tell if this analogy really holds."

The quasi-periodic eruptions spotted in GSN 069 could also explain another intriguing property observed in the X-ray emission from nearly all bright, accreting supermassive black holes: the so-called soft excess.

It consists in enhanced emission at low X-ray energies, and there is still no consensus on what causes it, with one leading theory invoking a cloud of electrons heated up near the accretion disc.

Like similar black holes, GSN 069 exhibits such a soft X-ray excess during bursts, but not between eruptions.

"We may be witnessing the formation of the soft excess in real time, which could shed light on its physical origin," says co-author Richard Saxton from the XMM-Newton operation team at ESA's astronomy center in Spain.

"How the cloud of electrons is created is currently unclear, but we are trying to identify the mechanism by studying the changes in the X-ray spectrum of GSN 069 during the eruptions."

The team is already trying to pinpoint the defining properties of GSN 069 at the time when the periodic eruptions were first detected to look for more cases to study.

"One of our immediate goals is to search for X-ray quasi-periodic eruptions in other galaxies, to further understand the physical origin of this new phenomenon," adds co-author Margherita Giustini of Madrid's Centro de Astrobiología.

"GSN 069 is an extremely fascinating source, with the potential to become a reference in the field of black hole accretion," says Norbert Schartel, ESA's XMM-Newton project scientist.

The discovery would not have been possible without XMM-Newton's capabilities.

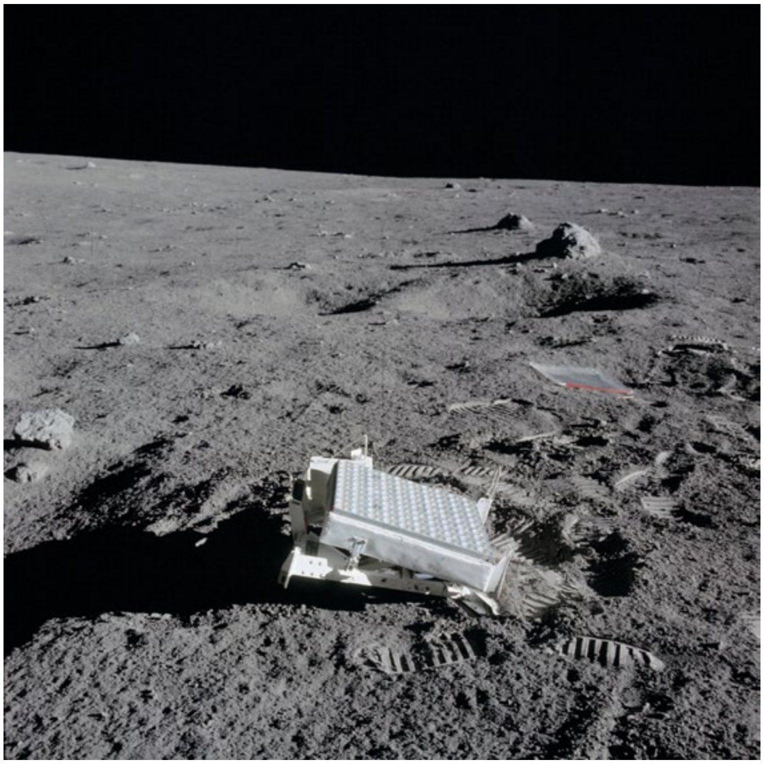
"These bursts happen in the low energy part of the X-ray band, where XMM-Newton is unbeatable. We will certainly need to use the observatory again if we want to find more of these kinds of events in the future," concludes Schartel.

For more about this discovery of QPEs, please visit: https://astronomycommunity.nature.com/users/300795-giovanni-miniutti/posts/53402-newly-discovered-x-ray-quasi-periodic-eruptions-qpes-from-a-galactic-nucleus-may-shed-light-on-bh-accretion

The Apollo Experiment That Keeps on Giving

Neil Armstrong, Buzz Aldrin and Michael Collins departed from the Moon 50 years ago, but one of the experiments they left behind continues to return fresh data to this day: arrays of prisms that reflect light back toward its source, providing plentiful insights. Along with the Apollo 11 astronauts, those of Apollo 14 and 15 left arrays behind as well. The Apollo 11 and 14 arrays have 100 quartz glass prisms (called corner cubes) each, while the array of Apollo 15 has 300.

The longevity of the experiment can be attributed at least in part to its simplicity because the arrays themselves require no power. Four telescopes at observatories in New Mexico, France, Italy, and Germany fire lasers at them,



A close-up view, taken on February 5, 1971, of the laser ranging retro reflector (LR3), which the Apollo 14 astronauts deployed on the moon during their lunar surface extravehicular activity. Credit: NASA.

measuring the time that it takes for a laser pulse to bounce off the reflectors and return to Earth. This allows the distance to be measured to within a few millimeters.

The orbit, rotation, and orientation of the Moon are accurately determined by lunar laser ranging. The lunar orbit and the orientation of the rotating Moon are needed by spacecraft that orbit and land on the Moon. For instance, cameras on spacecraft in lunar orbit can see the reflecting arrays, relying on them as locations accurate to less than a fraction of a meter.

Laser ranging measurements have deepened our understanding of the dance between the Moon and Earth as well. The Moon orbits Earth at an average distance of 385,000 kilometers (239,000 miles), but lunar laser ranging has accurately shown that the distance between the two increases by 3.8 centimeters (1.5 inches) a year.

Tides in Earth's oceans are highest not when the Moon is overhead, but hours later. The highest tide is east of the Moon. There are two tidal bulges, the second one half a day later. The gravitational force between the tidal bulges and the Moon pull against and slow Earth's rotation while also pulling the Moon forward along the direction it moves in its orbit about Earth. The forward force causes the Moon to spiral away from Earth by 3 millimeters (0.1 inches) each month.

In a similar way, Earth's gravity tugs on the Moon, causing two tidal bulges of the lunar rock. In fact, the positions of the reflecting arrays vary as much as 15 centimeters (6 inches) up and down each month as the Moon flexes. Measuring how much the arrays move has enabled scientists to better understand the elastic properties of the Moon.

Analysis of lunar laser data shows that the Moon has a fluid core. This was a surprise when discovered two decades ago because many scientists thought that the core would be cool and solid. The fluid core affects the directions in space of the Moon's north and south poles, which lunar laser detects.

Einstein's theory of gravity assumes that the gravitational attraction between two bodies does not depend on their composition. The Sun's gravity attracts the Moon and Earth. If this attraction depended on the composition of the two objects, it would affect the lunar orbit. Earth contains more iron than the Moon. Analysis of data from the lunar laser ranging experiment finds no difference in how gravity attracts the Moon and Earth due to their makeup.

The north star Polaris is nearly overhead at Earth's north pole. That pole changes direction compared to the stars due to the gravitational pull of the Moon and Sun on Earth's shape (the diameter at the equator is larger than the diameter at the poles). The pole will trace out a circle in the sky returning to the north star in 26,000 years. This motion of the pole is sensed and measured by lunar laser ranging.

With renewed interest in the exploration of the Moon, NASA has approved a new generation of reflectors to be placed on the lunar surface within the next decade. The improved performance of new reflectors and their wider geographical distribution on the Moon would allow improved tests of Einstein's relativity, study the deep lunar interior, investigation of the history of our celestial neighbor, and support of future exploration. The legacy of the first human visit to the Moon half a century ago will be continued.

For more about the Apollo missions, please visit: https://www.nasa.gov/mission_pages/apollo/missions/index.html

MEETING HIGHLIGHTS

Pluto System After New Horizons

The Pluto System After New Horizons (PSANH) conference was held at the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland, on July 14–18, 2019. The conference provided an opportunity to summarize our understanding of the Pluto system and the Kuiper belt following the New Horizons encounters with Pluto and 2014 MU69 (nicknamed "Ultima Thule"). Contributions spanning all relevant research on the Kuiper belt, including both observations and theory, were presented.

The conference began with a reception on July 14 to celebrate the fourth anniversary of the New Horizons flyby of Pluto. Scientific sessions filled the next four days with a mix of invited reviews and contributed oral presentations. The morning and evening oral sessions were organized according to the following themes: Pluto Geology, Pluto Composition, Charon, Pluto's Small Satellites, Pluto Atmosphere (including haze), Pluto Climate, MU69 and KBOs, Potential Future Missions to Pluto and the Outer Solar System, and Origins. For each theme, a panel discussion followed the individual presentations to delve deeper into each subject and to identify any remaining unresolved issues. A two-hour poster session spanning all the scientific themes was held on the afternoon of July 16.

The invited reviews at the conference form the basis for the chapters in a new book being prepared to summarize our current understanding of the Pluto system and the Kuiper belt, following the discoveries and insights provided by both the New Horizons mission and ongoing remote sensing observations. This book will be part of the Space Science Series published by the University of Arizona Press in collaboration with the Lunar and Planetary Institute and will be the successor to the "Pluto and Charon" volume published in 1997.

The results from the New Horizons mission revolutionized our view of the Pluto system, but those findings provide only a snapshot in time of a very dynamic place. Fortunately, the New Horizons results also provide ground truth for ongoing remote sensing observations, informing the interpretation of their results. Hopefully, this rich "third zone" of the solar system will continue to be explored in the years ahead by both in situ spacecraft and ever more sophisticated remote sensing facilities.

For more information about the PSANH conference, including links to the program and abstracts, visit the meeting website at https://www.hou.usra.edu/meetings/plutosystem2019/.

— Summary provided by Hal Weaver

Lunar ISRU Workshop

The 2019 Lunar ISRU Workshop was held at USRA Headquarters in Columbia, Maryland, on July 15–17. An international group of approximately 200 people from Europe, Australia, Canada, Korea, and Japan participated in this workshop, and represented government, commercial, and academic institutions.

The workshop brought together several broad communities not accustomed to working together: policy, legislation, law, and regulation; marketing, valuation, and finance; mineral exploration (characterization); mining (extraction); mineral processing; and planetary science. Each community has its own levels of history and terminology. A common observation among the workshop attendees was that moving forward would be faster and more effective with better communication. In addition to speeding information dispersal, better communication would help replace unknowing repetitions of effort with more nuanced, broadly based cooperative work. To that end, a glossary or dictionary focused on Space Resources should be developed in 2020 and maintained indefinitely in an easy-to-find location.

The workshop was set up to investigate the five phases of resource utilization: identification, characterization, extraction, processing, and markets. The first morning was devoted to introducing the workshop and community updates from space agencies and commercial entities. During the workshop, the attendees were polled on 14 questions and statements using Mentimeter (www.mentimeter.com) to get a sense of where the majority opinion was regarding lunar in situ resource utilization (ISRU). These questions were distributed throughout the sessions to encourage audience participation.

The major findings from this workshop included:

- Architectures for human spaceflight should be designed to utilize local resources.
- The most critical immediate issue for lunar ISRU is to execute a resource prospecting campaign to understand if the resources are actually geological reserves.
- Terrestrial mining companies will engage in lunar ISRU if they can see a net benefit to their operations.
- In order to get terrestrial mining companies involved, a market potential needs to be evident for products derived from space resources. A commitment to human permanence on the Moon and Mars is enabling for the commercial aspects of lunar ISRU and creation of markets.

At the end of the workshop, the audience was asked to respond to the question "What are the three takeaway messages you have learned at this workshop?" using one- or two-word answers. Ground truth, prospecting, collaboration, propellant, and simulants were the most popular answers.

To view the program, abstracts, and presentations, visit the workshop website at https://www.hou.usra.edu/meetings/lunarisru2019/.

— Summary provided by Clive Neal

Large Meteorite Impacts and Planetary Evolution VI

The sixth Large Meteorite Impacts and Planetary Evolution Conference (LMI VI) was held from September 30 to October 3, 2019, at the FINATEC (Fundação De Empreendimentos Científicos E Tecnológicos) on the University of Brasília (UnB) campus in Brasilia. The event attracted 90 participants from 21 countries. The LMI conference series arose out of the Workshop on Cryptoexplosions and Catastrophes in the Geological Record held in Parys (Vredefort Dome) in 1987, with the first two LMI meetings held in Sudbury in 1992 and 1997, followed by Nördlingen (Ries Crater) in 2003, the Vredefort Dome in 2008, and Sudbury in 2013. LMI VI is the first dedicated impact cratering meeting ever hosted in South America.

The conference group photograph taken in front of the FINATEC conference venue.

In a departure from previous meeting formats, two workshops were held prior to the start of the conference proper. Twenty-eight additional presentations were delivered at these workshops. Ludovic Ferrière and Michael Poelchau hosted the 1.5-day workshop for 17 participants on "Recognition of Impact Structures and Ejecta Layers on Earth – Shock Metamorphism in Rocks and Minerals." Presentations ranged from introductory shock physics to reviews of impact-diagnostic criteria, and new research results related to identification of impact structures, crater fields, and ejecta layers, as well as practical sessions covering microscopy of shock phenomena and PDF indexing. The one-day "Electron Backscatter Diffraction (EBSD) and Geochronology" workshop, organized by Aaron Cavosie, Erin Walton, Timmons Erickson, and Gavin Kenny, updated 17 participants on state-of-the-art EBSD applications to zircon and a range of other accessory minerals that hold great promise as additional criteria for confirmation of shock metamorphism and as shock barometers. In addition, data relating to different dating techniques (LA-ICP-MS, SIMS, and ID-TIMS) for accessory minerals were compared.

The program of the main conference commenced on September 30. A total of 70 oral and 51 poster presentations were made, with special sessions on The Chicxulub Impact Event and the K-Pg Boundary, Shock Wave/Material Interactions, Distal

Impact Ejecta, and Impact Cratering on Lunar and Planetary Bodies, besides more general themes such as Cratering Processes, Complex Impact Structures, Large Impacts and the Evolution of Life, Impactites, and Impact Melts. The more relaxed 20-minute oral time slots provided ample opportunity for further interactions, which continued into the tea and lunch breaks, as well as well-organized evening functions. More than 30 presentations have been promised for a conference proceedings volume that is likely to take the form of a GSA Special Paper.

Following the conference, from October 4–8, 27 participants joined the Araguainha Dome excursion in central-western Brazil, which was led by Natalia Hauser; Elder Yokoyama led 13 participants through the Vista Alegre and Vargeão impact structures in southern Brazil. Despite threats of heavy thunderstorms, particularly kind weather allowed the Araguainha group to complete two lengthy hikes through the central uplift of South America's largest impact structure, in which regional stratigraphy and the wide variety of Araguainha impactites, including several types of impact-formed melt breccias, were examined. Hauser was ably assisted by Uwe Reimold and Ph.D. student Carolinna Souza Maia. Additional contributors to the field guide included Alvaro Crósta, Marcos Vasconcelos, and Ana Rita Maciel. The Vargeão and Vista Alegre structures afforded participants excellent opportunities to observe and discuss the formation of shatter cones, and examine monomict and polymict breccias and pseudotachylitic breccias formed in the Serra Geral basalt and its sedimentary footwall, with extensive discussion of these features as analogs for lunar and martian targets. The field guide was co-compiled by Alvaro Crósta.

The Araguainha tour in front of the Serra de Arnica folded quartzites.

Considering that 17 researchers and postgraduate students from Brazil attended the workshops and conference, and judging from the discussion held during the conference and excursions, LMI VI is likely to prove to be a significant catalyst for future impact research on the continent, with several new international collaborations already in progress.

The conference also provided an opportunity for a plenary discussion on the future of the terrestrial impact database. The conference (1) approved that a formal approach be made to The Meteoritical Society by the organizing committee of the conference to explain the current situation and request guidance and support for planned efforts to revise the database, and (2) nominated a task group to review the existing state of the terrestrial database and propose changes to be considered at the 2020 LPSC and MetSoc meetings.

The success of LMI VI is largely thanks to the tireless efforts of the local organizing committee of Wolf Uwe Reimold (UnB; Chair), Natalia Hauser, Luciana Prado, and Elder Yokoyama (all UnB), and Alvaro P. Crósta (University of Campinas), supported by David Baratoux, Jeff Plescia, and Kai Wünnemann. Christian Koeberl chaired the Scientific Committee, which, in addition to the members of the organizing committee, included Aaron Cavosie, Gareth Collins, Roger Gibson, Paula Lindgren, Lidia Pittarello, and Mark Wieczorek. The meetings support group of the Lunar and Planetary Institute, Houston, provided sterling conference support to the organizing committee.

Financial support for the conference was provided by the Barringer Crater Company, The Institute of Geosciences at UnB, the University of Brasília, the CAPES foundation of Brasil, the IRD (Institut de Recherche pour le Développement, France), the FINATEC Foundation at the University of Brasília, and The Meteoritical Society. The Barringer Crater Company, The Meteoritical Society, and the IRD provided significant sponsorships that — combined — allowed 21 travel grants to be offered to postgraduate students and early career researchers. Philippe Claeys (Chair), Lidia Pittarello, Steven Jared, and Lutz Hecht formed the travel award committee, which was also supported by David Baratoux on behalf of the IRD.

In conclusion, the organizing committee would like to use this opportunity to express sincere thanks to all organizations and individuals who contributed to the success of LMI VI and, therefore, the future of impact cratering studies, in general, and in South America, in particular.

For more information about the program and abstracts, visit the conference website at https://www.hou.usra.edu/meetings/lmi2019/.

— Summary provided by Roger Gibson, Wolf Uwe Reimold, and Natalia Hauser

OPPORTUNITIES FOR STUDENTS

LPI Summer Intern Program in Planetary Science

The LPI Summer Intern Program in Planetary Science provides undergraduate students with an opportunity to perform cutting-edge, peer-reviewed research, learn from widely respected planetary scientists, and discover exciting careers in planetary science. During the 10-week internship, students have the opportunity to participate in enrichment activities, including NASA Johnson Space Center scientific visits, lectures, and career development workshops. Many of today's planetary science leaders got their start as LPI summer interns. Every career starts somewhere, and we encourage you to join us as you embark on your journey.

The Lunar and Planetary Institute invites undergraduates with at least 50 semester hours of credit to experience cutting-edge research in the lunar and planetary sciences. Students with majors in a physical or natural science, engineering, computer science, or mathematics have an advantage, but any eligible student may apply.

The 10-week program runs from June 1 to August 7, 2020. As a summer intern, you will work one-on-one with a scientist at the LPI or at the NASA Johnson Space Center on a research project of current interest in lunar and planetary science. Interns are selected by the project advisors who look for academic excellence and scientific interest and backgrounds compatible with their specific project needs.

Benefits of an internship:

- Gain valuable research experience
- Develop new skills and refine others
- Meet and work with professionals, establishing contacts for letters of reference and networking
- Experience a new work environment

The LPI is located near the NASA Johnson Space Center, on the south side of Houston, Texas. On NASA's behalf, the LPI provides leadership in the scientific community for research in lunar, planetary, and solar system sciences, and linkage with related terrestrial programs. The deadline for applying for the 2020 program is **January 6, 2020**.

For more information, including eligibility and selection criteria, areas of research, and an online application form, visit https://www.lpi.usra.edu/lpiintern/.

LPSC Student Opportunities

LUNAR AND PLANETARY SCIENCE CONFERENCE

LPI Career Development Award

The Lunar and Planetary Institute Career Development Award, which is open to both U.S. and non-U.S. applicants, will be given to selected graduate students who have submitted a first-author abstract for presentation at the 51st Lunar and Planetary Science Conference.

The application deadline will be **January 8, 2020.**

Stephen E. Dwornik Student Awards

The Dwornik awards are open to students at any degree level in a field related to planetary geosciences who are either (1) U.S. citizens or non-citizens currently enrolled in a U.S. educational institution, or (2) U.S. citizens currently enrolled in an international educational institution. Recent graduates, pre-college students, and post-doctoral fellows are not eligible. Students who have previously won a "best presentation" award as a graduate student are not eligible to compete again in either category. Students who have won a "best presentation" award as an undergraduate are not eligible to compete again in either category as an undergraduate but are eligible to compete in either category as a graduate student. Students who have won honorable mention award(s) as a graduate or undergraduate student in either category are eligible to compete again.

The deadline for Dwornik Award applications is **January 8, 2020.**

For more details about either of these awards,

visit https://www.hou.usra.edu/meetings/lpsc2020/student-awards/

NASA's Summer Undergraduate Program for Planetary Research

(formerly PGGRP)

The Summer Undergraduate Program for Planetary Research (SUPPR) is an eight-week summer internship providing undergraduates majoring in geology and related sciences with an opportunity to participate in NASA planetary geosciences research.

Students work under the direction of a NASA-sponsored planetary science investigator at various science institutions. The program is designed to help students gain educational experience in their fields of study while contributing to NASA missions and science.

College undergraduates who have not yet begun graduate studies and who are interested in learning about research in planetary geoscience are eligible. Previous participants of SUPPR (formerly PGGURP) are not eligible. Preference is given to U.S. citizens and permanent residents.

All online application information must be received at the LPI no later than **January 31, 2020**. Notification of selection will be made by March 13, 2020. Successful applicants should be prepared to make a decision regarding the offer to participate within two days of notification.

For more information, visit https://www.lpi.usra.edu/suppr/

SURF CALTECH

California Institute of Technology Summer Undergraduate Research Fellowships

The Summer Undergraduate Research Fellowships (SURF) program is one of the "crown jewels" of Caltech. Since 1979, SURF students have had the opportunity to conduct research under the guidance of experienced mentors working at the frontier of their fields. Students experience the process of research as a creative intellectual activity from beginning (defining and developing a project) to end (presenting their results at SURF Seminar Day).

SURF is modeled on the grant-seeking process:

- Students collaborate with a potential mentor to define and develop a project.
- Applicants write research proposals as part of the application process.
- Faculty review the proposals and recommend awards.
- Students carry out the work over a 10-week period during the summer.
- At the conclusion of the program, students submit a technical paper and give an oral presentation at one of several SURF Seminar Days, symposia modeled on a professional technical meeting.

The deadline for all application materials is **February 22, 2020**. For more information, visit https://www.sfp.caltech.edu/programs/surf.

NASA Internships and Fellowships

NASA Internships are competitive awards to support educational opportunities that provide unique NASA-related research and operational experiences for high school, undergraduate, and graduate students, as well as educators. These opportunities serve students by integrating interns with career professionals emphasizing mentor-directed, degree-related tasks, while contributing to the operation of a NASA facility or the advancement of NASA's missions.

The application deadlines for the 2020 program are:

Spring Session: **November 5, 2019**

Summer Session: **March 8, 2020**

For more information, visit https://intern.nasa.gov/.

NASA Fellowships are competitive awards to support independently conceived or designed research, or senior design projects by highly qualified faculty, undergraduate, and graduate students, in disciplines needed to help advance NASA's missions, thus affording them the opportunity to directly contribute to advancements in STEM-related areas of study. Our Fellowship opportunities are focused on innovation and generate measurable research results that contribute to NASA's current and future science and technology goals.

NASA Postdoctoral Program

The NASA Postdoctoral Program (NPP) provides early-career and more senior scientists the opportunity to share in NASA's mission, to reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.

NASA Postdoctoral Fellows work on 1- to 3-year assignments with NASA scientists and engineers at NASA centers and institutes to advance NASA's missions in Earth science, heliophysics, planetary science, astrophysics, space bioscience, aeronautics, engineering, human exploration and space operations, astrobiology, and science management.

NASA Postdoctoral Program Fellows contribute to our national scientific exploration, confirm NASA's leadership in fundamental research, and complement the efforts of NASA's partners in the national science community.

Application cycle deadlines for the NASA Postdoctoral Program are March 1, July 1, and November 1, annually. Currently, the Astrobiology Program accepts applications only during the March and November rounds and does not consider applications submitted during the July round.

Note: You may submit only ONE application for ONE research opportunity per application cycle.

For more information, visit [https://npp.usra.edu/.](https://npp.usra.edu/)

SAO Summer Intern Program

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

The Smithsonian Astrophysical Observatory (SAO) Summer Intern Program is an NSF Research Experience for Undergraduates (REU) internship where students take on an astrophysics research project with an SAO or Harvard scientist. In 2020, the program will run for 10 weeks, from June 7 to August 15. Students are expected to work at the Harvard-Smithsonian Center for Astrophysics for the full duration of the program. Interns are housed in Harvard's graduate student dormitory facilities.

Potential areas of research include (with a few example study subjects that reflect ongoing research at the Harvard Center for Astrophysics):

- Galaxies: How do they form, what powers them, how will they evolve over cosmic time?
- Our solar system: What are near-Earth asteroids? What kinds of objects populate the Oort cloud and Kuiper belt?
- Stars and planets: Are stellar models accurate? Where are new planets to be found?
- Lab astrophysics: What chemistry takes place in space? Do ices matter? How did the Earth get its water?
- Extreme astrophysics: What connects supermassive black holes to their host galaxies? What can we learn from X-ray emitting binary stars?
- Extreme astrophysics: What connects supermassive black holes to their host galaxies? What can we learn from X-ray emitting binary stars?

Undergraduate students interested in astronomy, astrophysics, physics, or related physical sciences are encouraged to apply. The program can offer a wide range of projects to interns.

For more information, visit https://www.cfa.harvard.edu/opportunities/reu/.

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Each summer, more than 400 college students from across the country are invited to intern at APL. As a college intern, you'll spend the summer contributing to engineering and research projects that help protect our nation and expand the frontiers of science.

APL College Summer Intern Program

APL offers science and engineering internships each summer. The Laboratory's internship program provides practical work experience and an introduction to APL. Students spend the summer working with APL scientists and engineers, conducting research, developing leadership skills, and growing professionally.

ATLAS Intern Program

The APL Technology Leadership Scholars (ATLAS) program provides a unique educational opportunity for a select group of students from Historically Black Colleges and Universities, Hispanic-Serving Institutions, and Tribal Colleges and Universities.

Discovery Program for College Graduates

The Discovery Program is an exciting opportunity for select recent college graduates. It consists of three to four assignments spanning multiple technical organizations across APL. The rotational assignments are six months in length each and are designed to provide participants with challenging work that will stimulate professional growth.

For more information about these and other programs, visit http://www.jhuapl.edu/Careers/Internships.

SPOTLIGHT ON EDUCATION

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration. Contact local astronomical societies, planetariums and museums, local scientists, and NASA's Solar System Ambassadors (solarsystem.nasa.gov/ssa/directory.cfm). Ask them to join your events and share their experiences or resources with your audience.

NASA: 60 Years and Counting

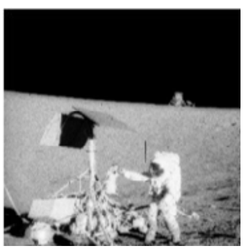
https://www.nasa.gov/60

From 2018 through 2022, NASA is marking a series of important milestones including the 60th anniversary of the agency's founding.

Transit of Mercury **November 11, 2019**

http://www.eclipsewise.com/oh/tm2019.html

This transit will be visible to observers in the U.S., New Zealand, Europe, Africa and western Asia. This event is a great opportunity to discuss the sun, Mercury, and/or the scale of the solar system with your communities!



50th Anniversary, Apollo 12 Landing

November 19, 2019

https://www.lpi.usra.edu/apollo50/

This November marks the 50th anniversary of the Apollo 12 landing on Oceanus Procellarum. Apollo 12 provided the first opportunity to study the Moon extensively within a radius of 0.5 kilometers of the landing site. The LPI has compiled a sample of its Apollo and future exploration resources, as well as public engagement resources at https://www.lpi.usra.edu/apollo50/.

Geminids Meteor Shower **December 13–14, 2019**

https://in-the-sky.org/news.php?id=20191214_10_100

The Geminids Meteor Shower is produced by dust particles left behind by asteroid 3200 Phaethon. Meteors will radiate from the constellation Gemini. The shower peaks this year on December 14; however, viewing will be less than ideal given the waning gibbous phase of the Moon. Meteor showers provide a great opportunity to discuss small bodies with your audiences!

Mars 2020 Rover Engagement Activities

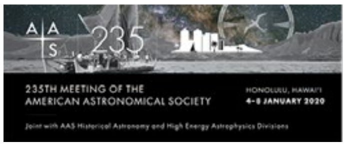
Beginning in Fall 2019, NASA will run a nationwide "Name the Rover" contest open to K–12 students in the U.S. Entries are now being accepted. The deadline is **November 1, 2019**.

https://mars.nasa.gov/mars2020/participate/name-the-rover/

Judges are also needed for the "Name the Rover" contest:
https://www.futureengineers.org/registration/judge/nametherover

All are invited to watch the live feed from the Spacecraft Assembly Facility cleanroom at JPL, where engineers are building and testing Mars 2020 before it is shipped to its launch site.

https://mars.nasa.gov/mars2020/mission/where-is-the-rover



Free Public Outreach Workshop for Early-Career Astronomers

The American Astronomical Society (AAS) is sponsoring a free skill-building workshop to support early-career astronomers in doing effective outreach to schools, families, and the public. The AAS Astronomy Ambassadors program is offering two days of hands-on training, extensive resources, and pre-tested activities with a like-minded group of peers. This workshop is offered in conjunction with the 235th meeting of the AAS in Honolulu in January 2020.

For more information and to apply to attend, visit https://aas.org/content/aas-astronomy-ambassadors-program-2020-application

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Resources for Planetary Scientists Involved in Public Engagement

The Lunar and Planetary Institute's education and public engagement team is pleased to assist planetary scientists in their communication and public engagement activities. The LPI conducts scientist workshops to provide insight on meeting audience needs, and has placed a variety of recommendations online.

https://www.lpi.usra.edu/education/scientist-engagement

"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.

Samuel A. Bowring 1953–2019

Samuel Bowring, the Robert R. Schrock Professor Emeritus of Geology in the Earth and Planetary Sciences (EAPS) Department of the Massachusetts Institute of Technology (MIT), has passed away.

Bowring was a legend in geochronology (pushing the limits of geochronologic techniques to unprecedented analytical precision and accuracy) and a world expert in constraining rates of geologic processes and the timing of significant events in the geologic record. He investigated the explosion of multi-cellular life in the Early Cambrian as well as the end-Permian and the end-Cretaceous mass extinctions. He is also highly regarded for his work on the origin and evolution of continental crust, showing, for instance, that that the Acasta Gneisses in the Northwest Territories of Canada were 4 billion years old.

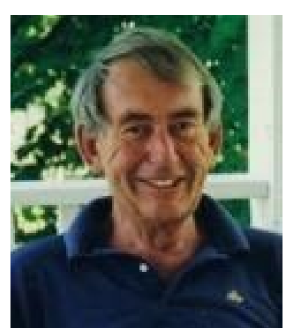
Bowring was born in Portsmouth, New Hampshire and raised in Durham, New Hampshire. He graduated from the University of New Hampshire with a B.S. in Geology in 1976, from the New Mexico Institute of Mining and Technology with an M.S. in 1980, and from the University of Kansas with a Ph.D. in Geology in 1985. He was an Assistant Professor at Washington University from 1984 to 1990. In 1991, he joined the faculty of MIT.

Bowring's major contributions were recognized by many organizations and institutions, including the National Academy of Sciences (Member, 2015), the American Academy for the Advancement of Science (Member, 2013), the American Geophysical Union (Fellow, 2008; Norman L. Bowen Award, 2010; Walter H. Bucher Medal, 2016), the Geochemical Society (Fellow, 2011), the Geological Society of America (Fellow, 1999), and MIT (Breene M. Kerr Professorship, 2002–2007; Margaret MacVicar Faculty Fellow, 2006 to 2019). Bowring was a dedicated teacher and mentor and made many contributions to EAPS, including serving the first-year learning community Terrascope (2006–2014) as associate director and then director, and chairing the (former) Undergraduate Committee (2002–2016). While he will be missed by friends, family, colleagues, and students, his enormous impact on MIT and Earth science will endure.

— Text courtesy of Rob van der Hilst, Massachusetts Institute of Technology

Robin Brett 1935–2019

Peter Robin Brett, the Australian-born scientist, who was one of the first to study rocks from the Moon during NASA's Apollo space program, died at home in Washington on September 27 as the result of Alzheimer's disease. He was 84 years old.



Born in 1935, in Adelaide, South Australia, Brett received his B.S. in geology from the University of Adelaide in 1956, and then left Australia to attend Harvard, where he earned a master's and Ph.D. in geology and geochemistry in 1963. Brett joined the staff of NASA's Johnson Space Center in 1969, and as chief of the geochemistry branch, was responsible for much of the planning for the study of the Apollo lunar samples. He conducted research on the materials brought back by astronauts on successive flights. He was also involved in planning missions, debriefing astronauts, relaying scientific information to the NASA community, and working with the press. His interest in interacting with the press was to excite the taxpayers about the knowledge and insights we gained from extraterrestrial science and why it mattered, explaining that by learning about the Moon, we learn much more about the Earth at present, by putting its past in context.

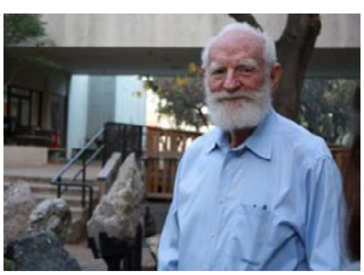
With the early lunar missions, there was a fear that lunar dust might harbor some lethal threat to humankind, so the astronauts were quarantined in a sealed-off section of the Lunar Receiving Lab (LRL) where Brett and the other scientists worked. After the Apollo 12 astronauts settled in, there was a spill in the LRL, potentially exposing Brett and his colleagues and sending them into quarantine with the astronauts. Brett received a NASA Exceptional Scientific Achievement Award in 1973 for his work in Houston.

Before his career with NASA, Brett worked at the U.S. Geological Survey (USGS) in Washington and returned there in 1974 to head the Division of Earth Sciences at the National Science Foundation. He and his staff were responsible for the funding of Earth science research and the Ocean Drilling Program (formerly the Deep Sea Drilling Project), a multi-national effort to explore and study the composition and structure of the Earth's oceanic basins. Brett published more than 90 papers on mineral deposits, lunar petrology, meteor impact structures, and the biological extinction of the dinosaurs. He was the first, in 1992, to suggest that heavily shocked anhydrite was a major killing mechanism of the dinosaurs when a meteor crashed into Mexico's Yucatan Peninsula 65 million years ago.

Starting with the Moon landings, Brett learned the importance of educating and informing those outside the science community about the importance of Earth science. "Few disciplines, no matter how meritorious, can survive if the public and decision makers do not find them interesting and relevant to everyday life," he said. "If we have not convinced them that basic science is fundamental to our existence, then we have failed ourselves and our future."

Brett was the first scientist from the U.S. to be named secretary general and president of the International Union of Geological Sciences. At various times, he was president of the Meteoritical Society and the Geological Society of Washington, as well as the chair of the planetology section of the Geological Society of America. In 2002, Brett was presented with the Superior Service Award of the U.S. Department of the Interior for outstanding career and contributions to the mission of the USGS. Asteroid 6179 Brett (1986 EN) was named in his honor.

James Carter 1937–2019



Credit: University of Texas at Dallas

Dr. James Carter, associate professor emeritus and one of the longest-serving faculty members at The University of Texas at Dallas (UT Dallas), died in Richardson, Texas, on September 21. He was 82.

Carter grew up in McAllen, Texas, and earned his bachelor's degree in mining and geological engineering from Texas Western College, now The University of Texas at El Paso, in 1961 and his Ph.D. in geochemistry from Rice University in 1965. Carter joined the Graduate Research Center of the Southwest (GRCSW) — the precursor institution to UT Dallas — as a postdoctoral researcher in 1964. He remained with the GRCSW when it became UT Dallas in 1969 and retired in 2008 after 43 years of teaching and research.

Throughout his career as a geoscientist, Carter studied everything from Earth's upper crust to environmental geochemistry to paleontology. A leading expert on lunar geology, Carter was one of the scientists who analyzed samples of Moon rocks brought back from the Apollo missions. NASA contacted him in the early 1990s to help create a material that was similar to actual lunar soil in chemical composition, texture, mineralogy, and other properties. The material was produced for engineering and equipment studies in support of future human activities on the Moon. Carter founded a company called ETSimulants to make and ship tons of the lunar regolith simulant, or fake Moon dirt, to NASA and other researchers.

He also made a name for himself when he discovered and helped excavate the articulated neck of an Alamosaurus in Big Bend National Park. One of the largest dinosaur fossils ever found in Texas, the skeleton is on display at the Perot Museum of Nature and Science.

Carter, who served as head of the Department of Geosciences from 1985 to 1993, taught classes, mentored many graduate students and led numerous geology field camps. When he retired, the School of Natural Sciences and Mathematics recognized the professor and his years of service by establishing the James L. Carter Scholarship/Fellowship Endowment Fund for students pursuing degrees in geosciences. The James L. Carter Master's Scholarship Fund for Geosciences was subsequently established in 2016.

David Criswell 1941–2019

David Criswell, a noted space physicist with many science publications and worldwide patents, as well as a former member of the science staff at the Lunar Science/Lunar and Planetary Institute, passed away on September 10. He was 78 years old.

Criswell received his Ph.D. in 1968 from Rice University in the Department of Space Physics and Astronomy. His graduate research at Rice University included experimental work on auroral photometry and particle detection using rockets and satellites. He joined the technical staff of TRW Inc.-Houston Operations in 1968 and pursued a wide range of projects in support to the Apollo program. In 1970, Criswell came to the newly created Lunar Science Institute in Houston as a visiting scientist, becoming a senior staff scientist by the time the Institute was renamed as the Lunar and Planetary Institute.

Criswell conducted research on Moon-solar wind interactions, dynamics of the soil regolith, lunar surface seismology, and related topics. He directed the only post-Apollo study funded by NASA during the 1970s on the conversion of lunar resources into basic industrial materials. He directed a number of LPI functions such as local and international scientific conferences and study groups, edited major proceedings and special journal issues, and operated the Lunar and Planetary Review Panel, which that reviewed more than 3000 research proposals submitted to NASA in the 1970s.

Criswell began writing articles and papers on the use of extraterrestrial materials for commercial usage and space settlements in 1979. His article in The Industrial Physicist, "Solar Power via the Moon" (April/May 2002), was the continuation of many years of dedicated service to the development of space resources for developing Third World Countries, seeking to develop a source of safe, efficient, and cost-effective energy for future generations of Earth's inhabitants.

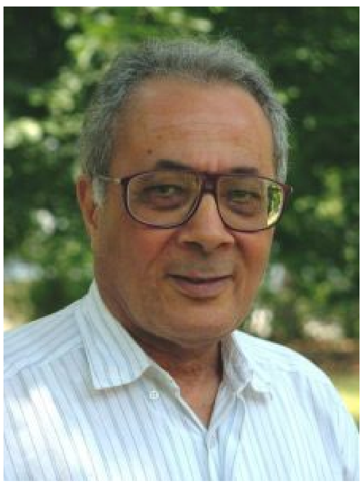
In 1980, Criswell accepted a research position with the newly formed California Space Institute (CalSpace) headquartered at the University of California, San Diego. He participated in formulation of local and statewide Cal Space research programs and acquired NASA and private funds for the development of systems to process lunar materials, directing high-level program reviews for NASA and the congressional Office of Technology Assessment.

From 1982 to 1990 Criswell served as an aerospace consultant, working with industry, government, and academic clients. He also organized and participated in reviews of advanced research programs at the Institute of Geophysics and Planetary Physics at Los Alamos National Laboratory and provided similar assistance to the Illinois Space Institute. He directed the CalSpace Automation and Robotics Panel, which conducted an independent evaluation of the use of advanced automation and robotics within the NASA space station program. Criswell was also the primary developer and Director of the Consortium for Space/Terrestrial Automation and Robotics of the Universities Space Research Association. Criswell organized and wrote the proposal under which the University of California won the National Space Grant

College and Fellowship program in California in 1989 and operated the program for the first year before returning to Texas in 1990.

While successful in a number of professional research areas, Criswell was most passionate about and most noted for his work on a potential lunar solar power system, which was designed to build bases on the Moon in order to beam clean, renewable energy from the Sun to Earth. People often said he was a man ahead of his time. In his personal life, he was a devoted, funny, sweet husband, father, grandfather, brother, and friend. In every sense, the world will be much the poorer without him.

Ahmed El Goresy 1934–2019



Credit: Bayerisches Geoinstitut

Ahmed El Goresy died at his home in Heidelberg on October 3, 2019, at the age of 85. El Goresy was a highly regarded mineralogist with a worldwide reputation. His research focused on minerals and mineral assemblages of extraterrestrial samples. With his major tool, reflected light microscopy, he studied meteorite samples from asteroids, the Moon, and Mars, as well as lunar rocks and terrestrial impactites. He was a pioneer in complementing his microscopic findings by using scanning electron microscopy, the electron microprobe, and later the ion probe and Raman spectroscopy. He made numerous discoveries of shock-induced high-pressure phases in meteorites and samples from terrestrial impact craters, and detected unusual mineral assemblages in a variety of meteorite types, studying their chemistry and isotopic composition. With his work he significantly contributed to a better understanding of cosmochemical processes in the early solar system.

El Goresy obtained his B.Sc. in 1955 in Mineralogy and Petrology at the University of Heliopolis, Cairo, Egypt. In 1961, he received his Ph.D. for work on ore deposits by using ore microscopy. His supervisor was the famous pioneer of ore microscopy, Paul Ramdohr at the University of Heidelberg. El Goresy was Ramdohr's last and best student. In 1969, Ramdohr became principal investigator of NASA's lunar sample analysis program. El Goresy was his co-investigator, and eventually took over as principal investigator. El Goresy and Ramdohr made fundamental contributions to the study of opaque mineralogy and phase assemblages of lunar mare basalts as well as highland rocks, estimating temperature and oxygen fugacity during crystallization of lunar mare basalts.

In 1961, he briefly returned to Egypt, taking a research position in Cairo. In 1963, he became a research scientist at the Max-Planck Institut für Kernphysik in Heidelberg. He then spent some months as a guest scientist at the Smithsonian Astrophysical Observatory and at Harvard University before taking a two-year post-doctoral fellowship at the Carnegie Institution of Washington. After his return to Germany, he became a senior scientist at the Max-Planck-Institut für Kernphysik in Heidelberg and later Professor at the Universität Heidelberg. In 1998 he officially retired from his position in Heidelberg and moved to the cosmochemistry department of the Max-Planck-Institut für Chemie in Mainz. After closure of the cosmochemistry department in 2005, El Goresy moved to the Bayerisches Geoinstitut in Bayreuth, where he stayed active until August 2017.

In scientific meetings, El Goresy was very outspoken. He clearly stated his opinion and never avoided discussion of controversial issues. He was extremely enthusiastic about his research, and it was almost impossible to talk to him about things other than his own research. He was so excited about his findings that in his talks he would often exceed the time limit; his contributions in meetings and discussions will be missed.

El Goresy had about 25 students, many of whom have made a career in science. The first thing he always taught his students was to look through a microscope, as the basis of any further work. El Goresy saw features in thin sections others did not see. His knowledge of minerals, particularly opaque minerals, was enormous and because he was familiar with all relevant phase relations, he could immediately explain these or speculate on the origin of the observed mineral assemblage.

El Goresy served the scientific community as Council Member of the Meteoritical Society; Chairman of the International Commission on Cosmic Mineralogy of the International Mineralogical Association; and United Nations Visiting Professor at the Institute of Mineral Deposits of the Chinese Academy of Geology, Beijing, China. He participated in the NASA Lunar and Planetary Science Review Board, and was awarded with the Victor-Moritz Goldschmidt Award and the Abraham-Gottlob-Werner Medal of the German Mineralogical Society. In 1972, he became a fellow of the Meteoritical Society, and was the recipient of the Leonard Medal in 2013. He was invited as Fairchild Distinguished Scholar in 1983 at the California Institute of Technology in Pasadena, and was a guest Professor at the Muséum National d'Histoire Naturelle in Paris in 1994, and more recently at the Tohoku University in Sendai, Japan, and at the Ecole Polytechnique Fédérale de Lausanne, Switzerland.

With the passing of El Goresy, the Meteoritical Society has lost a highly motivated researcher with extraordinary abilities. He dedicated his work to the observation and interpretation of microstructures in meteorites and was one of the key drivers for progress in the field of cosmochemistry. Scientists like him have become rare.

NASA Administrator Selects Douglas Loverro as Next Human Spaceflight Head

Credit: Bayerisches
Image credit: Department of Defense

NASA Administrator Jim Bridenstine named Douglas Loverro as the agency's new associate administrator for the Human Exploration and Operations Mission Directorate. Loverro succeeds former astronaut Kenneth Bowersox, who has been acting associate administrator since July.

For three decades, Loverro was in the Department of Defense and the National Reconnaissance Office developing, managing, and establishing national policy for the full range of national security space activities.

From 2013 to 2017, Loverro served as the Deputy Assistant Secretary of Defense for Space Policy. In this role, he was responsible for establishing policy for United States allies to the benefits of space capabilities and to help guide the department's strategy for addressing space-related issues. He led departmental activities in international space cooperation, assessment of the national security impacts of commercial space activities, and oversaw the establishment of a strategy for addressing growing challenges in space security.

Loverro is the recipient of many prestigious honors, including the Secretary of Defense's Medal for Outstanding Public Service, the Lifetime Achievement Award from the Federation of Galaxy Explorers, the Society of Satellite Professional Engineers Stellar Award, and the AFCEA Benjamin Oliver Gold Medal for Engineering among many other civilian and military honors.

Loverro holds a Master's of Science in Physics from the University of New Mexico, a Master's of Political Science from Auburn University, and a Master of Business Administration from the University of West Florida, in addition to his Bachelor of Science in Chemistry from the United States Air Force Academy. He was a distinguished graduate from the Air Force's Air Command and Staff College and Squadron Officer School and was the top graduate from the Defense Department's Industrial College of the Armed Forces.

For information about NASA's missions, programs, and activities, including the Artemis and Commercial Crew programs, visit: https://www.nasa.gov.

NASA Administrator Names Acting Director for Goddard Space Flight Center

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Credits: NASA/
Bill Hrybyk

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For information about NASA's missions, programs, and activities, including the Artemis and Commercial Crew programs, visit: https://www.nasa.gov.

NASA Announces New Director of Langley Research Center

Image credit: NASA

NASA Administrator Jim Bridenstine announced the selection of Clayton Turner as the next director of the agency's Langley Research Center in Hampton, Virginia. Turner assumed the director's position on September 30, when current Center Director David Bowles retired after 39 years with the agency.

Since 2015, Turner has served as Langley's deputy center director. As center director, he will lead a diverse group of about 3,400 civil servant and contractor scientists, researchers, engineers and support staff, who work to make revolutionary improvements to aviation, expand understanding of Earth's atmosphere, and develop technology for space exploration.

Prior to his appointment as deputy center director, Turner served as the associate director responsible for managing daily operations with a focus on center commitments. In this capacity, he was responsible for aligning Langley's institutional resources and infrastructure to meet current and future NASA mission needs. Turner also served as director of the Engineering Directorate at Langley. In this capacity, he was responsible for the conceptualization, design, development and delivery of ground and flight systems and for designing, enabling and implementing engineering capabilities to meet NASA missions.

Turner began his career with NASA in 1990 by serving as a design engineer with the Lidar In-Space Technology Experiment project, where he spearheaded development of the laser aligning, bore-sight limit system. Over the next 29 years, Turner served in various roles with progressively increasing responsibility, leading the agency's engineering contributions to many successful flight projects, including: the

Earth Science Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation Project; the Earth observing technology development Gas and Aerosol Monitoring Sensorcraft Project; the materials technology development Gas Permeable Polymer Materials Project; the Space Shuttle Program Return-to-Flight; the flight test of the Ares 1-X rocket; the flight test of the Orion Launch Abort System; and the entry, decent and landing segment of the Mars Science Laboratory.

Turner earned a Bachelor of Science Degree in electrical engineering from Rochester Institute of Technology. Throughout his career, Turner has received many prestigious awards, including the Presidential Rank Award, the NASA Outstanding Leadership Medal, the NASA Exceptional Engineering Achievement Medal, and the Paul F. Holloway Non-Aerospace Technology Transfer Award.

For more information about Turner, visit: https://www.nasa.gov/feature/langley/clayton-p-turner-deputy-director-nasa-langley-research-center.

NASA Awards $2.3 Million in Fellowships to U.S. Universities for Aviation, Planetary, Space Research

NASA has awarded fellowships to 14 minority-serving institutions through its Minority University Research and Education Project (MUREP) and five majority institutions through its Aeronautics Research Mission Directorate (ARMD), all totaling $2.3 million, to support graduate student research.

The university projects funded by these fellowships represent the highest levels of the innovative breadth and depth of research and contribute directly to the nation's aviation and space priorities, including America's return to the Moon through the Artemis program.

The recipient institutions of MUREP fellowships are:

- The University of California, Riverside
- The University of Minnesota (two awards)
- University of New Mexico
- University of Texas, Arlington
- University of California, Irvine
- University of Maryland
- University of Washington, Seattle
- Montclair State University
- Florida International University
- New Mexico State University
- University of Hawaii Systems
- University of Houston System
- San Diego State University Foundation

The recipient institutions of ARMD fellowships are:

- University of Florida
- Ohio State University
- Pennsylvania State University
- Georgia Institute of Technology
- Pennsylvania State University

The awards provide for the augmentation of each award with the possibility of a fourth-year extension based on an institution's ability to expand on the previous years' accomplishments, offering further opportunities to infuse new research into NASA's work in the areas of science and aeronautics, and providing a timeline conducive to aiding the agency's forward momentum with lunar missions. The agency's lunar exploration plans are based on a multifaceted approach, first landing astronauts on the Moon by 2024 and then establishing a sustained human presence on and around the Moon by 2028 as a way to prepare to send astronauts to Mars.

For more information these fellowship awards and the projects they will fund, visit: https://www.lpi.usra.edu/publications/newsletters/lpib/new/nasa-awards-2-3-million-fellowships-u-s-universities-aviation-planetary-space-research/

NASA Marshall to Lead Artemis Program's Human Lunar Lander Development

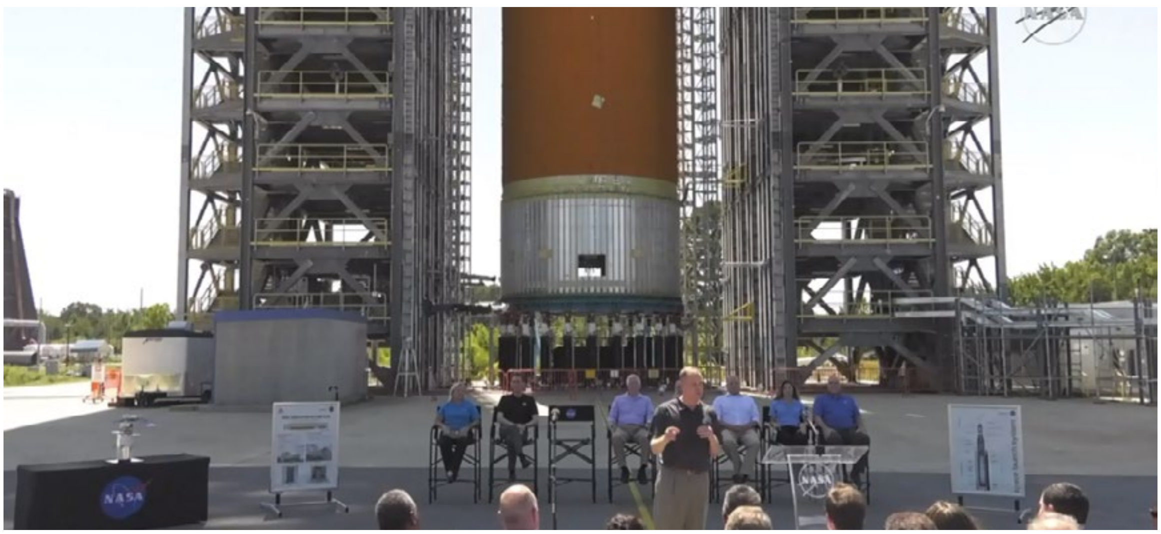


Image credit: NASA Television

NASA Administrator Jim Bridenstine was joined by U.S. Representatives Mo Brooks and Robert Aderholt of Alabama and Scott DesJarlais of Tennessee at the agency's Marshall Space Flight Center in Huntsville, Alabama, to announce the center's new role leading the agency's Human Landing System Program for its return to the Moon by 2024.

"Marshall Space Flight Center is the birthplace of America's space program. It was Marshall scientists and engineers who designed, built, tested, and helped launch the giant Saturn V rocket that carried astronauts on the Apollo missions to the Moon," Brooks said. "Marshall has unique capabilities and expertise not found at other NASA centers. I'm pleased NASA has chosen Marshall to spearhead a key component of America's return to the Moon and usher in the Artemis era. Thanks to Administrator Bridenstine for travelling here to share the great news in person."

Bridenstine discussed the announcement in front of the 149-foot-tall Space Launch System (SLS) rocket liquid hydrogen tank structural test article currently being tested.

Informed by years of expertise in propulsion systems integration and technology development, engineers at Marshall will work with American companies to rapidly develop, integrate, and demonstrate a human lunar landing system that can launch to the Gateway, pick up astronauts. and ferry them between the Gateway and the surface of the Moon.

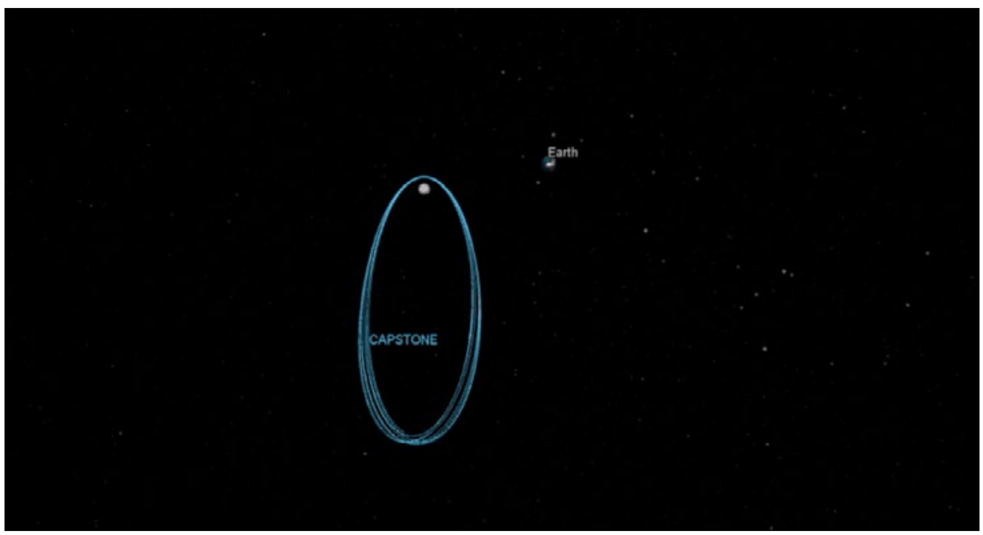
"Marshall Space Flight Center, and North Alabama, have played a key role in every American human mission to space since the days of Mercury 7. I am proud that Marshall has been selected to be the lead for the landers program," said Aderholt. "I am also very proud that Marshall has designed and built the rocket system, the

Space Launch System, which will make missions to the Moon and Mars possible. We look forward to working with our industry partners and our NASA partners from around the country."

NASA's Johnson Space Center in Houston, which manages major NASA human spaceflight programs including the Gateway, Orion, Commercial Crew and International Space Station, will oversee all aspects related to preparing the landers and astronauts to work together. Johnson also will manage all Artemis missions, beginning with Artemis 1, the first integrated test of NASA's deep space exploration systems.

For more on NASA's Artemis program, visit: https://www.nasa.gov/artemis.

NASA Funds CubeSat Pathfinder Mission to Unique Lunar Orbit



NASA has awarded a $13.7 million contract to Advanced Space of Boulder, Colorado, to develop and operate a CubeSat mission to the same lunar orbit targeted for Gateway – an orbiting outpost astronauts will visit before descending to the surface of the Moon in a landing system as part of NASA's Artemis program.

The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) is expected to be the first spacecraft to operate in a near rectilinear halo orbit around the Moon. In this unique orbit, the CubeSat will rotate together with the Moon as it orbits Earth and will pass as close as 1,000 miles and as far as 43,500 miles from the lunar surface.

The pathfinder mission represents a rapid lunar flight demonstration and could launch as early as December 2020. CAPSTONE will demonstrate how to enter into and operate in this orbit as well as test a new navigation capability. This information will help reduce logistical uncertainty for Gateway, as NASA and international partners work to ensure astronauts have safe access to the Moon's surface. It will also provide a platform for science and technology demonstrations.

The 12-unit CubeSat is about the size of a small microwave oven. Onboard is a communications system capable of determining how far CAPSTONE is from NASA's Lunar Reconnaissance Orbiter and how fast the distance between the two spacecraft is changing. The inter-spacecraft information will be used to demonstrate software for autonomous navigation, allowing future missions to determine their location without having to rely exclusively on tracking from Earth.

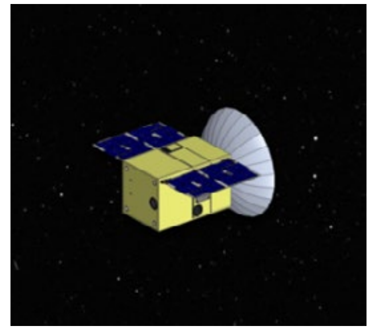
CAPSTONE will provide NASA

and its partners with important insights to support exploration of the Moon and Mars, including:

- Demonstration of spacecraft-to-spacecraft navigation services
- Verification of near rectilinear halo orbit characteristics for future spacecraft
- Experience entering this orbit with a highly efficient lunar transfer
- Experience with rideshare or small dedicated launches to the Moon
- Commercial experience providing mission planning and operations support services for
- CubeSats beyond Earth
- Rapid commercial delivery of a CubeSat mission beyond Earth orbit

A number of launch options are possible for the mission, including being the primary payload on a small spacecraft launch vehicle. After launch, CAPSTONE will take approximately three months to enter its target orbit and begin a six-month primary demonstration phase to understand operations in this unique regime.

The award to Advanced Space is through a Phase III Small Business Innovation Research (SBIR) contract, a follow-on to earlier SBIR awards that developed CAPSTONE's autonomous positioning and navigation system experiment.

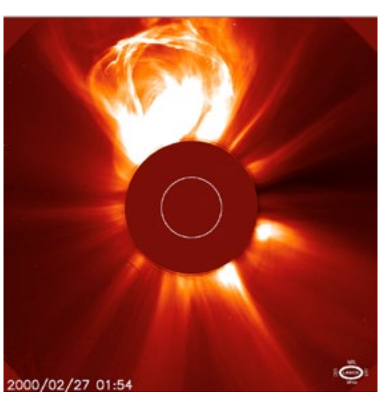


Credits: Tyvak Nano-Satellite Systems

The CAPSTONE team includes Advanced Space and Tyvak Nano-Satellite Systems, Inc. of Irvine, California. The project is managed by NASA's Small Spacecraft Technology (SST) program within the agency's Space Technology Mission Directorate. Based at NASA's Ames Research Center in California's Silicon Valley, SST expands U.S. capability to execute unique missions through rapid development and demonstration of capabilities for small spacecraft applicable to exploration, science and the commercial space sector. Advanced Exploration Systems (AES) within NASA's Human Exploration and Operations Mission Directorate will fund the launch and support mission operations. AES engages in activities focused on advanced design, development, and demonstration of exploration capabilities to reduce risk, lower life cycle cost and validate operational concepts for future human missions.

NASA's Artemis lunar exploration program includes sending a suite of new science instruments and technology demonstrations to study the Moon, landing the first woman and next man on the lunar surface by 2024, and establishing a sustained presence by 2028. The agency will leverage its Artemis experience and technologies to prepare for the next giant leap – sending astronauts to Mars.

NASA Selects Proposals to Demonstrate SmallSat Technologies to Study Interplanetary Space



Credits: ESA/NASA/SOHO

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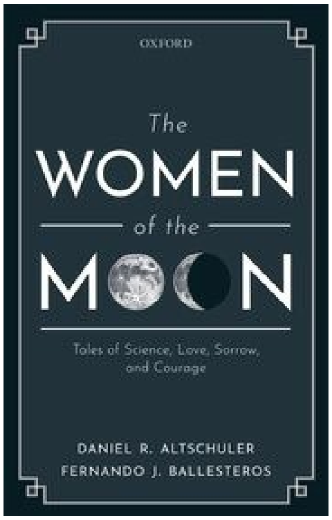
NEW AND NOTEWORTHY



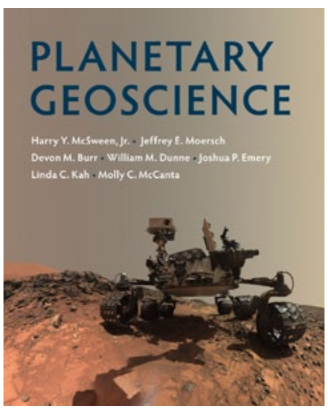
THE WOMEN OF THE MOON: Tales of Science, Love, Sorrow, and Courage

By Daniel R. Altschuler and Fernando J. Ballesteros

Oxford University Press, 2019, 336 pp., Hardcover. $26.95. global.oup.com

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration. Contact local astronomical societies, planetariums and museums, local scientists, and NASA's Solar System Ambassadors (solarsystem.nasa.gov/ssa/directory.cfm). Ask them to join your events and share their experiences or resources with your audience.

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



PLANETARY GEOSCIENCE

By Harry Y. McSween, Jr., Jeffrey E. Moersch, Devon M. Burr, William M. Dunne, Joshua P. Emery, Linda C. Kah, and Molly C. McCanta

Cambridge University Press, 2019, 350 pp., Hardcover. $64.99. www.cambridge.org

For many years, planetary science has been taught as part of the astronomy curriculum, from a very physics-based perspective, and from the framework of a tour of the solar system — body by body. Over the past decades, however, spacecraft exploration and related laboratory research on extraterrestrial materials have given us a new understanding of planets and how they are shaped by geological processes. Based on a course taught at the University of Tennessee, Knoxville, this is the first textbook to focus on geologic processes, adopting a comparative approach that demonstrates the similarities and differences between planets, and the reasons for these. Profusely illustrated, and with a wealth of pedagogical features, this book provides an ideal capstone course for geoscience majors — bringing together aspects of mineralogy, petrology, geochemistry, volcanology, sedimentology, geomorphology, tectonics, geophysics, and remote sensing.

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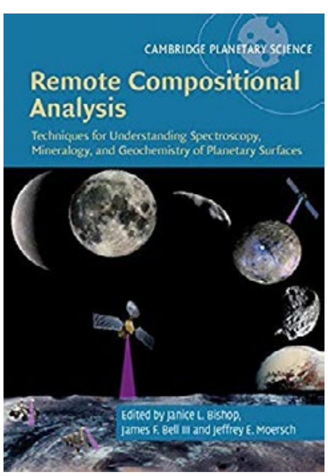

REMOTE COMPOSITIONAL ANALYSIS: Techniques for Understanding Spectroscopy, Mineralogy, and Geochemistry of Planetary Surfaces

Edited by Janice L. Bishop, James F. Bell III, and Jeffrey E. Moersch

Cambridge University Press, 2019, 666 pp., Hardcover, $110.00. www.cambridge.org

How do planetary scientists analyze and interpret data from laboratory, telescopic, and spacecraft observations of planetary surfaces? What elements, minerals, and volatiles are found on the surfaces of our solar system's planets, moons, asteroids, and comets? This comprehensive volume answers these topical questions by providing an overview of the theory and techniques of remote compositional analysis of planetary surfaces. Bringing together eminent researchers in solar system exploration, it describes state-of-the-art results from spectroscopic, mineralogical, and geochemical techniques used to analyze the surfaces of planets, moons, and small bodies. The book introduces the methodology and theoretical background of each technique, and presents the latest advances in space exploration, telescopic and laboratory instrumentation, and major new work in theoretical studies. This engaging volume provides a comprehensive reference on planetary surface composition and mineralogy for advanced students, researchers, and professional scientists.

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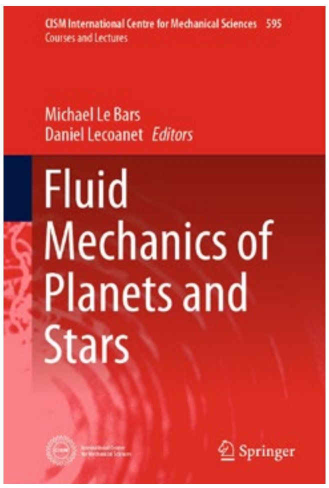

FLUID MECHANICS OF PLANETS AND STARS

Edited by Michael Le Bars and Daniel Lecoanet

Springer, 2020, 241 pp., Hardcover. $159.99. www.springer.com

This book explores the dynamics of planetary and stellar fluid layers, including atmospheres, oceans, iron cores, and convective and radiative zones in stars, describing the different theoretical, computational, and experimental methods used to study these problems in fluid mechanics, including the advantages and limitations of each method for different problems. This scientific domain is by nature interdisciplinary and multi-method, but while much effort has been devoted to solving open questions within the various fields of mechanics, applied mathematics, physics, Earth sciences and astrophysics, and while much progress has been made within each domain using theoretical, numerical, and experimental approaches, cross-fertilizations have remained marginal. Going beyond the state of the art, the book provides readers with a global introduction and an up-to-date overview of relevant studies, fully addressing the wide range of disciplines and methods involved. This book is volume 595 of the CISM International Centre for Mechanical Sciences Courses and Lectures series.

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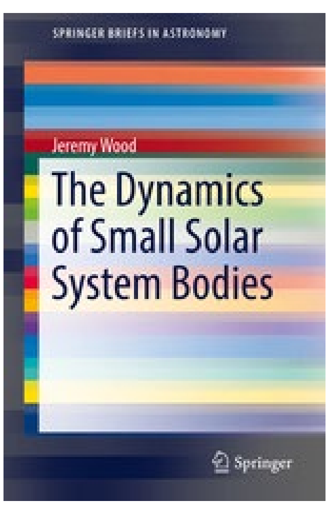


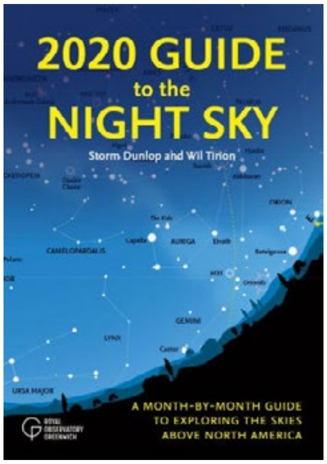
THE DYNAMICS OF SMALL SOLAR SYSTEM BODIES

By Jeremy Wood

Springer, 2019, 124 pp., Paperback. $59.99. www.springer.com

This Springer Brief in Astronomy summarizes the latest relevant research and discoveries that have been made in the area of ringed small bodies and small body taxonomy, including those that lay the groundwork for future discoveries. Before 2013, ringed small bodies were only theoretical. Thus, there are very limited publications available on this relatively new subfield of astronomy. With the introduction of the GAIA catalog, star positions are now known better than ever before. Since rings are discovered through the use of starlight occultation, we could very well be looking at an explosion of discoveries of ringed small bodies in the near future. Each chapter is accompanied by exercises, and an end-of-book answer key is provided. As such, this brief will benefit students and researchers alike who wish to have a single document and quick access to the latest information on ringed small bodies and small body taxonomy.

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



2020 GUIDE TO THE NIGHT SKY

By Storm Dunlap and Wil Tirion

Firefly Books, 2019, 112 pp., Paperback. $14.95. www.fireflybooks.com

2020 Guide to the Night Sky is the ideal resource for novices and experienced amateurs in the United States and Canada, and has been updated to include 16 more pages of even more new and practical information covering events to occur in North America's night sky throughout 2020. The book has all the guidance, information, and data that skywatchers need. The book covers astro-tourism, the impact on the hospitality industry and its growth linked to astronomical events and stargazing destinations, and space probes, including the seemingly immortal Hubble Telescope, taking our cameras to worlds farther and farther away, even to Mars. This guide is organized by month and provides lunar phases, planet activity, constellation maps and tables of planet and star movement, and sky activity and events. Each month has all the compass points, dates, and exact times to view the planets. There are also monthly constellation maps with dates, times, and hourly rates of comets, fireballs, and meteor showers. Skywatchers in the United States and Canada won't miss a thing, even with just binoculars. Amateur astronomers have come to rely upon and expect each year's edition of this proven sell-through title. It is the handy reference they grab as they head out to do some skywatching, and now they can use it to plan an astrovacation.

MOON CALENDAR CARD PACK

By Kim Long

Workman Publishing, 2019. 10 × 6.75-inch reference cards, $15.00 for 5 cards, $120.00 for 40 cards. www.workman.com

This is the 38th edition of Kim Long's classic Moon calendar, the first of its kind and a fan favorite since 1982. With a graphic, at-a-glance 2020 lunar calendar on the front and easy-to-read, detailed data provided by the U.S. Naval Observatory on the reverse, this handy card is a fun reminder to tack up by your desk or in your garden shed. Available in a pack of 5 and a pack of 40, it also makes a great gift for kids, gardeners, fishermen and sportsmen, sky watchers, and followers of the many faiths that mark time by the Moon. Whatever your reason for Moon watching, you won't miss a thing with the 2020 Moon Calendar Card.

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SOLAR SYSTEM OBJECTS, STARS AND GALAXIES FLASHCARD SET

Produced by Carddia

52 standard playing-card-size flashcards, $24.99. www.carddia.com

Learning about the solar system can be a bit tough, with so many planets and their satellites, and reading through textbooks may make students even more confused. These flashcards could be a great help. This set covers the entire solar system and other major astronomical objects such as galaxies, clusters, and nebulae. Each card has an image on one side, and the object's name (with its abbreviation or astronomical symbol), structure, and brief description on the other side. Both sides are printed in full-color, and the cards are water- and tear-resistant. A universe infographic is included.

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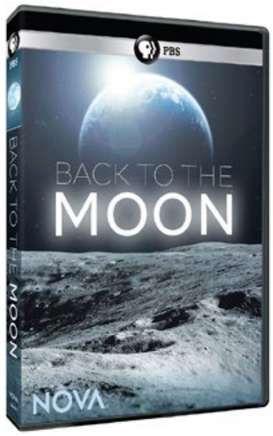

BACK TO THE MOON

Produced by WGBH Boston

One disc, $24.99. shop.pbs.org

On February 6, 2018, the world watched as the first Falcon Heavy rocket blasted toward the heavens. It was the most powerful rocket to leave Earth since the iconic Saturn V lifted Apollo astronauts to the Moon. With millions watching via livestream, it became clear: Crewed space travel is making a comeback. And we are going back to the Moon. On the 50th anniversary of the historic Apollo 11 Moon landing, NOVA looks ahead to the hoped-for dawn of a new age in lunar exploration. This time, governments and private industry are working together to reach our nearest celestial neighbor. But why go back? The Moon can serve as a platform for basic astronomical research, as an abundant source of rare metals and hydrogen fuel, and ultimately as a stepping stone for human missions to Mars and beyond. Join the next generation of engineers that aim to take us to the Moon and discover how our legacy of lunar exploration won't be confined to the history books for long.

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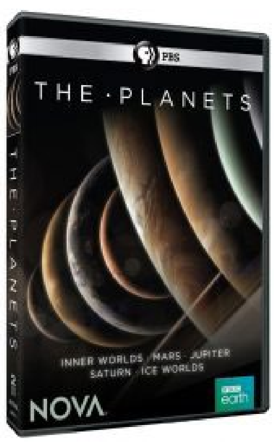

THE PLANETS

Produced by WGBH Boston

Two discs, $29.99. shop.pbs.org

Among the stars in the night sky wander the worlds of our own solar system, each home to truly awe-inspiring sights: a volcano three times as tall as Mount Everest, geysers erupting with icy plumes, a cyclone larger than Earth that's been churning for hundreds of years. In this five-part series, NOVA explores the awesome beauty of The Planets. With special effects and extraordinary footage captured by orbiters, landers, and rovers, you'll get an up-close look at Saturn's 45,000-mile-wide rings, Mars' towering ancient waterfalls, and Neptune's supersonic winds. Scientists share the inside story of the missions that revealed everything from methane lakes on a distant moon to the mysterious unfrozen sea in Pluto's heart. Along the way, NOVA reveals how each of these spectacular worlds has shaped our own planet: Earth.

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MOON'S FIRST FRIENDS

By Susanna Leonard Hill

Sourcebooks Wonderland, 2019, 40 pp., Hardcover. $17.99. shop.sourcebooks.com

This is a heartwarming story of a friendship-seeking Moon that also celebrates the extraordinary 50th anniversary of the Apollo 11 Moon landing. From high up in the sky, the Moon has spent her whole life watching Earth and hoping for someone to visit. Dinosaurs roam, pyramids are built, and boats are made, but still no one comes. Will friends ever come visit her? One day a spaceship soars from Earth…and so does her heart. This book includes bonus educational pages about the Moon mission. For ages 4 to 8.

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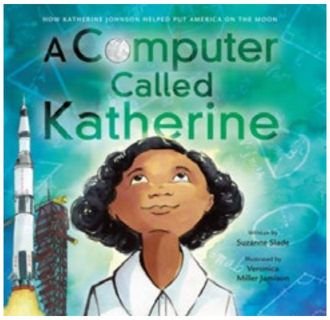

A COMPUTER CALLED KATHERINE: How Katherine Johnson Helped Put America on the Moon

By Suzanne Slade

Little, Brown Young Readers, 2019, 40 pp., Hardcover. $18.99. www.littlebrownlibrary.com

This book tells the inspiring true story of mathematician Katherine Johnson – made famous by the award-winning film Hidden Figures – who counted and computed her way to NASA and helped put a man on the Moon. Katherine knew it was wrong that African Americans didn't have the same rights as others – as wrong as 5+5=12. She knew it was wrong that people thought women could only be teachers or nurses – as wrong as 10-5=3. And she proved everyone wrong by zooming ahead of her classmates, starting college at fifteen, and eventually joining NASA, where her calculations helped pioneer America's first manned flight into space, its first manned orbit of Earth, and the world's first trip to the Moon. Award-winning author Suzanne Slade and debut artist Veronica Miller Jamison tell the story of a NASA "computer" in this smartly written, charmingly illustrated biography. For ages 4 to 8.

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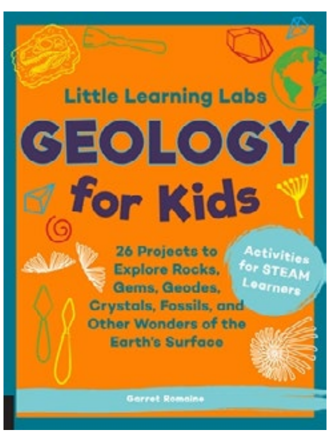

LITTLE LEARNING LABS GEOLOGY FOR KIDS: 26 Projects to Explore Rocks, Gems, Geodes, Crystals, Fossils, and Other Wonders of the Earth's Surface

By Garret Romaine

Quarry Books, 2019, 80 pp., Paperback. $12.99. www.quartoknows.com

Dig in and learn about the Earth under your feet. Little Learning Labs: Geology for Kids features 26 simple, inexpensive, and fun experiments that explore the Earth's surface, structure, and processes. This family-friendly guide explores the wonders of geology, such as the formation of crystals and fossils, the layers of the Earth's crust, and how water shapes mountains, valleys, and canyons. There is no excuse for boredom with these captivating STEAM (Science, Technology, Engineering, Art and Math) activities. This book covers how to identify the most common rocks and minerals, how to maintain and display your rock collection, how insects are trapped and preserved in amber, how geysers and volcanoes form and erupt, how layers of rock reveal a record of time, and how to pan for gold like a real prospector. Geology is an exciting science that helps us understand the world we live in, and Little Learning Labs: Geology for Kids actively engages readers in simple, creative activities that reveal the larger world at work. For ages 8 to 12.

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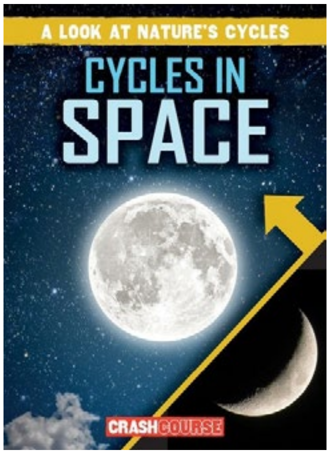

CYCLES IN SPACE:
A Look at Nature's Cycles

By Bray Jacobson

Gareth Stevens Publishing, 2019, 32 pp. Hardcover. $26.60. www.garethstevens.com

As Earth moves around the sun, the seasons on Earth change. The movement of the Moon affects the tides in Earth's oceans. What happens in space has an influence on our lives. In this book, readers explore the cycles in the space that most affect us and the space science taught in upper elementary science classes. Accessible language and simple explanations make this the perfect introduction to Earth's cycles for readers struggling with traditional textbooks. Diagrams of each cycle provide a great review of each cycle as well as another way to understand each concept. For ages 4 to 11.

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CALENDAR

2019 Upcoming Events

October | November | December

October

The Venera-D Landing Sites and Cloud Habitability Workshop
October 2–5
Moscow, Russia
https://www.hou.usra.edu/meetings/venera-d2019/

38th International Meteor Conference
October 3–6
Bollmannsruh, Germany
https://imc2019.imo.net/

The Tenth Moscow Solar System Symposium (10M-53)
October 7–11
Moscow, Russia
https://ms2019.cosmos.ru

Planet2/RESCEU Symposium: From Protoplanetary Disks through Planetary System Architecture to Planetary Atmospheres and Habitability
October 14–18
Okinawa, Japan
http://www.resceu.s.u-tokyo.ac.jp/symposium/resceu_sympo2019/

Global Experts Meeting on Frontiers in Chemistry
October 17–19
Rome, Italy
https://frontiersmeetings.com/conferences/chemistry/

70th International Astronautical Congress (IAC)
October 21–25
Washington, DC
https://www.iac2019.org

White Dwarfs as Probes of Fundamental Physics and Tracers of Planetary, Steller, and Galactic Evolution
October 21–25
Hilo, Hawaii
http://www.gemini.edu/iau357/

Brown Dwarf to Exoplanet Connection III
October 21–22
Newark, Deleware
http://www.jackiefaherty.com/bdexocon2019

14th Geant4 Space Users Workshop
October 21–23
Xylokastro, Greece
https://indico.esa.int/event/304

Annual Meeting of the Lunar Exploration Analysis Group
October 28–30
Washington D.C. Area
https://www.hou.usra.edu/meetings/leag2019/

2nd RPI Space Imaging Workshop
October 28–30
Saratoga Springs, New York
http://seal.rpi.edu/workshop/2019

Voyage 2050 Workshop — Shaping the European Space Agency's Space Science Programme
October 29–31
Madrid, Spain
https://www.cosmos.esa.int/web/voyage-2050

November

Rocky Exoplanets in the Era of JWST: Theory and Observation
November 4–8
Greenbelt, Maryland
https://seec.gsfc.nasa.gov/Symposium.html

VEXAG Meeting
November 4–8
Boulder, Colorado
https://www.lpi.usra.edu/vexag/

COSPAR 2019
November 4–8
Herzliya, Israel
http://www.cospar2019.org/

Asteroid Science in the Age of Hayabusa2 and OSIRIS-Rex
November 5–7
Tucson, AZ
https://corex.lpl.arizona.edu/international-workshop

Mars Extant Life: What's Next?
November 5–8
Carlsbad, New Mexico
https://www.hou.usra.edu/meetings/lifeonmars2019/

17th Meeting of the Venus Exploration Group (VEXAG)
November 6–8
Boulder, Colorado
https://www.lpi.usra.edu/vexag/meetings/vexag-17/

Subaru Telescope 20th Anniversary – Optical and Infrared Astronomy for the Next Decade
November 17–22
Waikoloa Villiage, Hawaii
https://subarutelescope.org/subaru20anniv/index.html

Planet Formation Workshop 2019
November 25–28
Tokyo, Japan
http://th.nao.ac.jp/meeting/planet-formation-workshop2019/

International Conference on Chemistry and Applied Research
November 27–28
Dubai, UAE
https://www.meetingsint.com/conferences/chemistryresearch

7th European Nanotechnology Congress
November 27–28
Madrid, Spain
https://www.meetingsint.com/conferences/euronanotechnology

December

First International Orbital Debris Conference (IOC)

December 9-12

Houston, Texas

https://www.hou.usra.edu/meetings/orbitaldebris2019/

2019 AGU Fall Meeting

December 9-13

San Francisco, California

http://fallmeeting.agu.org