JET PROPULSION LABORATORY

WHERE PLANETARY EXPLORATION BEGAN

CONTENTS

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Note from the Editors: This issue's lead article is the seventh 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 the Jet Propulsion Laboratory (JPL), which since before World War II has been a leading engineering research and development center, creating America's first satellite and most of its lunar and planetary spacecraft. It is now a major NASA center, focusing on robotic space exploration. While JPL is also very active in Earth observation and space technology programs, this article focuses on JPL's planetary efforts. — Paul Schenk and Renee Dotson

From the roar of pioneering Space Age rockets to the soft whir of servos on twenty-first-century robot explorers on Mars, spacecraft designed and built at NASA's Jet Propulsion Laboratory (JPL) have blazed the trail to the planets and into the universe beyond for nearly 60 years.

The United States (U.S.) first entered space with the 1958 launch of the satellite Explorer 1, built and controlled by JPL. From orbit, Explorer 1's voyage yielded immediate scientific results — the discovery of the Van Allen radiation belts — and led to the creation of NASA. Innovative technology from JPL has taken humanity far beyond regions of space where we can actually travel ourselves. The most distant human-made objects, Voyagers 1 and 2, were built at and are operated by JPL. From JPL's labs and clean rooms come telescopes and cameras that have extended our vision to unprecedented depths and distances, peering into the hearts of galactic clouds where new stars and planets are born, and even toward the beginning of time at the edge of the universe.

Meeting the challenges of robotic space exploration has resulted in new knowledge that has kept JPL a world leader in science and technology. The tools JPL has developed for space exploration have also proved invaluable in providing new insights and discoveries in studies of Earth, its atmosphere, climate, oceans, geology, and biosphere. The ongoing invention of ever-more-sensitive sensors has also resulted in myriad technology applications finding wide medical, industrial, and commercial uses on Earth.

JPL's Beginnings —

JPL's history dates back to the 1930s, when California Institute of Technology (Caltech) professor Theodore von Kármán oversaw pioneering work in jet and rocket propulsion. Von Kármán was head of Caltech's Guggenheim Aeronautical Laboratory. Several of his graduate students and assistants gathered to test a primitive rocket engine in a dry riverbed wilderness area in the Arroyo Seco, a dry canyon wash north of the Rose Bowl in Pasadena, California. Their first rocket firing took place there on October 31, 1936.

Theodore von Kármán (center) performs last-minute calculations during a historic test flight in 1941.

von Kármán, who also served as a scientific adviser to the U.S. Army Air Corps, persuaded the Army to fund development of strap-on rockets (called "jet-assisted takeoff") to help overloaded Army airplanes take off from short runways. The Army helped Caltech acquire land in the Arroyo Seco for test pits and temporary workshops. By this time, World War II had begun and the rockets were in demand.

This photo shows a group of Caltech students and local rocket enthusiasts performing one of the first rocket motor tests in the Arroyo Seco near JPL.

As the group wound up the work on the jet-assisted takeoff, the Army Air Corps asked von Kármán for a technical analysis of the German V-2 program, just discovered by Allied intelligence. von Karman and his research team proposed a U.S. research project to understand, duplicate, and reach beyond the guided missiles beginning to bombard England. In the proposal, the Caltech team referred to their organization for the first time as "the Jet Propulsion Laboratory." Funded by Army Ordnance, JPL's early efforts would eventually involve technologies beyond those of aerodynamics and propellant chemistry, technologies that would evolve into tools for space flight, secure communications, rocket guidance, spacecraft navigation and control, and planetary exploration.

The team of about 100 rocket engineers began to expand and began tests in the California desert of small unguided missiles (Private) that reached an altitude of nearly 18 kilometers (about 11 miles). They experimented with radio telemetry from missiles, and began planning for ground radar and radio sets. By 1945, with a staff approaching 300, the group had begun to launch rockets from White Sands, New Mexico, to an altitude of 60 kilometers (200,000 feet), monitoring performance by radio.

Control of the guided missile was the next step, requiring two-way radio as well as radar and a primitive computer (using radio tubes) at the ground station. The result was JPL's answer to the German V-2 missile, named Corporal, first launched in May 1947, about two years after the end of war with Germany. Subsequent Army work further sharpened the technologies of communications and control and of design, test, and performance analysis. This work made it possible for JPL to develop the flight and ground systems to fly the first successful U.S. satellite, Explorer 1. The entire three-month effort began in November 1957 and culminated with the successful launch on January 31, 1958.

On December 3, 1958, two months after NASA was created by Congress, JPL was transferred from Army jurisdiction to that of the new civilian space agency. It brought to the new agency experience in building and flying spacecraft, an extensive background in solid and liquid rocket propulsion systems, guidance, control, systems integration, broad testing capability, and expertise in telecommunications using low-power spacecraft transmitters and very sensitive Earth-based antennas and receivers.

The JPL facility now covers some 72 hectares (177 acres) adjacent to the site of von Kármán's early rocket experiments.

Planetary Exploration —

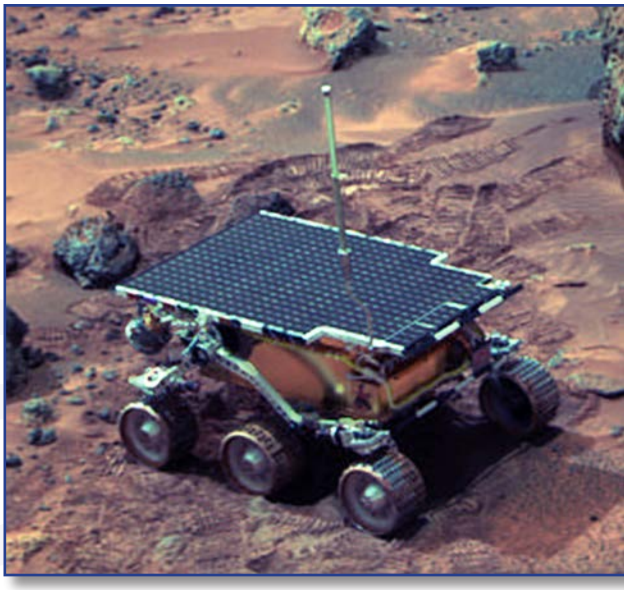
In the 1960s, JPL began to conceive and execute robotic spacecraft to explore other worlds. This effort began with the Ranger missions to the Moon and the Mariner missions to the planets in the 1960s. With the addition of the later, soft-landing Surveyor lunar missions, these efforts paved the way for NASA's Apollo human lunar landings.

Mariner 2 was the first successful mission to another planet by any country. Launched just 36 days after the failure of its twin, Mariner 1, it flew by Venus as planned at a range of 34,762 kilometers (21,600 miles), scanning the planet's atmosphere and surface for 42 minutes.

Mariner 2 became the first spacecraft to fly by another planet (Venus) in December 1962. Other successful planetary flybys were conducted by 1964's Mariner 4 to Mars, 1967's Mariner 5 to Venus, and 1969's Mariner 6 and 7 to Mars. In 1971, Mariner 9 became the first spacecraft to orbit and map another planet when it was sent to Mars.

Mariner 10 was the first mission to use a "gravity assist" from one planet to boost and send the spacecraft on to another — a key innovation in spaceflight that would later enable the exploration of outer planets that would have otherwise been unreachable. Mariner 10's launch in November 1973 sent the spacecraft to Venus in February 1974, where a gravity-assist swing-by allowed it to fly to Mercury in March 1974 and then two more times, once in September 1974 and again in March 1975.

The highly ambitious Viking mission launched in 1975 consisted of two orbiter spacecraft and two landers, designed to search for evidence of life on Mars. Although the elaborate mission was managed by NASA's Langley Research Center, JPL built the Viking orbiters, conducted mission communications, and operated the spacecraft at Mars. Returning to Venus, the Magellan mission used a sophisticated imaging radar to pierce the cloud cover and map the planet's surface. Magellan completed its third 243-day period mapping the planet in September 1992. At the conclusion of the mission, flight controllers commanded Magellan to dip into the atmosphere of Venus in a test of aerobraking — a technique to use atmospheric drag to slow the spacecraft and change its orbit that has since been used in many other planetary missions. The Mars Observer, launched onboard a Titan III rocket in September 1992, ended with disappointment in August 1993 when contact was lost with the spacecraft shortly before it was to enter orbit around Mars.



Mars Pathfinder's rover, Sojourner, was the first rover to operate outside the Earth-Moon system.

The next JPL planetary launches were those of the Mars Global Surveyor and Mars Pathfinder. Mars Pathfinder put a lander and rover on the surface of the Red Planet on July 4, 1997. Mars Global Surveyor went into orbit around the Red Planet in September 1997, and spent a year and a half lowering its orbit using the technique of aerobraking tested by Magellan. The spacecraft made highly detailed maps of the martian surface until its last communication with Earth in November 2006.

A disappointment at Mars occurred in late 1999, with the loss of the orbiter and lander developed and launched under the Mars '98 project — named Mars Climate Orbiter and Mars Polar Lander, respectively. Climate Orbiter entered the planet's atmosphere too low and did not survive orbit insertion in September 1999. Polar Lander and two Deep Space 2 microprobes piggybacking on it to Mars were lost during arrival at the planet in December.

The Mars Exploration Rover project sent a pair of robotic geologists to sites halfway around Mars from each other. Spirit functioned until 2010, while Opportunity continues to function today. Each found evidence of long-ago martian environments where liquid water was active and conditions may have been suitable for life.

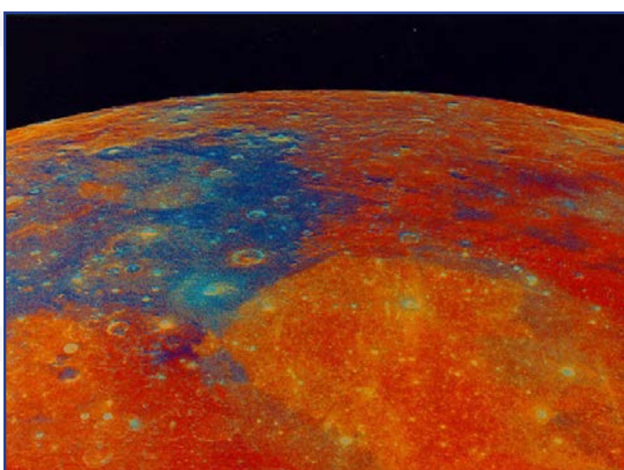
The Mars Reconnaissance Orbiter arrived at the Red Planet in 2006 with the most powerful telescopic camera ever sent to another planet, plus five other scientific instruments. In 2008, the Mars Phoenix lander set down on the frozen terrain near the planet's north pole, and spent the next five months digging trenches with a robotic arm — establishing that there is in fact a phenomenal amount of water locked up in the form of ice near the martian north pole.

The Curiosity rover landed in 2012 using a novel system called the Sky Crane to set it down gently onto the surface in Gale Crater. Curiosity spent two years inside the crater before arriving in September 2014 at the base of Mount Sharp, its ultimate destination. In 2018, the Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission will send a lander to Mars that will drill beneath the surface to investigate the Red Planet's interior structure. The mission is designed to give scientists a better understanding of Mars' evolution as a rocky planet. Two years later, the Mars 2020 mission will send the most sophisticated rover ever built to investigate key questions about the habitability of Mars, and assess natural resources and hazards in preparation for future human expeditions to the Red Planet. It will collect and store rock and soil samples for potential future return to Earth.

JPL has sent sophisticated missions to the outer planets as well. Credit for the single mission that has visited the most planets goes to JPL's Voyager spacecraft. Launched in 1977, the twin Voyager 1 and Voyager 2 spacecraft both flew by the planets Jupiter (1979) and Saturn (1980–1981). Voyager 2 then went on to an encounter with the planet Uranus in 1986 and a flyby of Neptune in 1989, completing a reconnaissance survey of the gas giant planets and their satellites. Early in 1990, Voyager 1 turned its camera around to capture a series of images assembled into a "family portrait" of the solar system. Still communicating their findings as they speed out toward interstellar space, the Voyagers are expected to have enough power to continue communicating information about the Sun's energy field until approximately the year 2025. In August 2012, Voyager 1 crossed the heliopause to become the first spacecraft to enter interstellar space.

This wide-angle view shows the High Bay 1 cleanroom inside the Spacecraft Assembly Facility at JPL. The room is about 36 meters (120 feet) long and 24 meters (80 feet) wide. Since it was built in 1961, it has been the birthplace of many historic spacecraft, from Ranger missions to the Moon in the early 1960s to the Mars rovers Spirit and Opportunity, launched in 2003.

Along the way to Jupiter, the Galileo spacecraft flew by the asteroid Gaspra in October 1991 and the asteroid Ida in August 1993, the first asteroid encounters ever. On its final approach to the giant planet, Galileo observed Jupiter being bombarded by fragments of the broken-up Comet Shoemaker-Levy 9. On December 7, 1995, Galileo fired its main engine to enter Jupiter orbit and collected data radioed from its probe during its parachute descent into the planet's atmosphere. Galileo conducted multiple targeted flybys of Jupiter's major moons, especially Europa, where Galileo discovered a subsurface ocean. On September 21, 2003, after eight years orbiting Jupiter, Galileo ended its mission by plunging into the giant planet's atmosphere.



This false-color image of part of the Moon was constructed from four images taken by Galileo's imaging system as the spacecraft flew past the Moon on December 7, 1992.

JPL also designed, built, and is flying the Cassini-Huygens mission to Saturn. Carrying a record number of 12 instruments, Cassini arrived at Saturn in June 2004, and began an intensive study of Saturn's rings, its moons, and magnetosphere, including the discovery of internal activity (water jets) on the tiny moon Enceladus. Cassini delivered a probe named Huygens, provided by the European Space Agency, which descended to the surface of Titan, Saturn's largest moon, in January 2005. Titan has organic chemistry possibly like that which led to the existence of life on Earth. Now in its second extended mission, Cassini is making the first observations of a complete seasonal period for Saturn and its moons before completing its tour with a dive into the giant planet in September 2017.

Jupiter became the target for a new spacecraft mission when Juno entered orbit on July 4, 2016. Juno for the first time will peer below Jupiter's dense cover of clouds to answer questions about the formation and evolution of the gas giant and the origins of our solar system. Using long-proven technologies on a spinning spacecraft placed in an elliptical polar orbit, Juno will observe Jupiter's gravity and magnetic fields, atmospheric dynamics and composition, and evolution.

A major new mission to Jupiter's moon Europa is being developed for the 2020s. As planned, this mission would conduct a detailed reconnaissance of Jupiter's moon Europa — a world that shows strong evidence for an ocean of liquid water beneath its icy crust and that could host conditions favorable for life. The mission would deploy a highly capable, radiation-tolerant spacecraft into a long, looping orbit around Jupiter to perform these repeated flybys of Europa.

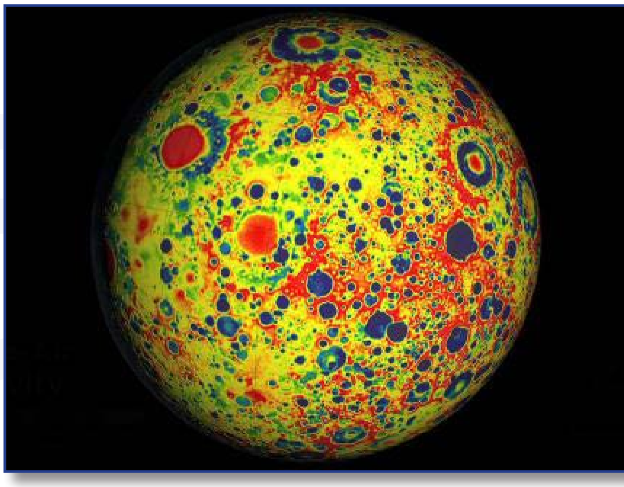
Even the solar system's smallest members have not been neglected. In 1999, NASA launched a JPL-teamed mission called Stardust under the space agency's Discovery program of low-cost missions. Flying by Comet Wild 2 in January 2004, Stardust collected dust and volatile materials that were returned to Earth in a capsule that parachuted to a landing on a dry lake bed in Utah in January 2006. The spacecraft was then reprogrammed to conduct a flyby of Comet Tempel 1 in February 2011. JPL also managed another Discovery mission, Genesis, that collected samples of charged particles in the solar wind and returned them to Earth in September 2004. Although the capsule's parachutes did not deploy, scientists achieved most of their science objectives with samples recovered from the capsule.

A Genesis collector array in the Genesis clean lab at the Johnson Space Center. The hexagons consist of a variety of ultra-pure, semiconductor-grade wafers, including silicon, commercial "sapphire" (i.e., corundum), gold on sapphire, diamond-like carbon films, and other materials.

JPL managed a Discovery mission called Deep Impact that propelled a large copper projectile into the surface of Comet Tempel 1, creating a crater to reveal the composition and structure of the comet nucleus. Launched in January 2005, Deep Impact arrived at the comet in July of that year. The spacecraft was then redirected to fly by Comet Hartley 2 in late 2010.

An asteroid and a dwarf planet were the destinations for Dawn, the first spacecraft ever designed to orbit two different bodies after leaving Earth. Dawn arrived at the asteroid Vesta in July 2011, then departed in September 2012 for the dwarf planet Ceres, which it reached in 2015 and is currently orbiting.

Another major initiative that led to a new breed of NASA spacecraft was New Millennium, designed to flight-test new technologies so that they can be reliably used in science missions of the twenty-first century. The first New Millennium spacecraft, Deep Space 1, was launched in October 1998 to test solar electric propulsion and 11 other new technologies, including autonomous navigation. The spacecraft flew by the asteroid 9969 Braille in July 1999 and then gathered images and other information from a bonus September 2001 flyby of Comet Borrelly. Deep Space 2, two microprobes to test the martian soil for water vapor piggybacked on Mars Polar Lander (MPL), were lost with the MPL spacecraft on Mars arrival in December 1999. The New Millennium program also includes deep space and Earth-orbiting missions managed by other NASA centers.



Variations in the lunar gravity field as measured by GRAIL during the primary mapping mission from March to May 2012. Very precise microwave measurements between two spacecraft, named Ebb and Flow, were used to map gravity with high precision and high spatial resolution.

In September 2011, the twin Gravity Recovery and Interior Laboratory (GRAIL) spacecraft was launched to create the most accurate gravitational map of the Moon to date. Combined with precision topographic data from Goddard's Lunar Reconnaissance Orbiter mission, this map provides insight into the Moon's internal structure, composition, and evolution.

JPL also created the Near-Earth Asteroid Tracking system, an automated system used at an Air Force observatory in Hawaii to scan the skies for asteroids or comets that could threaten Earth. In 1999, the project made its first observations from a second site, the 1.2-meter-diameter (48-inch) Oschin telescope on Palomar Mountain, California. In 1998, NASA designated JPL as home of the agency's Near-Earth Objects Office, which is charged with coordinating observations of Earth-crossing asteroids and comets by various NASA scientists.

Astronomy and Physics —

Other JPL missions extend our view deeper into the universe. Many of these have focused on examining the cosmos using infrared light invisible to the human eye. JPL was the U.S. manager of the Infrared Astronomical Satellite, a joint project with the Netherlands and the United Kingdom. Launched in 1983, the mission was an Earth-orbiting telescope that mapped the sky in infrared wavelengths.

That expertise also prepared JPL to develop and manage the Spitzer Space Telescope, a sibling to the Hubble Space Telescope. Launched August 25, 2003, Spitzer produced a long string of discoveries, ranging from views of the earliest stars in the universe to the revelation that the stuff that comets and planets are made of is common throughout our galaxy. Perhaps most memorably, Spitzer was the first telescope ever to directly capture light from planets orbiting other stars. In 2009, Spitzer's coolant was depleted, and it shifted to a new, "warm" mission. Astronomers also plan to use it to assess hazards from near-Earth asteroids.

The Two Micron All-Sky Survey was astronomy's most thorough high-resolution digital survey of the entire sky, completed by twin infrared telescopes. Operations began in Arizona in June 1997 and in Chile in March 1998, and observations concluded in February 2001. The survey produced catalogues brimming with nearly half a billion objects.

In December 2009, NASA launched the JPL-managed Wide-field Infrared Survey Explorer (WISE), originally designed to detect hundreds of millions of objects from asteroids to distant galaxies as it maps the entire sky. After going into hibernation for 2.5 years, the spacecraft was reactivated in late 2013 for an extended mission called NeoWISE, in which the spacecraft has turned its attention on near-Earth objects.

JPL also designed and built the Wide Field/Planetary Camera, the main observing instrument attached to NASA's Hubble Space Telescope. After a flaw was discovered in the space telescope's main mirror, JPL created a second-generation camera, the Wide Field and Planetary Camera 2, that compensated for the optical problem — essentially like fitting Hubble with a set of corrective eyeglasses. Spacewalking astronauts installed this second camera during a shuttle mission in December 1993. The new instruments were installed on Hubble just in time to witness the impacts of Comet Shoemaker-Levy 9 into Jupiter in July 1994.

The Hubble Space Telescope has captured some of the most iconic space images ever seen, including this image of the of a young stellar grouping called R136, only a few million years old and situated in the 30 Doradus Nebula. The nebula itself is a turbulent star-birth region in the Large Magellanic Cloud (LMC), a satellite galaxy of our Milky Way. Credit: Hubble Space Telescope/NASA/ESA.

JPL managed flight project development for Kepler, a space-based telescope designed to search for Earth-sized planets around other stars. Kepler accomplishes this by watching for changes in the light from stars as planets pass in front of them, concentrating on an area of the sky around the constellations Cygnus and Lyra.

JPL handed off science operations of Kepler to NASA's Ames Research Center. Using data from the mission, scientists have identified more than 4500 candidate exoplanets, and have confirmed more than 1000 of these as bona fide planets. A handful of planets are thought to be rocky like Earth (but a bit bigger) and orbit in the habitable zone of their stars, where liquid water (an essential ingredient of life as we know it) might exist. In 2013, Kepler was assigned a new mission called "K2." Two of the spacecraft's reaction wheels had failed, so engineers came up with a clever scheme to redesign the mission. K2 still hunts for planets, but it scans a larger swath of sky than before, along the ecliptic plane.

JPL is currently developing the Mid-Infrared Instrument for NASA's James Webb Space Telescope, a successor to Hubble that will be placed at the Earth-Sun L2 libration point and that will look back in time over more than 90% of the history of the universe. JPL also has a major role in NASA's Wide-Field Infrared Survey Telescope, a future mission to study dark energy and extrasolar planets. JPL is contributing starshade technology to allow this telescope to detect exoplanets.

Looking Forward —

JPL is the leading U.S. center for robotic exploration of the solar system, with 19 spacecraft and 10 major instruments currently carrying out planetary, Earth science, and space-based astronomy missions. Imagination is our window into the future, and the goal of JPL is to strive to be bold in advancing the edge of possibility so that some day, with the help of new generations of innovators and explorers, these visions of the future can become a reality.

JPL is a federally funded research and development center managed by Caltech for NASA. The text for this article was provided by the JPL Media Relations Office. All images included herein are courtesy of NASA/JPL-Caltech unless otherwise specified.

About the Cover:

Top: Aerial view of NASA's Jet Propulsion Laboratory in Los Angeles County.

Inset: NASA's Jet Propulsion Laboratory was the only federal organization in 2014 to make the list of 100 top information technology (IT) employers. Shown here are the control rooms at JPL, with the Dark Room in the foreground, Deep Space Network control room on the right, and Mars Science Laboratory Mission Support Area in the back left.

Bottom: Starting with the launch of Explorer 1 in 1958, JPL has taken part in more than 100 missions and instruments designed to explore our Earth, solar system, and beyond. Past and current JPL mission projects include Mariner, Surveyor, Galileo, Voyager, Mars Exploration Rovers, Cassini, Deep Impact, Spitzer, GRACE, and the Curiosity rover, as well as nearly a dozen more launching in the next decade.

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

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

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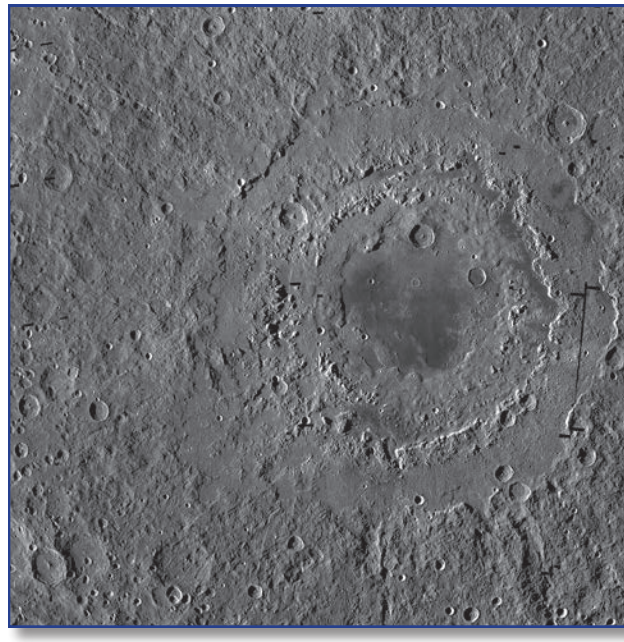
NASA Moon Mission Shares Insights into Giant Impacts



Orientale basin is about 580 miles (930 kilometers) wide and has three distinct rings, which form a bulls-eye-like pattern. This view is a mosaic of images from NASA's Lunar Reconnaissance Orbiter. Credit: NASA/GSFC/Arizona State University.

New results from NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission are providing insights into the huge impacts that dominated the early history of Earth's Moon and other solid worlds, like Earth, Mars, and the satellites of the outer solar system. In two papers, published in October in the journal *Science,* researchers examine the origins of the Moon's giant Orientale impact basin. The research helps clarify how the formation of Orientale, approximately 3.8 billion years ago, affected the Moon's geology.

Located along the Moon's southwestern limb — the lefthand edge as seen from Earth — Orientale is the largest and best-preserved example of what's known as a "multi-ring basin." Impact craters larger than about 300 kilometers (180 miles) in diameter are referred to as basins. With increasing size, craters tend to have increasingly complex structures, often with multiple concentric, raised rings. Orientale is about 930 kilometers (580 miles) wide and has three distinct rings, which form a bulls-eye-like pattern. Multi-ring basins are observed on many of the rocky and icy worlds in our solar system, but until now scientists had not been able to agree on how their rings form. What they needed was more information about the crater's structure beneath the surface, which is precisely the sort of information contained in gravity science data collected during the GRAIL mission.

The powerful impacts that created basins like Orientale played an important role in the early geologic history of our Moon. They were extremely disruptive, world-altering events that caused substantial fracturing, melting, and shaking of the young Moon's crust. They also blasted out material that fell back to the surface, coating older features that were already there; scientists use this layering of ejected material to help determine the age of lunar features as they work to unravel the Moon's complex history.

Because scientists realized that Orientale could be quite useful in understanding giant impacts, they gave special importance to observing its structure near the end of the GRAIL mission. The orbit of the mission's two probes was lowered so they passed less than 2 kilometers (1.2 miles) above the crater's mountainous rings.

"No other planetary exploration mission has made gravity science observations this close to the Moon. You could have waved to the twin spacecraft as they flew overhead if you stood at the ring's edge," said Sami Asmar, GRAIL project scientist at NASA's Jet Propulsion Laboratory.

Of particular interest to researchers has been the size of the initial crater that formed during the Orientale impact. With smaller impacts, the initial crater is left behind, and many characteristics of the event can be inferred from the crater's size. Various past studies have suggested each of Orientale's three rings might be the remnant of the initial crater. In the first of the two new studies, scientists teased out the size of the transient crater from GRAIL's gravity field data. Their analysis shows that the initial crater was somewhere between the size of the basin's two innermost rings.

"We've been able to show that none of the rings in Orientale basin represent the initial, transient crater," said GRAIL Principal Investigator Maria Zuber of the Massachusetts Institute of Technology in Cambridge, lead author of the first paper. "Instead, it appears that, in large impacts like the one that formed Orientale, the surface violently rebounds, obliterating signs of the initial impact." The analysis also shows that the impact excavated at least 3.4 million cubic kilometers (816,000 cubic miles) of material — 153 times the combined volume of the Great Lakes.

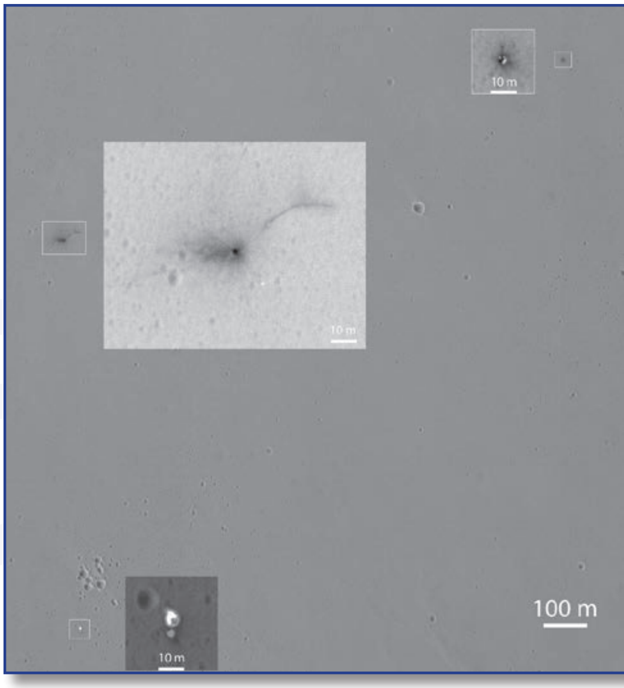
"Orientale has been an enigma since the first gravity observations of the Moon, decades ago," said Greg Neumann, a co-author of the paper at NASA's Goddard Space Flight Center. "We are now able to resolve the individual crustal components of the bulls-eye gravity signature and correlate them with computer simulations of the formation of Orientale."

The second study describes how scientists successfully simulated the formation of Orientale to reproduce the crater's structure as observed by GRAIL. These simulations show, for the first time, how the rings of Orientale formed, which is likely similar for multi-ring basins in general. "Because our models show how the subsurface structure is formed, matching what GRAIL has observed, we're confident we've gained understanding of the formation of the basin close to 4 billion years ago," said Brandon Johnson of Brown University, in Providence, Rhode Island, lead author of the second paper.

The results also shed light on another Moon mystery: Giant impacts like Orientale should have dredged up deep material from the Moon's mantle, but instead, the composition of the crater's surface is the same as that of the lunar crust. So, scientists have wondered, where did the mantle material go? The simulation shows that the deep, initial crater quickly collapses, causing material around the outside to flow inward, and covering up the exposed mantle rock.

The new GRAIL insights about Orientale suggest that other ringed basins, invisible in images, could be discovered by their gravity signature. This may include ringed basins hidden beneath lunar maria — the large, dark areas of solidified lava that include the Sea of Tranquility and the Sea of Serenity.

For more information about GRAIL, visit *http://www.nasa.gov/grail*.



This October 25, 2016, image from the HiRISE camera on NASA's Mars Reconnaissance Orbiter shows the area where the Schiaparelli test lander struck Mars, with magnified insets of three sites where spacecraft components hit the ground. It adds detail not seen in earlier imaging of the site. Credit: NASA/JPL-Caltech/Univ. of Arizona.

Further Clues to Fate of Mars Lander, Seen From Orbit

The most powerful telescope orbiting Mars is providing new details of the scene near the martian equator where Europe's Schiaparelli test lander hit the surface in October. An October 25 observation using the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter (MRO) shows three impact locations within about 1.5 kilometers (0.9 miles) of each other. An annotated view is available online at *http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA21131.*

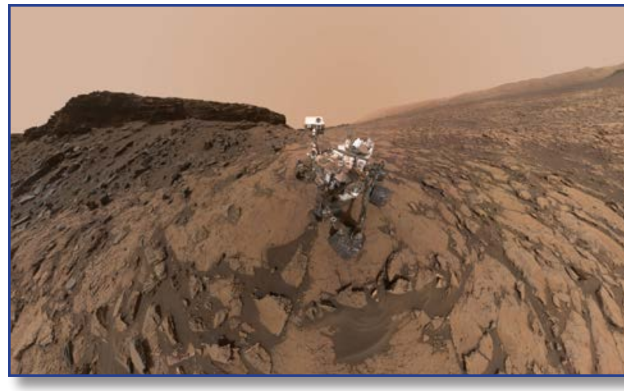
The scene shown by HiRISE includes three locations where hardware reached the ground. A dark, roughly circular feature is interpreted as where the lander itself struck. A pattern of rays extending from the circle suggests that a shallow crater was excavated by the impact, as expected given the premature engine shutdown. About 1.4 kilometers (0.8 miles) eastward, an object with several bright spots surrounded by darkened ground is likely the heat shield. About 0.9 kilometers (0.6 miles) south of the lander impact site, two features side-by-side are interpreted as the spacecraft's parachute and the back shell to which the parachute was attached.

The test lander is part of the European Space Agency's ExoMars 2016 mission, which placed the Trace Gas Orbiter into orbit around Mars on October 19. The orbiter will investigate the atmosphere and surface of Mars and provide relay communications capability for landers and rovers on Mars.

Data transmitted by Schiaparelli during its descent through Mars' atmosphere is enabling analysis of why the lander's thrusters switched off prematurely. The new HiRISE imaging provides additional information, with more detail than visible in an earlier view with the Context Camera (CTX) on MRO. For more information, visit *http://mars.nasa.gov/mro.*

Curiosity Rover Begins Next Mars Chapter

After collecting drilled rock powder in arguably the most scenic landscape yet visited by a Mars rover, NASA's Curiosity mobile laboratory is driving toward uphill destinations as part of its two-year mission extension that commenced October 1. The destinations include a ridge capped with material rich in the iron-oxide mineral hematite, about 2.5 kilometers (1.5 miles) ahead, and an exposure of clay-rich bedrock beyond that. These are key exploration sites on lower Mount Sharp, which is a layered, Mount-Rainier-size mound where Curiosity is investigating evidence of ancient, water-rich environments that contrast with the harsh, dry conditions on the surface of Mars today.



This September 2016 self-portrait of NASA's Curiosity Mars rover shows the vehicle at the "Quela" drilling location in the scenic "Murray Buttes" area on lower Mount Sharp. The panorama was stitched together from multiple images taken by the MAHLI camera at the end of the rover's arm. Credit: NASA/JPL-Caltech/MSSS.

"We continue to reach higher and younger layers on Mount Sharp," said Curiosity Project Scientist Ashwin Vasavada of NASA's Jet Propulsion Laboratory. "Even after four years of exploring near and on the mountain, it still has the potential to completely surprise us."

Hundreds of photos Curiosity took in recent weeks amid a cluster of mesas and buttes of diverse shapes are fresh highlights among the more than 180,000 images the rover has taken since landing on Mars in August 2012. Newly available vistas include the rover's latest self-portrait from the color camera at the end of its arm and a scenic panorama from the color camera at the top of the mast.

"Bidding good-bye to 'Murray Buttes,' Curiosity's assignment is the ongoing study of ancient habitability and the potential for life," said Curiosity Program Scientist Michael Meyer at NASA Headquarters in Washington, DC. "This mission, as it explores the succession of rock layers, is reading the 'pages' of martian history — changing our understanding of Mars and how the planet has evolved. Curiosity has been and will be a cornerstone in our plans for future missions."

The component images of the self-portrait were taken near the base of one of the Murray Buttes, at the same site where the rover used its drill on September 18 to acquire a sample of rock powder. An attempt to drill at this site four days earlier had halted prematurely due to a short-circuit issue that Curiosity had experienced previously, but the second attempt successfully reached full depth and collected sample material. After departing the buttes area, Curiosity delivered some of the rock sample to its internal laboratory for analysis.

This latest drill site — the 14th for Curiosity — is in a geological layer about 180 meters (600 feet) thick, called the Murray formation. Curiosity has climbed nearly half of this formation's thickness so far and found it consists primarily of mudstone, formed from mud that accumulated at the bottom of ancient lakes. The findings indicate that the lake environment was enduring, not fleeting. For roughly the first half of the new two-year mission extension, the rover team anticipates investigating the upper half of the Murray formation. "We will see whether that record of lakes continues further," Vasavada said. "The more vertical thickness we see, the longer the lakes were present, and the longer habitable conditions existed here. Did the ancient environment change over time? Will the type of evidence we've found so far transition to something else?"

The "Hematite Unit" and "Clay Unit" above the Murray formation were identified from Mars orbiter observations before Curiosity's landing. Information about their composition, from the Compact Reconnaissance Imaging Spectrometer onboard NASA's Mars Reconnaissance Orbiter, made them high priorities as destinations for the rover mission. Both hematite and clay typically form in wet environments. Vasavada said, "The Hematite and the Clay Units likely indicate different environments from the conditions recorded in older rock beneath them and different from each other. It will be interesting to see whether either or both were habitable environments."

NASA approved Curiosity's second extended mission this summer on the basis of plans presented by the rover team. Additional extensions for exploring farther up Mount Sharp may be considered in the future. The Curiosity mission has already achieved its main goal of determining whether the landing region ever offered environmental conditions that would have been favorable for microbial life, if Mars has ever hosted life. The mission found evidence of ancient rivers and lakes, with a chemical energy source and all of the chemical ingredients necessary for life as we know it.

For more information, visit *http://mars.jpl.nasa.gov/msl.*

Study Predicts Next Global Dust Storm on Mars

Global dust storms on Mars could soon become more predictable — which would be a boon for future astronauts there — if the next one follows a pattern suggested by those in the past. A published prediction, based on this pattern, points to Mars experiencing a global dust storm in the next few months. "Mars will reach the midpoint of its current dust storm season on October 29 of this year. Based on the historical pattern we found, we believe it is very likely that a global dust storm will begin within a few weeks or months of this date," said James Shirley, a planetary scientist at NASA's Jet Propulsion Laboratory (JPL).

Two 2001 images from the Mars Orbiter Camera on NASA's Mars Global Surveyor orbiter show a dramatic change in the planet's appearance when haze raised by dust-storm activity in the south became globally distributed. The images were taken about a month apart. Credit: NASA/JPL-Caltech/MSSS.

Local dust storms occur frequently on Mars. These localized storms occasionally grow or coalesce to form regional systems, particularly during the southern spring and summer, when Mars is closest to the Sun. On rare occasions, regional storms produce a dust haze that encircles the planet and obscures surface features beneath. A few of these events may become truly global storms, such as one in 1971 that greeted the first spacecraft to orbit Mars, NASA's Mariner 9. Discerning a predictable pattern for which martian years will have planet-encircling or global storms has been a challenge.

The most recent martian global dust storm occurred in 2007, significantly diminishing solar power available to two NASA Mars rovers then active halfway around the planet from each other — Spirit and Opportunity. "The global dust storm in 2007 was the first major threat to the rovers since landing," said JPL's John Callas, project manager for Spirit and Opportunity. "We had to take special measures to enable their survival for several weeks with little sunlight to keep them powered. Each rover powered up only a few minutes each day, enough to warm them up, then shut down to the next day without even communicating with Earth. For many days during the worst of the storm, the rovers were completely on their own."

Dust storms will present challenges for astronauts on the Red Planet. Although the force of the wind on Mars is not as strong as portrayed in an early scene in the movie *The Martian*, dust lofted during storms could affect electronics and health, as well as the availability of solar energy. The Red Planet has been observed shrouded by planet-encircling dust nine times since 1924, with the five most recent planetary storms detected in 1977, 1982, 1994, 2001, and 2007. The actual number of such events is no doubt higher. In some of the years when no orbiter was observing Mars up close, Mars was poorly positioned for Earth-based telescopic detection of dust storms during the martian season when global storms are most likely.

Shirley's 2015 paper in the journal *Icarus* reported finding a pattern in the occurrence of global dust storms when he factored in a variable linked to the orbital motion of Mars. Other planets have an effect on the momentum of Mars as it orbits the solar system's center of gravity. This effect on momentum varies with a cycle time of about 2.2 years, which is longer than the time it takes Mars to complete each orbit: about 1.9 years. The relationship between these two cycles changes constantly. Shirley found that global dust storms tend to occur when the momentum is increasing during the first part of the dust storm season. None of the global dust storms in the historic record occurred in years when the momentum was decreasing during the first part of the dust storm season. The paper noted that conditions in the current Mars dust-storm season are very similar to those for a number of years when global storms occurred in the past. Observations of the martian atmosphere over the next few months will test whether the forecast is correct.

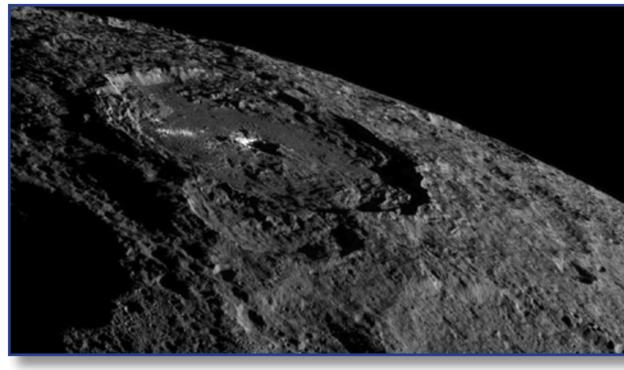
Researchers at Malin Space Science Systems in San Diego post Mars weather reports each week based on observations using the Mars Color Imager camera on NASA's Mars Reconnaissance Orbiter. A series of local southern-hemisphere storms in late August grew into a major regional dust storm in early September, but subsided by mid-month without becoming global. Researchers will be closely watching to see what happens with the next regional storm.

New Ceres Views as Dawn Moves Higher

The brightest area on Ceres stands out amid shadowy, cratered terrain in a dramatic new view from NASA's Dawn spacecraft, taken as it looked off to the side of the dwarf planet. Dawn snapped this image on October 16, from its fifth science orbit, in which the angle of the Sun was different from that in previous orbits. Dawn was about 1480 kilometers (920 miles) above Ceres when this image was taken — an altitude the spacecraft had reached in early October.

Occator Crater, with its central bright region and secondary, less-reflective areas, appears quite prominent near the limb, or edge, of Ceres. At 92 kilometers (57 miles) wide and 4 kilometers (2.5 miles) deep, Occator displays evidence of recent geologic activity. The latest research suggests that the bright material in this crater is comprised of salts left behind after a briny liquid emerged from below, froze, and then sublimated, meaning it turned from ice into vapor.

The impact that formed the crater millions of years ago unearthed material that blanketed the area outside the crater, and may have triggered the upwelling of salty liquid. "This image captures the wonder of soaring above this fascinating, unique world that Dawn is the first to explore," said Marc Rayman, Dawn's chief engineer and mission director, based at NASA's Jet Propulsion Laboratory.



Occator Crater, home of Ceres' intriguing brightest areas, is prominently featured in this image from NASA's Dawn spacecraft. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

Dawn scientists have also released an image of Ceres that approximates how the dwarf planet's colors would appear to the human eye. This view, produced by the German Aerospace Center in Berlin, combines images taken from Dawn's first science orbit in 2015, using the framing camera's red, green, and blue filters. The color was calculated based on the way Ceres reflects different wavelengths of light.

The spacecraft has gathered tens of thousands of images and other information from Ceres since arriving in orbit on March 6, 2015. After spending more than eight months studying Ceres at an altitude of about 385 kilometers (240 miles), closer than the International Space Station is to Earth, Dawn headed for a higher vantage point in August. In October, while the spacecraft was at its 1480-kilometer (920-mile) altitude, it returned images and other valuable insights about Ceres.

On November 4, Dawn began making its way to a sixth science orbit, which will be over 7200 kilometers (4500 miles) from Ceres. While Dawn needed to make several changes in its direction while spiraling between most previous orbits at Ceres, engineers have figured out a way for the spacecraft to arrive at this next orbit while the ion engine thrusts in the same direction that Dawn is already going. This uses less hydrazine and xenon fuel than Dawn's normal spiral maneuvers. Dawn should reach this next orbit in early December.

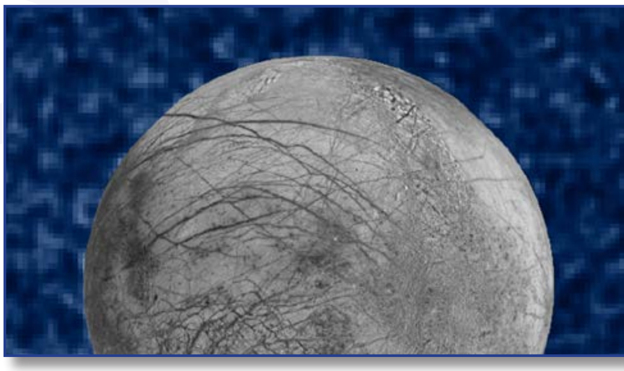
One goal of Dawn's sixth science orbit is to refine previously collected measurements. The spacecraft's gamma ray and neutron spectrometer, which has been investigating the composition of Ceres' surface, will characterize the radiation from cosmic rays unrelated to Ceres. This will allow scientists to subtract "noise" from measurements of Ceres, making the information more precise.

The spacecraft is healthy as it continues to operate in its extended mission phase, which began in July. During the primary mission, Dawn orbited and accomplished all of its original objectives at Ceres and protoplanet Vesta, which the spacecraft visited from July 2011 to September 2012. For more information, visit *http://dawn.jpl.nasa.gov.*

Possible Water Plumes on Jupiter's Moon Europa

Astronomers using NASA's Hubble Space Telescope have imaged what may be water vapor plumes erupting off the surface of Jupiter's moon Europa. This finding bolsters other Hubble observations suggesting the icy moon erupts with high-altitude water vapor plumes. The observation increases the possibility that missions to Europa may be able to sample Europa's ocean without having to drill through miles of ice.

"Europa's ocean is considered to be one of the most promising places that could potentially harbor life in the solar system," said Geoff Yoder, acting associate administrator for NASA's Science Mission Directorate in Washington. "These plumes, if they do indeed exist, may provide another way to sample Europa's subsurface."



This composite image shows suspected plumes of water vapor erupting at the 7 o'clock position off the limb of Jupiter's moon Europa. The plumes, photographed by NASA's Hubble's Space Telescope Imaging Spectrograph, were seen in silhouette as the moon passed in front of Jupiter. Credit: NASA/ESA/W. Sparks (STScI)/USGS Astrogeology Science Center.

The plumes are estimated to rise about 200 kilometers (125 miles) before, presumably, raining material back down onto Europa's surface. Europa has a huge global ocean containing twice as much water as Earth's oceans, but it is protected by a layer of extremely cold and hard ice of unknown thickness. The plumes provide a tantalizing opportunity to gather samples originating from under the surface without having to land or drill through the ice.

The team, led by William Sparks of the Space Telescope Science Institute in Baltimore, observed these finger-like projections while viewing Europa's limb as the moon passed in front of Jupiter. The original goal of the team's observing proposal was to determine whether Europa has a thin, extended atmosphere, or exosphere. Using the same observing method that detects atmospheres around planets orbiting other stars, the team realized if there was water vapor venting from Europa's surface, this observation would be an excellent way to see it.

"The atmosphere of an extrasolar planet blocks some of the starlight that is behind it," Sparks explained. "If there is a thin atmosphere around Europa, it has the potential to block some of the light of Jupiter, and we could see it as a silhouette. And so we were looking for absorption features around the limb of Europa as it transited the smooth face of Jupiter." In 10 separate occurrences spanning 15 months, the team observed Europa passing in front of Jupiter. They saw what could be plumes erupting on three of these occasions.

This work provides supporting evidence for water plumes on Europa. In 2012, a team led by Lorenz Roth of the Southwest Research Institute in San Antonio detected evidence of water vapor erupting from the frigid south polar region of Europa and reaching more than 160 kilometers (100 miles) into space. Although both teams used Hubble's Space Telescope Imaging Spectrograph instrument, each used a totally independent method to arrive at the same conclusion.

"When we calculate in a completely different way the amount of material that would be needed to create these absorption features, it's pretty similar to what Roth and his team found," Sparks said. "The estimates for the mass are similar; the estimates for the height of the plumes are similar. The latitude of two of the plume candidates we see corresponds to their earlier work." As of yet, the two teams have not simultaneously detected the plumes using their independent techniques. Observations thus far have suggested the plumes could be highly variable, meaning that they may sporadically erupt for some time and then die down. For example, observations by Roth's team within a week of one of the detections by Sparks' team failed to detect any plumes.

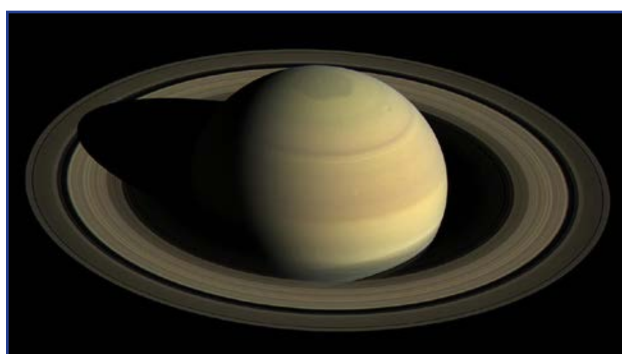
If confirmed, Europa would be the second moon in the solar system known to have water vapor plumes. In 2005, NASA's Cassini orbiter detected jets of water vapor and dust spewing off the surface of Saturn's moon Enceladus. Scientists may use the infrared vision of NASA's James Webb Space Telescope, which is scheduled to launch in 2018, to confirm venting or plume activity on Europa. NASA also is formulating a mission to Europa with a payload that could confirm the presence of plumes and study them from close range during multiple flybys.

"Hubble's unique capabilities enabled it to capture these plumes, once again demonstrating Hubble's ability to make observations it was never designed to make," said Paul Hertz, director of the Astrophysics Division at NASA Headquarters in Washington. "This observation opens up a world of possibilities, and we look forward to future missions — such as the James Webb Space Telescope — to follow-up on this exciting discovery."

The work by Sparks and his colleagues is published in the September 29 issue of the *Astrophysical Journal*. For more information about Europa and Hubble, visit *http://www.nasa.gov/hubble.*

NASA Saturn Mission Prepares for "Ring-Grazing Orbits"

A thrilling ride has begun for NASA's Cassini spacecraft. Engineers have been pumping up the spacecraft's orbit around Saturn this year to increase its tilt with respect to the planet's equator and rings. On November 30, following a gravitational nudge from Saturn's moon Titan, Cassini entered the first phase of the mission's dramatic endgame. Launched in 1997, Cassini has been touring the Saturn system since arriving there in 2004 for an up-close study of the planet, its rings, and its moons. During its journey, Cassini has made numerous dramatic discoveries, including a global ocean within Enceladus and liquid methane seas on Titan.



Cassini has begun a series of 20 orbits that will fly high above and below Saturn's poles, plunging just past the outer edge of the main rings. Credit: NASA/JPL-Caltech/Space Science Institute.

Between November 30 and April 22, Cassini will circle high over and under the poles of Saturn, diving every 7 days — a total of 20 times — through the unexplored region at the outer edge of the main rings. "We're calling this phase of the mission Cassini's Ring-Grazing Orbits, because we'll be skimming past the outer edge of the rings," said Linda Spilker, Cassini project scientist at NASA's Jet Propulsion Laboratory (JPL). "In addition, we have two instruments that can sample particles and gases as we cross the ringplane, so in a sense Cassini is also 'grazing' on the rings."

On many of these passes, Cassini's instruments will attempt to directly sample ring particles and molecules of faint gases that are found close to the rings. During the first two orbits, the spacecraft will pass directly through an extremely faint ring produced by tiny meteors striking the two small moons Janus and Epimetheus. Ring crossings in March and April will send the spacecraft through the dusty outer reaches of the F ring. "Even though we're flying closer to the F ring than we ever have, we'll still be more than 7800 kilometers (4850 miles) distant. There's very little concern over dust hazard at that range," said Earl Maize, Cassini project manager at JPL.

The F ring marks the outer boundary of the main ring system; Saturn has several other, much fainter rings that lie farther from the planet. The F ring is complex and constantly changing: Cassini images have shown structures like bright streamers, wispy filaments, and dark channels that appear and develop over mere hours. The ring is also quite narrow — only about 800 kilometers (500 miles) wide. At its core is a denser region about 50 kilometers (30 miles) wide.

Cassini's ring-grazing orbits offer unprecedented opportunities to observe the menagerie of small moons that orbit in or near the edges of the rings, including best-ever looks at the moons Pandora, Atlas, Pan, and Daphnis. Grazing the edges of the rings will provide some of the closest-ever studies of the outer portions of Saturn's main rings (the A, B, and F rings). Some of Cassini's views will have a level of detail not seen since the spacecraft glided just above them during its arrival in 2004. The mission will begin imaging the rings in December along their entire width, resolving details smaller than 1 kilometer (0.6 miles) per pixel and building up Cassini's highest-quality complete scan of the rings' intricate structure.

The mission will continue investigating small-scale features in the A ring called "propellers," which reveal the presence of unseen moonlets. Because of their airplane propeller-like shapes, scientists have given some of the more persistent features informal names inspired by famous aviators, including "Earhart." Observing propellers at high resolution will likely reveal new details about their origin and structure. And in March, while coasting through Saturn's shadow, Cassini will observe the rings backlit by the Sun, in the hope of catching clouds of dust ejected by meteor impacts.

During these orbits, Cassini will pass as close as about 90,000 kilometers (56,000 miles) above Saturn's cloud tops. But even with all their exciting science, these orbits are merely a prelude to the planet-grazing passes that lie ahead. In April 2017, the spacecraft will begin its Grand Finale phase.

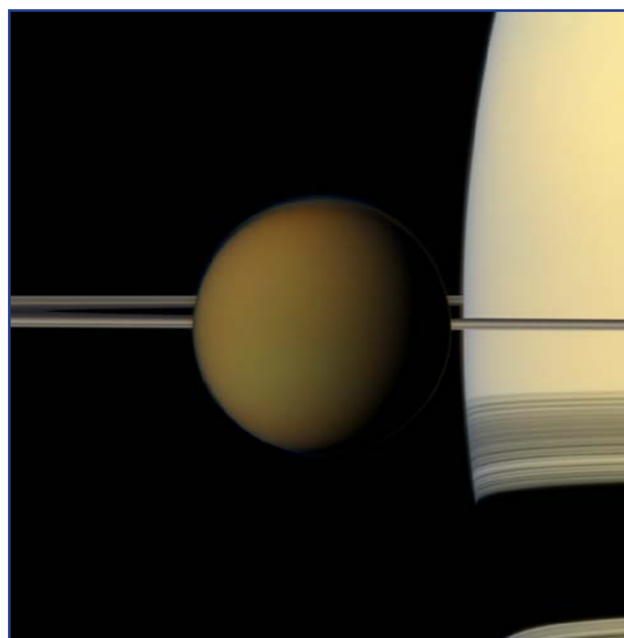
After nearly 20 years in space, the mission is drawing near its end because the spacecraft is running low on fuel. The Cassini team carefully designed the finale to conduct an extraordinary science investigation before sending the spacecraft into Saturn to protect its potentially habitable moons. During its grand finale, Cassini will pass as close as 1628 kilometers (1012 miles) above the clouds as it dives repeatedly through the narrow gap between Saturn and its rings, before making its mission-ending plunge into the planet's atmosphere on September 15. Before the spacecraft can leap over the rings to begin its finale, some preparatory work remains.

To begin with, Cassini was scheduled to perform a brief burn of its main engine during the first super-close approach to the rings on December 4. This maneuver is important for fine-tuning the orbit and setting the correct course to enable the remainder of the mission. To further prepare, Cassini will observe Saturn's atmosphere during the ring-grazing phase of the mission to more precisely determine how far it extends above the planet. Scientists have observed Saturn's outermost atmosphere to expand and contract slightly with the seasons since Cassini's arrival. Given this variability, the forthcoming data will be important for helping mission engineers determine how close they can safely fly the spacecraft.

For more information, visit *http://saturn.jpl.nasa.gov.*

NASA Scientists Find "Impossible" Cloud on Titan — Again

The puzzling appearance of an ice cloud seemingly out of thin air has prompted NASA scientists to suggest that a different process than previously thought — possibly similar to one seen over Earth's poles — could be forming clouds on Saturn's moon Titan. Located in Titan's stratosphere, the cloud is made of a compound of carbon and nitrogen known as dicyanoacetylene (C_4N_2), an ingredient in the chemical cocktail that colors the giant moon's hazy, brownish-orange atmosphere.



The hazy globe of Titan hangs in front of Saturn and its rings in this natural color view from NASA's Cassini spacecraft. Credit: NASA/JPL-Caltech/Space Science Institute.

Decades ago, the infrared instrument on NASA's Voyager 1 spacecraft spotted an ice cloud just like this one on Titan. What has puzzled scientists ever since is this: They detected less than 1% of the dicyanoacetylene gas needed for the cloud to condense. Recent observations from NASA's Cassini mission yielded a similar result. Using Cassini's composite infrared spectrometer (CIRS) — which can identify the spectral fingerprints of individual chemicals in the atmospheric brew — researchers found a large, high-altitude cloud made of the same frozen chemical. Yet, just as Voyager found, when it comes to the vapor form of this chemical, CIRS reported that Titan's stratosphere is as dry as a desert.

"The appearance of this ice cloud goes against everything we know about the way clouds form on Titan," said Carrie Anderson, a CIRS co-investigator at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and lead author of the study.

The typical process for forming clouds involves condensation. On Earth, we're familiar with the cycle of evaporation and condensation of water. The same kind of cycle takes place in Titan's troposphere — the weather-forming layer of Titan's atmosphere — but with methane instead of water. A different condensation process takes place in the stratosphere — the region above the troposphere — at Titan's north and south winter poles. In this case, layers of clouds condense as the global circulation pattern forces warm gases downward at the pole. The gases then condense as they sink through cooler and cooler layers of the polar stratosphere.

Either way, a cloud forms when the air temperature and pressure are favorable for the vapor to condense into ice. The vapor and the ice reach a balance point — an equilibrium — that is determined by the air temperature and pressure. Because of this equilibrium, scientists can calculate the amount of vapor where ice is present. "For clouds that condense, this equilibrium is mandatory, like the law of gravity," said Robert Samuelson, an emeritus scientist at Goddard and a co-author of the paper.

However, the numbers don't compute for the cloud made from dicyanoacetylene. The scientists determined that they would need at least 100 times more vapor to form an ice cloud where the cloud top was observed by Cassini's CIRS. One explanation suggested early on was that the vapor might be present, but Voyager's instrument wasn't sensitive enough in the critical wavelength range needed to detect it. When CIRS also didn't find the vapor, Anderson and her Goddard and Caltech colleagues proposed an altogether different explanation. Instead of the cloud forming by condensation, they think the C_4N_2 ice forms because of reactions taking place on other kinds of ice particles. The researchers call this "solid-state chemistry," because the reactions involve the ice, or solid, form of the chemical.

The first step in the proposed process is the formation of ice particles made from the related chemical cyanoacetylene (HC_3N). As these tiny bits of ice move downward through Titan's stratosphere, they get coated by hydrogen cyanide (HCN). At this stage, the ice particle has a core and a shell comprised of two different chemicals. Occasionally, a photon of ultraviolet light tunnels into the frozen shell and triggers a series of chemical reactions in the ice. These reactions could begin either in the core or within the shell. Both pathways can yield dicyanoacteylene ice and hydrogen as products.

The researchers got the idea of solid-state chemistry from the formation of clouds involved in ozone depletion high above Earth's poles. Although Earth's stratosphere has scant moisture, wispy nacreous clouds (also called polar stratospheric clouds) can form under the right conditions. In these clouds, chlorine-bearing chemicals that have entered the atmosphere as pollution stick to crystals of water ice, resulting in chemical reactions that release ozone-destroying chlorine molecules.

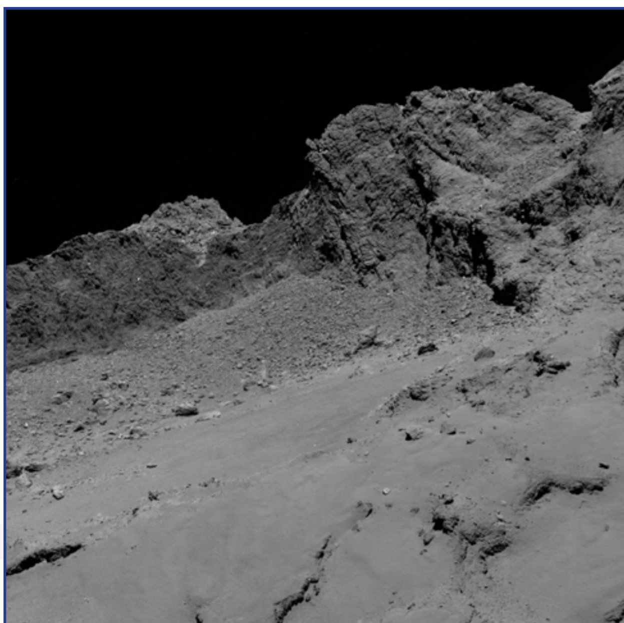
"It's very exciting to think that we may have found examples of similar solid-state chemical processes on both Titan and Earth," said Anderson. The researchers suggest that, on Titan, the reactions occur inside the ice particles, sequestered from the atmosphere. In that case, dicyanoacetylene ice wouldn't make direct contact with the atmosphere, which would explain why the ice and the vapor forms are not in the expected equilibrium.

"The compositions of the polar stratospheres of Titan and Earth could not differ more," said Michael Flasar, CIRS principal investigator at Goddard. "It is amazing to see how well the underlying physics of both atmospheres has led to analogous cloud chemistry."

The findings are published in the journal *Geophysical Research Letters*.

Farewell Rosetta: ESA Mission Comes to an End on Comet Surface

The European Space Agency's (ESA's) Rosetta mission came to a dramatic end on September 30, with a controlled touchdown of the spacecraft on a region of Comet 67P/Churyumov-Gerasimenko known for active pits that spew comet dust into space. ESA ended the mission due to the spacecraft's ever-increasing distance from the Sun, which resulted in significantly reduced solar power with which to operate the vehicle and its instruments. Rosetta was an international mission led by ESA with instruments provided by its member states, and additional support and instruments provided by NASA.



The OSIRIS narrow-angle camera onboard the ESA's Rosetta spacecraft captured this image of Comet 67P/Churyumov-Gerasimenko on September 30, 2016, from an altitude of about 16 kilometers (10 miles) above the surface during the spacecraft's controlled descent. The image scale is about 30 centimeters (12 inches) per pixel, and the image itself measures about 614 meters (2000 feet) across.

"The European Space Agency's Rosetta Mission is a magnificent demonstration of what excellent mission design, execution, and international collaboration can achieve," said Geoff Yoder, acting associate administrator for NASA's Science Mission Directorate in Washington. "Being neighbors with a comet for more than two years has given the world invaluable insight into these beautiful nomads of deep space. We congratulate ESA on its many accomplishments during this daring mission."

The final hours of descent enabled Rosetta to make many once-in-a-lifetime measurements, including analyzing gas and dust closer to the surface than ever possible before, and taking very high-resolution images of the comet nucleus. The images included views of the open pits of the Ma'at region, where the spacecraft made its controlled impact. Ma'at is home to several active pits more than 100 meters (330 feet) in diameter and 50 to 60 meters (160 to 200 feet) deep.

The walls of the pits exhibit intriguing lumpy structures about 1 meter wide (3 feet wide) called "goose bumps." Scientists believe those structures could be the signatures of early cometesimals that assembled to create the comet in the early phases of solar system formation. Rosetta attempted to get its closest look yet at these fascinating structures on September 30, when the spacecraft targeted a point adjacent to a 130-meter-wide (430-foot-wide), well-defined pit that the mission team has informally named Deir el-Medina.

"Rosetta [gave] us data to the very end," said Bonnie Buratti, project scientist for the U.S. Rosetta project from NASA's Jet Propulsion Laboratory in Pasadena, California. "NASA's three instruments [on]board Rosetta [were] among those collecting data all the way down."

Those three NASA science instruments are the Microwave Instrument for Rosetta Orbiter (MIRO), an ultraviolet spectrometer called Alice, and the Ion and Electron Sensor (IES). They were part of a suite of 11 science instruments on the orbiter.

MIRO was designed to provide data on how gas and dust leave the surface of the nucleus to form the coma and tail that give comets their intrinsic beauty. Studying the surface temperature and evolution of the coma and tail provides information on how the comet evolves as it approaches and leaves the vicinity of the Sun. MIRO had the ability to study water, carbon monoxide, ammonia, and methanol.

Alice, an ultraviolet spectrometer, analyzed gases in the comet's coma and tail; measured how fast the comet produced water, carbon monoxide, and carbon dioxide (clues to the surface composition of the nucleus); and measured argon levels. These measurements will help determine the temperature of the solar system when the nucleus formed more than 4.6 billion years ago.

The Ion and Electron Sensor was part of a suite of five instruments that analyzed the plasma environment of the comet, particularly the coma. The instrument measured the charged particles in the Sun's outer atmosphere, or solar wind, as they interact with the gas flowing out from the comet.

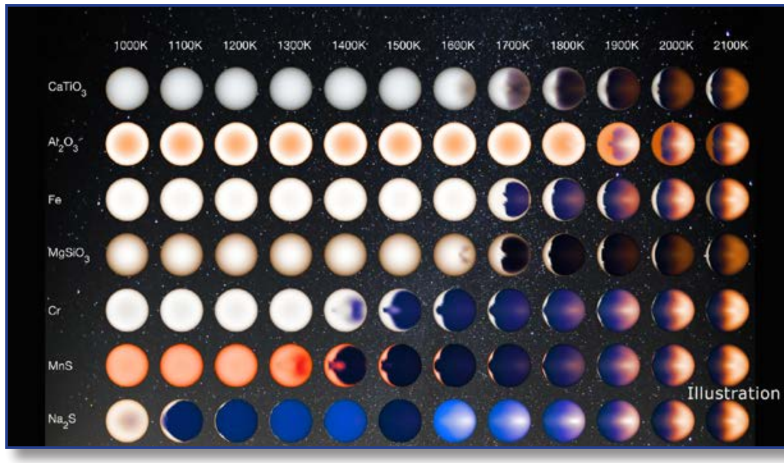
The Rosetta mission was launched in 2004 and arrived at Comet 67P/Churyumov-Gerasimenko on August 6, 2014. It was the first mission in history to rendezvous with a comet and escort it as it orbited the Sun. On November 4, 2014, a smaller lander named Philae — which had been deployed from the Rosetta mothership — touched down on the comet and bounced several times before alighting on the surface. Philae obtained the first images taken from a comet's surface and sent back valuable scientific data for several days.

"It [was] hard to see that last transmission from Rosetta come to an end," said Art Chmielewski of JPL, project manager for the U.S. Rosetta. "But whatever melancholy we will be experiencing will be more than made up for in the elation that we will feel to have been part of this truly historic mission of exploration."

For more information about Rosetta, visit *http://www.esa.int/rosetta.*

Cloudy Nights, Sunny Days on Distant Hot Jupiters

The weather forecast for faraway, blistering planets called "hot Jupiters" might go something like this: Cloudy nights and sunny days, with a high of 1300°C (~2400°F, or about 1600 Kelvin). These mysterious worlds are too far away for us to see clouds in their atmospheres. However, a recent study using NASA's Kepler space telescope and computer modeling techniques finds clues to where such clouds might gather and what they're likely made of. The study was published in the *Astrophysical Journal.*



This illustration represents how hot Jupiters of different temperatures and different cloud compositions might appear to a person flying over the dayside of these planets on a spaceship, based on computer modeling. Credit: NASA/JPL-Caltech/University of Arizona/V. Parmentier.

Hot Jupiters, among the first of the thousands of exoplanets (planets outside our solar system) discovered in our galaxy so far, orbit their stars so tightly that they are perpetually charbroiled. While that might discourage galactic vacationers, the study represents a significant advance in understanding the structure of alien atmospheres. Hot Jupiters are tidally locked, meaning one side of the planet always faces its sun and the other is in permanent darkness. In most cases, the "dayside" would be largely cloud-free and the "nightside" heavily clouded, leaving partly cloudy skies for the zone in between, the study shows. "The cloud formation is very different from what we know in the solar system," said Vivien Parmentier, a NASA Sagan Fellow and postdoctoral researcher at the University of Arizona, Tucson, who was the lead author of the study.

A "year" on such a planet can be only a few Earth days long, the time the planet takes to whip once around its star. On a "cooler" hot Jupiter, temperatures of, say, 1300°C (~2400°F) might prevail. But the extreme conditions on hot Jupiters worked to the scientists' advantage. "The day-night radiation contrast is, in fact, easy to model," Parmentier said. "[The hot Jupiters] are much easier to model than Jupiter itself."

The scientists first created a variety of idealized hot Jupiters using global circulation models — simpler versions of the type of computer models used to simulate Earth's climate. Then, they compared the models to the light Kepler detected from real hot Jupiters. Kepler, which is now operating in its K2 mission, was designed to register the extremely tiny dip in starlight when a planet passes in front of its star, which is called a "transit." In this case, researchers focused on the planets' "phase curves," or changes in light as the planet passes through phases, like Earth's Moon.

Matching the modeled hot Jupiters to phase curves from real hot Jupiters revealed which curves were caused by the planet's heat, and which by light reflected by clouds in its atmosphere. By combining

Kepler data with computer models, scientists were able to infer global cloud patterns on these distant worlds for the first time. The new cloud view allowed the team to draw conclusions about wind and temperature differences on the hot Jupiters they studied. Just before the hotter planets passed behind their stars — in a kind of eclipse — a blip in the planet's optical light curve revealed a "hot spot" on the planet's eastern side.

On cooler eclipsing planets, a blip was seen just after the planet reemerged on the other side of the star, this time on the planet's western side. The early blip on hotter worlds reveals that powerful winds were pushing the hottest, cloud-free part of the atmosphere, normally found directly beneath its sun, to the east. Meanwhile, on cooler worlds, clouds could bunch up and reflect more light on the "colder," western side of the planet, causing the post-eclipse blip. "We're claiming that the west side of the planet's dayside is more cloudy than the east side," Parmentier said.

While the puzzling pattern has been seen before, this research was the first to study all the hot Jupiters showing this behavior. This led to another first. By figuring out how clouds are distributed, which is intimately tied to the planet's overall temperature, scientists were able to determine what the clouds were probably made of.

Hot Jupiters are far too hot for water-vapor clouds like those on Earth. Instead, clouds on these planets are likely formed as exotic vapors condense to form minerals, chemical compounds like aluminum oxide, or even metals, like iron. The science team found that manganese sulfide clouds probably dominate on "cooler" hot Jupiters, while silicate clouds prevail at higher temperatures. On these planets, the silicates likely "rain out" into the planet's interior, vanishing from the observable atmosphere.

In other words, a planet's average temperature, which depends on its distance from its star, governs the kinds of clouds that can form. That leads to different planets forming different types of clouds. "Cloud composition changes with planet temperature," Parmentier said. "The offsetting light curves tell the tale of cloud composition. It's super interesting because cloud composition is very hard to get otherwise." The new results also show that clouds are not evenly distributed on hot Jupiters, echoing previous findings from NASA's Spitzer Space Telescope suggesting that different parts of hot Jupiters have vastly different temperatures.

The new findings come as we mark the 21st anniversary of exoplanet hunting. On October 6, 1995, a Swiss team announced the discovery of 51 Pegasi b, a hot Jupiter that was the first planet to be confirmed in orbit around a Sun-like star. Parmentier and his team hope their revelations about the clouds on hot Jupiters could bring more detailed understanding of hot Jupiter atmospheres and their chemistry, a major goal of exoplanet atmospheric studies.

For more information, visit *http://www.nasa.gov/kepler* or *https://exoplanets.nasa.gov.*

Biosignature Preservation and Detection in Mars Analog Environments

May 16–18, 2016
Lake Tahoe, Nevada

The Conference on Biosignature Preservation and Detection in Mars Analog Environments brought together 90 Mars scientists at the Hyatt Regency Lake Tahoe in Incline Village, Nevada. Most of the attendees at the conference came from academia (including an encouraging number of graduate students and postdoctoral researchers), from several of the NASA centers, and from research institutes. About 10% of the participants were international. The conference was sponsored by the Lunar and Planetary Institute, the Universities Space Research Association, and NASA.

Presentations at the conference focused on the attributes and preservation potential of a range of microbial biosignatures in Mars analog habitable environments on the Earth, and the program was organized around environmental commonalities. Understanding the properties of biosignatures on Earth is a key input into the discussion of strategies for detection of potential biosignatures on Mars. The conference emphasized discussion time, which was spread throughout the meeting in four different ways: immediately following each talk, a block of time at the end of each session, a higher-level block at the end of the conference, and unstructured discussions in association with the poster sessions.

The five analog environments most prominently discussed in the conference included (1) hydrothermal springs systems (wherever they intersected the surface), (2) subaqueous environments (including deltas, lakes, playas, and shallow oceanic environments), (3) subaerial environments (all environments where water comes from precipitation, snow melt, or ambient-temperature groundwater), (4) subsurface environments (all those below the active regolith, except those impacted by hydrothermal circulation), and (5) iron-rich systems (where circulating groundwater or hydrothermal systems mobilize iron).

For biomarkers in these environments, discussion focused on four key questions:

- How does the combination of habitability potential and preservation potential combine to create biosignatures in the geologic record?
- How do we use biosignatures to interpret the presence or absence of life in ancient analog environments?

- How might we translate what we learn about preservation of biosignatures in Mars analogs to the different physical conditions and environments on Mars?
- How could or should this knowledge influence the strategies and priorities for the astrobiological exploration of Mars?

Finally, at the conclusion of the conference, a field trip was led by Wendy Calvin and Jack Farmer to the nearby Steamboat Springs geothermal area, an important example of one of the major Mars analog environments discussed.

In a review paper to be published in the journal *Astrobiology*, 10 members of a writing committee selected before the conference used the conference discussions to catalyze a post-conference review of the issues discussed. This included a literature review of prior work on the major biosignature analog environments discussed above, some interpretations of how these analog studies may be useful in guiding strategic planning for the astrobiological exploration of Mars, and their thoughts on urgent needs for research and future research directions.

This conference was convened by Lindsay Hays and David Beaty (Mars Program Office, Jet Propulsion Laboratory) and Michael Meyer and Mary Voytek (NASA Headquarters). To view the full conference program and abstracts, as well as e-posters and electronic presentations, visit *http://www.hou.usra.edu/meetings/biosignature2016/*.

6th International Conference on Mars Polar Science and Exploration

September 5–9, 2016
Reykjavik, Iceland

Mars polar regions are of unique interest to researchers across many fields. The poles undergo active atmospheric and surface processes that shape the polar layered deposits (PLD) and nearby landforms. Additionally, the north and south PLDs contain many layers that have been used to understand the history of accumulation at the poles and extract a record of climate. Finally, imagery of geomorphic activity points to widespread volatile transport between the poles and mid-latitudes, and those volatiles are currently modifying the surface in dunes, gullies, and landforms particular to carbon dioxide frost.

To discuss recent observations and breakthroughs since the fifth conference in 2011, more than 100 attendees from 11 countries attended the Sixth International Conference on Mars Polar Science and Exploration. Additionally, the conference was organized with the goal of enunciating the outstanding questions for the community.

Because polar science is such a diverse topic, sessions were strategically organized by topic so that the previous sessions would inform later sessions. Papers were presented in two half sessions each morning and each afternoon (except for Wednesday, the day of the mid-conference field trip). Oral and poster sessions included:

1. Present Polar Atmosphere: Dynamics
2. Present Polar Atmosphere: H_2O and CO_2
3. Volatiles and Diurnal or Seasonal Cycles
4. Surface Activity
   a. CO_2 Ice as a Geomorphological Agent
   b. Surface Expression of Seasonal Processes I and II
5. Terrestrial Analogs
6. The Martian Climate Record
   a. Polar Cap Edition
   b. Ancient and Modern Ground Ice
7. Polar Geology
   a. Glaciers and Ground Ice
   b. Polar Geochemistry and Mineralogy
   c. Polar Structure
8. Glaciology and the Physics of Ice
9. Future Exploration of Mars Polar Regions

A synthesis of remaining scientific questions was created from the proceedings and will be published in an upcoming special issue of Icarus.

The conference was convened by Isaac B. Smith (Planetary Science Institute) and Thorsteinn Thorsteinsson (Icelandic Meterological Office). To view the full conference program and abstracts, visit *http://www.hou.usra.edu/meetings/marspolar2016/*.

Eighth Huntsville Gamma-Ray Burst Symposium

October 24–28, 2016
Huntsville, Alabama

More than 100 scientists engaged in different areas of research related to gamma-ray bursts (GRBs) gathered at the Westin Hotel in Huntsville, Alabama, to share the latest observational, analytical, and theoretical results. This was the eighth convening of the GRB symposium, with the first meetings in the 1990s taking place in Huntsville, home to the Burst And Transient Source Experiment (BATSE), which dominated the GRB landscape.

The new century ushered in a new era of GRB research centered on observations of afterglow radiation from GRBs across the electromagnetic spectrum, led in the U.S. by NASA's Swift telescope. The symposium series went on hiatus, with dedicated conferences moving away from Huntsville until the launch of the Fermi Gamma-Ray Space Telescope in 2008, with the Gamma-Ray Burst Monitor (GBM) taking over where BATSE left off. The symposium returned to Huntsville in 2008, made a brief detour to Nashville in 2013, then returned to Huntsville in 2016. With the Universities Space Research Association as a sponsor and conveners from both GBM and Swift instrument teams, participants included many who attended the first meetings in the 1990s as well as new crops of students and postdoctoral researchers attending their first Huntsville meeting.

With the discovery last year of gravitational wave radiation from merging black holes in a binary system and the expected connection between one of the two main classes of GRBs and compact binary mergers, the field has gained a new focus as we enter the era of multi-messenger time-domain astronomy. This development was reflected in the symposium program, with Tuesday devoted to the connection between gravitational waves and GRBs and Monday afternoon exploring the next possible breakthrough: observations of neutrinos connected to GRBs and the detection of very-high-energy gamma-ray radiation from GRBs. These multi-messenger sessions brought together scientists from different communities in astronomy, particle astrophysics, and fundamental physics.

Other sessions explored the connection between GRBs and supernovae, the use of GRBs as probes of the early universe, and the physics of jets and the central engines that power them. Thursday morning showcased the upcoming and proposed space experiments that will provide the observational data needed to advance the field, with eight invited presentations from key instrument experts. On Thursday evening after the conference banquet, the participants looked back in time with the principal investigator of the BATSE experiment, Jerry Fishman, who gave his personal recollections to mark the twenty-fifth anniversary of the launch of BATSE on the Compton Gamma-Ray Observatory and the first Huntsville GRB symposium.

For more information, including the program and abstracts, visit *http://www.hou.usra.edu/meetings/gammaray2016/*.

LPI Summer Intern Program in Planetary Science

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. 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. Furthermore, you will participate in peer-reviewed research, learn from top-notch planetary scientists, and preview various careers in science.

The 10-week program runs from June 5, 2017, to August 11, 2017. You will receive a $5675 stipend plus $1000 U.S. travel stipend, or $1500 foreign travel reimbursement for foreign nationals.

The LPI is located near 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 2017 program is **January 6, 2017**. For more information, including eligibility and selection criteria, areas of research, and an online application form, visit *http://www.lpi.usra.edu/lpiintern*.

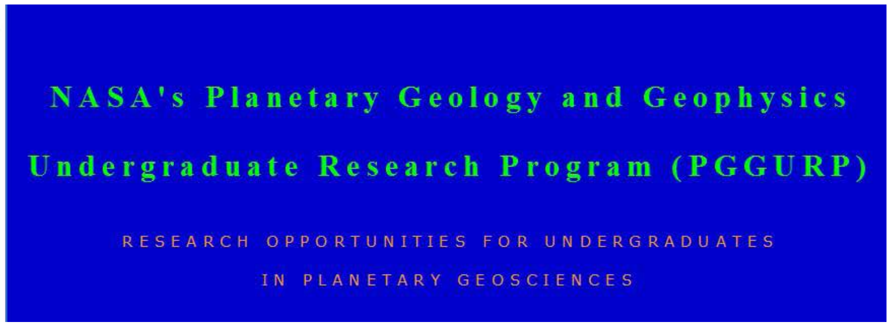
Graduate Students Eligible for the LPI Career Development Award

The Lunar and Planetary Institute (LPI) is proud to announce its tenth LPI Career Development Award, which is open to both U.S. and non-U.S. applicants. This award will be given to graduate students who have submitted a first-author abstract for presentation at the 48th Lunar and Planetary Science Conference (LPSC). A travel stipend of $1000 will be awarded to the top applicants to help cover travel expenses for attending the LPSC in March. Awards will be based on a review of the application materials by a panel of lunar and planetary scientists.

Applications must include a letter outlining why the applicant would like to participate at the LPSC and what he or she will contribute to the conference, a letter of recommendation from his or her research advisor, a copy of the first-author abstract, and a curriculum vitae for the applicant.

The deadline for application is **January 13, 2017**. Applications and all accompanying materials must be submitted electronically. All documents uploaded must be in text or PDF format. For more information and a link to the application form, visit *http://www.hou.usra.edu/meetings/lpsc2017/programAbstracts/cdaAward/*.

NASA's Planetary Geology and Geophysics Undergraduate Research Program



Through the Planetary Geology and Geophysics Undergraduate Research Program (PGGURP) qualified undergraduates are paired with NASA-funded investigators at research locations around the U.S. for eight weeks during the summer. PGGURP's goals are to provide incentive and development of future planetary geoscientists, broaden the base of students who participate in planetary geoscience, introduce students interested in the traditional sciences to planetary science, and give potential planetary geoscientists a chance to explore the exciting field of planetary research. Students will spend the summer at the NASA scientist's home institution, and the program will pay for housing, travel, and a cost-of-living stipend.

The program consists of an eight-week summer internship, in which qualified students are matched with a NASA-funded planetary scientist. Care is taken to match the skills of the student with the needs of the NASA mentor.

The application deadline is **February 10, 2017**. For more information, including eligibility requirements, visit *http://www.acsu.buffalo.edu/~tgregg/pggurp.html*.

California Institute of Technology Summer Undergraduate Research Fellowships

Caltech's Summer Undergraduate Research Fellowships (SURF) program introduces students to research under the guidance of seasoned research mentors at the California Institute of Technology (Caltech) and the Jet Propulsion Laboratory (JPL). Students experience the process of research as a creative intellectual activity. SURF is modeled on the grant-seeking process: students collaborate with potential mentors to define and develop a project; applicants write research proposals for their projects; a faculty committee reviews the proposals and recommends awards; students carry out the work over a 10-week period in the summer, mid-June to late August; and at the conclusion of the program, they submit a technical paper and give an oral presentation at SURF Seminar Day, a symposium modeled on a professional technical meeting.

The deadline for all application materials is **February 22, 2017**. For more information, visit *http://sfp.caltech.edu/programs/surf*.

Internships, Scholarships, and Fellowships with NASA

NASA Internships are educational hands-on opportunities that provide unique NASA-related research and operational experiences for high school, undergraduate, and graduate students as well as educators. These internships integrate participants with career professionals emphasizing mentor-directed, degree-related, real-time world task completion. During the internship participants engage in scientific or engineering research, development, and operations activities. In addition, there are non-technical internship opportunities to engage in professional activities which support NASA business and administrative processes. Through these internships, participants leverage NASA's unique mission activities and mentorship to enhance and increase their professional capabilities and clarify their long-term career goals.

NASA Internships can be full or part-time, conducted at a NASA facility, contractor facility, or anywhere activities are ongoing to advance NASA's missions. Mentors can be civil servants, contractors, or faculty conducting activities directly related to NASA's unique assets and ongoing mission activities.

NASA internships occur within the following four sessions per year generally corresponding to the academic calendar: spring, summer, fall, and year-long (often following the academic year August–May). Applications for summer 2017 opportunities are due **March 1, 2017**. To find available opportunities and fill out an OSSI online application, visit *http://intern.nasa.gov/ossi*.

SAO Summer Intern Program

The SAO (Smithsonian Astrophysical Observatory) Summer Intern Program is a Research Experiences for Undergraduates (REU) program where students work on astrophysics research with an SAO/Harvard scientist. In 2017, the program will run for 10 weeks, from June 4 through August 12 (these dates may change depending on the availability of Harvard housing). Students are expected to be in residence at the Harvard-Smithsonian Center for Astrophysics (CfA) for the full duration of the program.

The program is funded by the National Science Foundation and the Smithsonian Institution. Undergraduate students interested in a career in astronomy, astrophysics, physics, or related physical sciences are encouraged to apply for the 2017 program. Applicants must be U.S. citizens or permanent residents ("green card" holders), and must be enrolled in a degree program leading to a bachelors degree. Seniors who will graduate in June 2017 (or before) are not eligible.

Applications for the 2017 Summer Program are expected to open this month. For more details and updates, visit *http://hea-www.harvard.edu/REU/REU.html*.

Internships Available at APL

APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

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. The application deadline for the 2017 College Summer Internship Program is **March 31, 2017**. For more information, visit *http://www.jhuapl.edu/employment/summer/.*

Lloyd V. Berkner Space Policy Internships 2017

The goal of the Lloyd V. Berkner Space Policy Internship is to provide promising undergraduate and graduate students with the opportunity to work in the area of civil space research policy in the nation's capital, under the aegis of the National Research Council's Space Science Board and Aeronautics and Space Engineering Board. The summer program is only open to undergraduates. The autumn program is open to undergraduate and graduate students. The application deadlines are **February 3, 2017** (summer), and **June 2, 2017** (autumn). Additional information about the program, including the application procedure, can be found at *http://sites.nationalacademies.org/SSB/ssb_052239.*

"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.

48th LPSC Education and Public Engagement Activities

Education and public engagement events and opportunities will be available during the 48th Lunar and Planetary Science Conference (LPSC) for the education community and planetary scientists. For more information, visit *http://www.hou.usra.edu/meetings/lpsc2017/events/education/*.

Submit an Abstract for the Education and Engagement Poster Sessions —

Educators, planetary scientists, and engineers are invited to submit an abstract for the LPSC education and engagement poster sessions. The abstract deadline is Tuesday, January 10, 2017. To submit, follow the abstract submission instructions provided on the conference website and choose the topic "Education and Engagement" on the abstract submission form.

Education Workshop and Scientist Engagement Sessions —

The Lunar and Planetary Institute will be conducting sessions on Sunday afternoon, March 19, 2017, for planetary scientists, educators, and students.

Planetary Science Palooza:

Students, educators, program leaders, amateur astronomers, and their families are invited to the first LPSC Planetary Science Palooza! Explore hands-on activities, hear the latest findings from experts, and ask questions about their research, how they explore our solar system, and what motivates and challenges them in their work. More details and free registration will be available by mid-January 2017. For more information, contact *education@lpi.usra.edu.*

Early Career Presenters Review:

All early career scientists preparing to present research at the 48th LPSC are invited to present their talk or poster and receive feedback from senior scientists before presenting during the regular meeting. Registration information will be forthcoming. Presenters and scientists wishing to participate as reviewers are encouraged to contact Andy Shaner at *shaner@lpi.usra.edu* with any questions.

Upcoming Public Event Opportunities

Upcoming opportunities exist for educator and public engagement around the broader topics of NASA planetary exploration.

- NASA's Solar System Ambassadors (*http://solarsystem.nasa.gov/ssa/directory.cfm*) can volunteer to assist with your events
- The Night Sky Network (*http://nightsky.jpl.nasa.gov*) is a nationwide coalition of amateur astronomy clubs sharing their time and telescopes to provide astronomy experiences under the real night sky.
- To find out about existing events you can assist with, check out the NASA Museum Alliance events at *http://informal.jpl.nasa.gov/museum/Visit.*

Comet 41P/Tuttle-Giacobini-Kresák —

Comet 41P/Tuttle-Giacobini-Kresák will pass 0.148 AU (58 lunar distances) from Earth on April 5, 2017. The comet should be visible with binoculars and small telescopes between March and May 2017. Use the Night Sky Network to contact a local astronomy club about providing telescopes and/or binoculars and look for hands-on comet activities ideas at NASA Wavelength: *http://nasawavelength.org/resource-search?qq=comets&educationalLevel=#.*

Total Eclipse of the Sun —
http://eclipse2017.nasa.gov

On August 21, 2017, there will be a total eclipse of the Sun visible from the U.S. The path of the total eclipse is only about 97 kilometers (60 miles) wide and goes from a beach in Oregon to a beach in South Carolina. The National Science Teachers Association (NSTA) is making available a popular-level introduction to help explain the eclipse and how to view it to students and the public: *http://www.nsta.org/publications/press/extras/files/solarscience/SolarScienceInsert.pdf.*

Universe in the Classroom: Getting Ready for the All American Eclipse

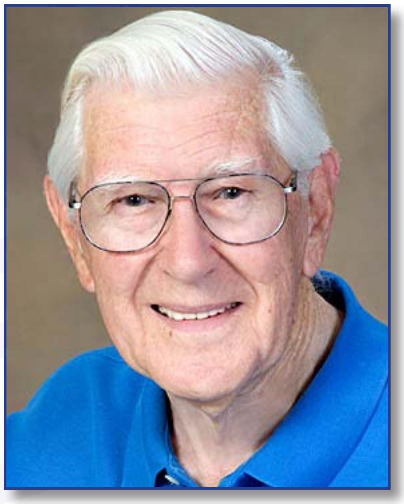
In this edition of *The Universe in the Classroom*, learn about a storyline approach to teaching about eclipses, including investigations into lunar phases, the size and scale of the Earth-Moon system, why eclipses happen, and the pattern and frequency of their occurrence. Visit *http://www.astrosociety.org/publications/universe-in-the-classroom*.

NASA's "Science WOW!" Newsletter

http://www.nasa.gov/education/sciencewow

NASA

NASA has a new science education newsletter. Science starts with a question, and so will "Science WOW!" Each week's message will kick off with a science question and a link to where you can find the answer. "Science WOW!" will also highlight an awesome science education tool each week.



Credit: University of Arizona.

Ewen Whitaker, 1922–2016

Ewen Whitaker, the last of the pre-Apollo selenographers and the last original member of the University of Arizona's Lunar and Planetary Laboratory, died on October 11 at the age of 94.

Whitaker was a British-born astronomer who during World War II was engaged in quality control — using ultraviolet spectrographic analysis — of the lead sheathing of hollow cables strung under the English Channel as part of the secret Project PLUTO (Pipe Line Under The Ocean) to supply gasoline to Allied military vehicles in France. After the war, he obtained a position at the Royal Greenwich Observatory working on the ultraviolet spectra of stars, but soon became interested in lunar studies.

After meeting Dr. Gerard P. Kuiper, Director of the Yerkes Observatory in Wisconsin, at an International Astronomical Union (IAU) meeting in Dublin in 1955, he was invited to join Kuiper's fledgling Lunar Project at Yerkes to work on producing a high-quality photographic atlas of the Moon. The dawn of the Space Age with the launch of the Russian Sputnik 1 soon put the Lunar Project in NASA's limelight.

In 1960, Whitaker followed Kuiper to the University of Arizona where the small Lunar Project evolved into the Lunar and Planetary Laboratory (LPL). When President John F. Kennedy announced in 1961 that America would land on the Moon by the end of the decade, lunar mapping became critical to that effort and the LPL grew exponentially. The resulting Photographic Lunar Atlas, Orthographic Atlas of the Moon (giving accurate positions on the lunar surface), and Rectified Lunar Atlas (giving astronaut-eye views of the whole lunar nearside) proved to be invaluable for the planning and operational stages of later spacecraft missions to the Moon. Whitaker was involved with several NASA missions, including successfully locating the landing site of Surveyor 3. This was used to set the landing site for the Apollo 12 mission, whose astronauts visited the Surveyor lander.

Whitaker was considered by some to be the world's leading expert on lunar mapping and nomenclature, and his work made it possible to select sites where the Apollo astronauts were able to land safely and explore the lunar surface. He was also active in the IAU's Task Group for Lunar Nomenclature, and in 1999 published a book on the history of lunar mapping and nomenclature, entitled *Mapping and Naming the Moon.*

Whitaker retired from the LPL in 1978, becoming a research scientist emeritus. He resided in Tucson, Arizona, until his death. Current LPL Director Tim Swindle called Whitaker "our remaining link to the founding of the lab and very much a part of its history," adding that Whitaker was "gracious, he was lovable, and in the 1960s, he knew more about the Moon than any person in history."

John Glenn, 1921–2016

John Herschel Glenn Jr. was an American aviator, engineer, astronaut, and U.S. Senator from Ohio. In 1962, he became the first American to orbit Earth, circling three times. Before joining NASA, he was a distinguished fighter pilot in both World War II and Korea, with six Distinguished Flying Crosses and eighteen clusters to the Air Medal. Glenn was born in Cambridge, Ohio, and was raised in nearby New Concord. After graduating from New Concord High School in 1939, he studied Engineering at Muskingum College. He earned a private pilot license for credit in a physics course in 1941. Glenn did not complete his senior year in residence or take a proficiency exam, both of which were requirements of the school for the Bachelor of Science degree. The school later granted Glenn his degree in 1962, after his Mercury space flight.

After a successful military career in both the U.S. Army and Marine Corps, Glenn became interested in space. In 1958, the newly formed NASA began a recruiting program for astronauts, and Glenn just barely met the requirements. He was close to the age cutoff of 40 and also lacked the required science-based degree at the time. Glenn was on a list of 100 test pilots who met the minimum requirements to become an astronaut. The prospective candidates were screened, and the number of potential candidates was reduced to 32. The candidates were put through a battery of tests, including physical tests to measure stamina and psychological tests to measure maturity, alertness, and to discover what motivated the candidates. After waiting nearly two weeks for the results, Glenn received a call from the associate director of Project Mercury, Charles Donlan, notifying him that he had been selected as one of the "Mercury Seven" group of military test pilots that would become America's first astronauts. On February 20, 1962, he flew the Friendship 7 mission, becoming the first American to orbit Earth and the fifth person in space. As the first American in orbit, Glenn became a national hero, met President Kennedy, and received a ticker-tape parade in New York City, reminiscent of that given for Charles Lindbergh and other great dignitaries. However, he became "so valuable to the nation as an iconic figure," said NASA administrator Charles Bolden, that Kennedy would not "risk putting him back in space again." Glenn's fame and political attributes were noticed by the Kennedys, and he became a personal friend of the Kennedy family. On February 23, 1962, President Kennedy awarded Glenn with the NASA Distinguished Service Medal. He also received the Congressional Space Medal of Honor in 1978, was inducted into the U.S. Astronaut Hall of Fame in 1990, and received the NASA Distinguished Service Medal.

After he resigned from NASA in 1964, and retired from the Marine Corps in 1965, Glenn announced that he would run for a U.S. Senate seat from Ohio. A member of the Democratic Party, he first won election to the Senate in 1974 where he served through January 3, 1999. In 1998, while still a sitting senator, he got his chance to return to space, becoming the oldest person to fly in space and the only one to fly in both the Mercury and Space Shuttle programs as crew member of the Discovery space shuttle. He was also awarded the Presidential Medal of Freedom in 2012. Glenn was the last surviving member of the Mercury Seven.

LPI Announces Shoemaker Impact Cratering Award Recipient

The Lunar and Planetary Institute (LPI) is pleased to announce that the 2016 recipient of the Eugene M. Shoemaker Impact Cratering Award is Morgan Cox of Curtin University in Australia. Cox is conducting a microstructural analysis on zircon, xenotime, and other accessory minerals in Warton sandstone exposed in the central uplift of the Spider impact crater in Western Australia.

The Eugene M. Shoemaker Impact Cratering Award is designed to support undergraduate and graduate students, of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. Grants support the study of impact cratering processes on Earth and other bodies in the solar system, including asteroids and comets that produce impacts and the geological, chemical, or biological results of impact cratering.

This award is generously provided by the Planetary Geology Division of the Geological Society of America and administered by the LPI. It commemorates the work of Eugene (“Gene”) Shoemaker, who greatly influenced planetary sciences during the Apollo era and for several decades thereafter, including the discovery of Comet Shoemaker-Levy 9 with his wife Carolyn and colleague David Levy.

Proposals for next year’s award will be due in September 2017. Applications will be accepted beginning in July 2017. Application details can be found at *http://www.lpi.usra.edu/science/kring/Awards/Shoemaker_Award/*.

Thomas Zurbuchen Named Head of NASA Science Mission Directorate

NASA Administrator Charles Bolden named Thomas Zurbuchen as the new associate administrator for the Science Mission Directorate at the agency’s headquarters in Washington, effective October 3. Before his appointment, Zurbuchen was a professor of space science and aerospace engineering at the University of Michigan in Ann Arbor. He is also the university’s founding director of the Center for Entrepreneurship in the College of Engineering. Zurbuchen’s experience includes research in solar and heliospheric physics, experimental space research, space systems, and innovation and entrepreneurship.

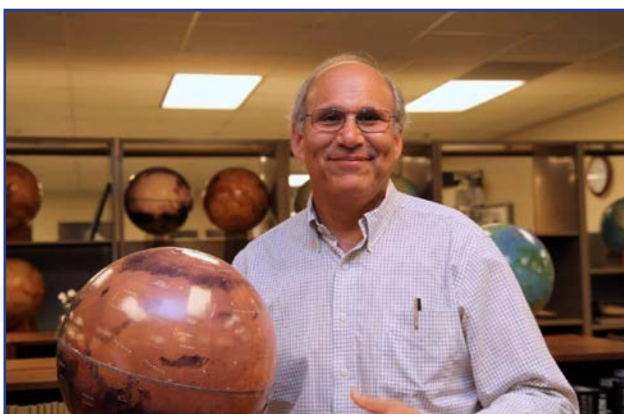
“Thomas brings a wealth of scientific research and engineering experience to the Science Mission Directorate,” Bolden said. “His diverse background and hands-on knowledge align well with NASA and our world-class team of scientists and engineers.”

During his career, Zurbuchen has authored or coauthored more than 200 articles in refereed journals on solar and heliospheric phenomena. Although he had never previously worked for NASA, Zurbuchen had connections to the agency. He has been involved with several NASA science missions, including Ulysses, the MESSENGER spacecraft to Mercury, and the Advanced Composition Explorer (ACE). He also has been part of two National Academy standing committees, as well as various science and technology definition teams for new NASA missions.

Zurbuchen earned his Ph.D. in physics and master of science degree in physics from the University of Bern in Switzerland. His honors include receiving the National Science and Technology Council Presidential Early Career for Scientists and Engineers (PECASE) Award in 2004, a NASA Group Achievement Award for the agency's Ulysses mission in 2006, and the Swiss National Science Foundation's Young Researcher Award in 1996–1997.

"It's absolutely thrilling to be embarking on this journey," Zurbuchen said. "Today, NASA is leading efforts to answer a host of important questions for humanity: Where do we come from? How did life originate? How are Earth's environments changing? There has never been a more pivotal time to solve these mysteries, and I'm looking forward to the charge."

Dr. Allan Treiman Named Associate Director of Science of the Lunar and Planetary Institute



The Universities Space Research Association has named Dr. Allan Treiman the Associate Director of Science of the Lunar and Planetary Institute (LPI) effective November 2016. Treiman will play a key role in interfacing with the local scientific community by leading the Johnson Space Center (JSC)/LPI Joint Working Group, which includes organizing astromaterials sample training to enhance the planetary community's understanding, use, and access to the planetary materials curated at NASA JSC.

"Dr. Treiman is a highly respected member of the international planetary science community, and I am very pleased to have him as my Associate Director," says LPI Director, Dr. Louise Prockter. "His knowledge and experience will prove invaluable in guiding the future scientific direction of the LPI, ensuring that the institute remains as relevant to NASA and the planetary community today as it was at its inception, 48 years ago."

Treiman studies planetary materials, particularly Moon rocks and martian meteorites. From these rocks, he teases out the early histories of the terrestrial planets, including large asteroids, emphasizing their volatiles — water, halogens, carbon, etc. His background is in chemistry, and he approaches planetary sciences from both geological and thermochemical perspectives.

Treiman's current work emphasizes Mars mineralogy (as a co-I with the CheMin instrument on the MSL rover), volatiles in the lunar crust, the origins of martian magmas, and crust-atmosphere interactions on Venus. Earlier work includes diverse topics like groundwater in Mars, as revealed by clay and carbonate minerals in martian meteorites; metamorphism in large water-rich asteroids; and water-deposited minerals on the asteroid Vesta. This research core has spun off work in other fields of planetary science. Work on the martian meteorite ALH 84001 led to studies of terrestrial analogs, the AMASE expeditions to Spitzbergen Island, and astrobiology. His work on water in martian meteorites led to investigations of possible surface manifestations of Mars water and the martian gullies.

Treiman is also active in science education. He has worked in many teacher training field experiences on volcanology, in central Oregon, Yellowstone National Park, and the Cascade Mountains; extreme environments such as Owens Valley, California; Yellowstone National Park; and general geology field work in northern Arizona and New Mexico.

Students Hone Exploration Skills at Meteor Crater Field Camp

Fifteen student participants (14 Ph.D. and 1 M.S.) from the U.S. and around the world successfully completed the fourth edition of the LPI-JSC Center for Lunar Science and Exploration's week-long Field Training and Research Program at Meteor Crater, held September 3–11, 2016, at Barringer Meteorite Crater, Arizona. The field training is designed to enhance the success of exploration of the Moon and the solar system. The goal of the camp is to introduce students to impact cratering processes and provide an opportunity to assist with a research project at the crater. Skills developed during the field camp should better prepare students for their own thesis studies in impact cratered terrains, whether they are on Earth, the Moon, Mars, or some other solar system planetary surface.

This field camp is organized under the auspices of the NASA Solar System Exploration Research Virtual Institute (formerly the NASA Lunar Science Institute), which is designed, in part, to train a new generation of explorers for the Moon and beyond. Thus far, more than 70 graduate students have been successfully trained at Meteor Crater since the inaugural session in 2010. The next planned session at Meteor Crater is anticipated for the fall of 2018.

The field camp is designed for graduate college students in geology and planetary science programs, although advanced undergraduate students are considered if they have successfully completed a summer field geology program and have a demonstrated interest in impact cratering processes.

The 2016 participants were Samuele Boschi (Lund University), Christy Caudill (University of Western Ontario), Mitali Chandnani (University of Alaska Fairbanks), Nicholas DiFrancesco (Stony Brook University), Shannon Hibbard (Temple University), Kynan Hughson (University of California Los Angeles), Mallory Kinczyk (North Carolina State University), Audrey Martin (University of Tennessee), Ellinor Martin (Lund University), Mélissa Martinot (Vrije Universiteit Amsterdam), Cameron McCarty (University of Tennessee), Kathryn Powell (Washington University), Adam Sarafian (Massachusetts Institute of Technology), Douglas Schaub (Stony Brook University), and Katherine Shirley (Stony Brook University).

For more information about the program, visit *http://www.lpi.usra.edu/exploration/mcFieldCamp/*.

Spinoff 2017 Shows How NASA Technology Makes a Difference on Earth

NASA has released its Spinoff 2017 publication, which takes a close look at 50 different companies that are using NASA technology — innovations developed by NASA, with NASA funding, or under a contract with the agency — in products from which we all benefit. Whether it's the self-driving tractor that harvests food, cameras used in car-crash safety tests, or tools making brain surgery safer, NASA technology plays a significant role in our daily lives.

"The stories published in Spinoff represent the end of a technology transfer pipeline that begins when researchers and engineers at NASA develop innovations to meet mission needs," said Stephen Jurczyk, associate administrator of the agency's Space Technology Mission Directorate in Washington. "This year's spinoffs includes products and services at work in every sector of the economy. They are innovations that make people more productive, protect the environment, and much more."

In Spinoff 2017, learn how

- NASA's work at its Jet Propulsion Laboratory on precise GPS measurements enabled John Deere to build the first widely available self-driving tractors, which now work much of the world's farmland;
- the agency's longstanding investment at its Glenn Research Center in heat pipes helped Thermacore Inc. adapt the technology to wick away dangerous heat during brain surgery;
- a high-speed, high-resolution camera designed to monitor the Orion spacecraft's landing parachutes at NASA's Johnson Space Center now is improving data in automobile crash tests.

Other highlights include laser imaging technology that discovered snow on Mars and which now helps archeologists uncover humanity's past, Earth-observing satellites that spot forest fires before they spread, and software that might help create supersonic jets we could all fly on. "NASA's ambitious mission goals require technology that pushes the envelope of what's possible," said Daniel Lockney, NASA's Technology Transfer Program executive. "And these innovations have many secondary benefits for our lives and planet."

The publication also includes a section, "Spinoffs of Tomorrow," that highlights 20 technologies ripe for commercial adaptation, including a new wing design that could make airplanes and wind turbines more efficient; an easy-to-use device that separates DNA, RNA, and proteins outside a traditional lab environment, in a developing country or in space; and a system that autonomously detects faulty wiring and reroutes around it. All are available for licensing and partnership opportunities through NASA's Technology Transfer Program.

An iPad version of Spinoff 2017, including shortened versions of the stories with multimedia and interactive features, also is available for download in the Apple iTunes store. For print and digital versions of Spinoff 2017, and for more information, visit *http://spinoff.nasa.gov*.

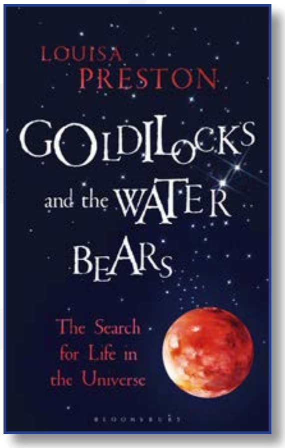
New and Noteworthy

Note: Product descriptions are taken from the publisher's website. LPI is not responsible for factual content.

BOOKS

Goldilocks and the Water Bears: The Search for Life in the Universe.

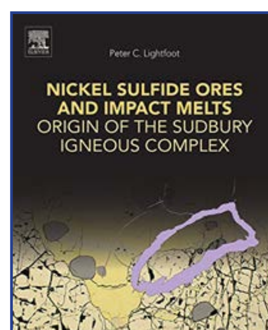
By Louisa Preston. Bloomsbury Publishing. 2016, 288 pp., Hardcover, $27.00. *www.bloomsbury.com*



Astrobiology is the study of life in the universe from its origins to its evolution into intelligent sentient beings. All life as we know it is carbon-based, reliant on sources of liquid water and energy for its survival, and as far as we are aware, exists only on Earth. Our planet occupies a unique spot in the solar system. It is just the right distance from the Sun — within the so-called Goldilocks Zone — to be not too hot nor too cold for liquid water to be stable on its surface, which, together with a protective shielding atmosphere, allowed the four-billion-year journey from a single-celled organism to an upright humanoid species. Most of primordial life, if seen today, would be classified as "alien," as it bears little resemblance to anything that currently exists. We can learn much about the possibilities of extraterrestrial life by studying the conveyer belt of life forms from our planet's history and by exploring organisms still present in harsh environments on Earth that mimic those on other worlds. These organisms, called "extremophiles," are directing our search for alien life throughout the solar system and beyond. Could we one day find Earth's toughest animal, the microscopic water bear, living under the surface of another world? *Goldilocks and the Water Bears* is an accessible introduction to the most fascinating of all the astrosciences — the quest to learn whether we are alone in the universe.

Nickel Sulfide Ores and Impact Melts: Origin of the Sudbury Igneous Complex.

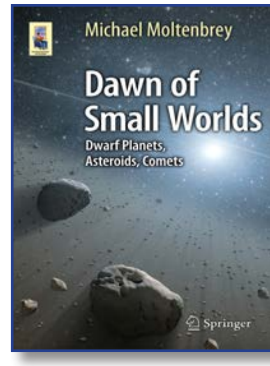
By Peter Lightfoot. Elsevier, 2016. 680 pp., Paperback, $120.00. *www.elsevier.com*



Nickel Sulfide Ores and Impact Melts: Origin of the Sudbury Igneous Complex presents a current state of understanding on the geology and ore deposits of the Sudbury Igneous Complex in Ontario, Canada. As the first complete reference on the subject, this book explores the linkage between the processes of meteorite impact, melt sheet formation, differentiation, sulfide immiscibility and metal collection, and localization of ores by magmatic and post-magmatic processes. The discovery of new ore deposits requires industry and government scientists and academic scholars to have access to the latest understanding of ore formation process models that link to the mineralization of their host rocks. The ore deposits at Sudbury are one of the world's largest ore systems, representing a classic case study that brings together very diverse datasets and ways of thinking. This book is designed to emphasize concepts that can be applied across a broad range of ore deposit types beyond Sudbury and nickel deposit geology. It is an essential resource for exploration geologists, university researchers, and government scientists, and can be used in rock and mineral analysis, remote sensing, and geophysical applications.

Dawn of Small Worlds: Dwarf Planets, Asteroids, Comets.

By Michael Moltenbrey. Springer, 2016, 273 pp., Paperback, $39.99. *www.springer.com*



This book gives a detailed introduction to the thousands and thousands of smaller bodies in the solar system. Written for interested laymen, amateur astronomers, and students, it describes the nature and origin of asteroids, dwarf planets, and comets and gives detailed information about their role in the solar system. The author reviews the history of small-world-exploration and describes past, current, and future spacecraft missions studying small worlds and presents their results. Readers will learn that small solar system worlds have a dramatically different nature and appearance than the planets. Even though research activity on small worlds has increased in the recent past, many of their properties are still in the dark and need further research.

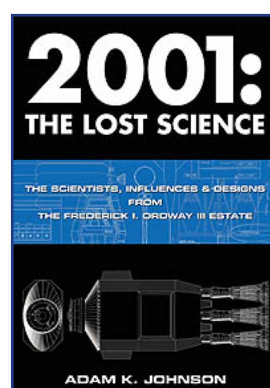
We Are All Stardust: Scientists Who Shaped Our World Talk About Their Work, Their Lives, and What They Still Want to Know.

By Stefan Klein. Workman Publishing, 2015, 288 pp., Paperback, $14.95. *www.workman.com*

When acclaimed journalist Stefan Klein sat down to talk with 18 of the world's leading scientists, he found that they are driven by, above all, curiosity. When they talk about their work, they turn to what's next, to what they still hope to discover. And they see inspiration everywhere. From the sports car that physicist Steven Weinberg says helped him on his quest for "the theory of everything," to the jazz musicians who gave psychologist Alison Gopnik new insight into raising children, they reveal how their paradigm-changing work entwines with their lives outside the lab. We hear from extraordinary natural and social scientists, including evolutionary biologist Richard Dawkins on ego and selflessness, primatologist Jane Goodall on chimpanzee behavior, neuroscientist V. S. Ramachandran on consciousness, geographer Jared Diamond on chance in history, anthropologist Sarah Hrdy on motherhood, and cosmologist Martin Rees on how "ultimately we ourselves are stardust."

2001: The Lost Science — The Scientists, Influences, and Designs from the Frederick I. Ordway III Estate.

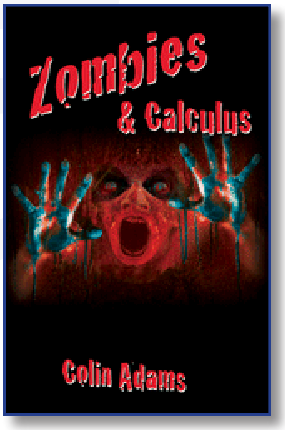
By Adam K. Johnson. Apogee Prime, 2016, 88 pp., Paperback, $49.95.
www.cgpublishing.com



In this sequel to his acclaimed book *2001: The Lost Science — The Frederick I. Ordway III Collection from the U.S. Space and Rocket Center Archives, Blueline Drawings, Images and Documents,* author and engineer Adam Johnson brings together an analysis of the complex facets of space and film history that went into the making of Stanley Kubrick's masterpiece motion picture *2001: A Space Odyssey.* This volume introduces the reader to the scientists, influences, and designs that predated Kubrick's film. Johnson also brings fans of this most influential film more of the rare blueprints, photographs, and artifacts from the collection of the late Frederick I. Ordway III.

Zombies and Calculus.

By Colin Adams. Princeton University Press. 2016, 240 pp., Paperback, $18.95. *press.princeton.edu*

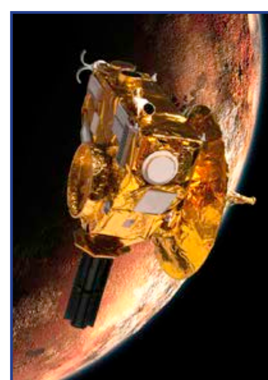


How can calculus help you survive the zombie apocalypse? Colin Adams, humor columnist for the *Mathematical Intelligencer* and one of today's most outlandish and entertaining popular math writers, demonstrates how in this zombie adventure novel. *Zombies and Calculus* is the account of Craig Williams, a math professor at a small liberal arts college in New England, who, in the middle of a calculus class, finds himself suddenly confronted by a late-arriving student whose hunger is not for knowledge. As the zombie virus spreads and civilization crumbles, Williams uses calculus to help his small band of survivors defeat the hordes of the undead. Along the way, readers learn how to avoid being eaten by taking advantage of the fact that zombies always point their tangent vector toward their target, and how to use exponential growth to determine the rate at which the virus is spreading. Williams also covers topics such as logistic growth, gravitational acceleration, predator-prey models, pursuit problems, the physics of combat, and more. With the aid of his story, you too can survive the zombie onslaught. Featuring easy-to-use appendixes that explain the book's mathematics in greater detail, *Zombies and Calculus* is suitable both for those who have only recently gotten the calculus bug, as well as for those whose disease has advanced to the multivariable stage.

SPACECRAFT MODEL KIT

New Horizons 1/24 Model Kit.

Produced by RealSpace Models. $50.00. *www.realspacemodels.com*



Launched in 2006, the New Horizons spacecraft made the first flyby of Pluto in July 2015, sending back spectacular images of the farthest object investigated at the time. It will continue into the Kuiper belt to explore more objects as time goes on. The model is 1/24 scale and made of resin. For ages 13 and up.

FOR KIDS!!!

Xtronaut: The Game of Solar System Exploration.

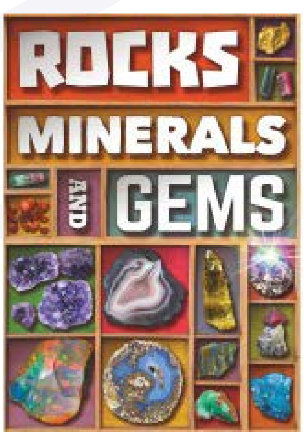
Produced by Xtronaut Enterprises, 2016. Player boards, playing and mission cards, tokens, and rulebook. $35.00. *www.xtronaut.com*

Designed by Dante Lauretta, a professor at the University of Arizona and principal investigator of the NASA OSIRIS-REx asteroid sample return mission, the game captures the challenges and fun of planning a space mission and combines real rocket science with mission planning, strategy, politics, and interactive play. Do you have what it takes to put together a space mission and race through the solar system? Identify your target and put together the right combination of rocket parts and spacecraft to achieve mission success. Watch out for other players as they confound your attempts to launch your mission by forcing you to wait out a government shutdown, swipe your hardware due to higher national priority, or cancel your mission for their own benefit. Don't worry — you will recover by receiving surplus funds, using extra parts, or even forging a mutually beneficial collaboration with another player. For ages 7 and up.

Astronaut Backpack.

Produced by Aeromax, Inc. $39.99. *www.aeromaxtoys.com*

This realistic backpack has all the right stuff to complete a junior astronaut's dream mission. This backpack can hold all your space gear — it includes a top compartment for your astronaut suit or boots, a bottom compartment for your astronaut space helmet, and side pockets for tools. A three-way harness system provides comfort and a realistic look and feel.



Rocks, Minerals and Gems.

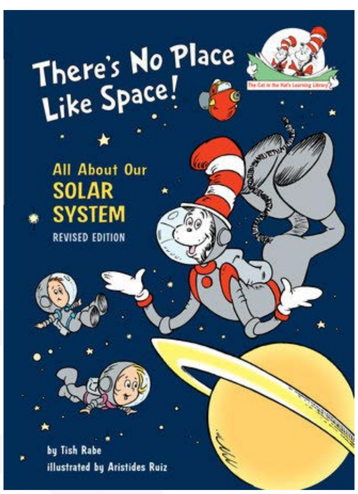
By John Farndon. Firefly Books, 2016, 120 pp., Paperback. $12.95. *www.fireflybooks.com*

This is a definitive full-color guide for young readers. It includes an introduction to rocks, minerals, and gems and how they form, how and where to look for them, how to identify rocks and minerals, and everything there is to know about building a collection. Packed with fun facts and practical activities, the book features high-definition color photography and data keys that show noteworthy qualities of each specimen in extraordinary detail. *Rocks, Minerals and Gems* shows how to read the landscape for clues and identify different rock types — from dazzling diamonds to grainy sandstone. It describes fascinating facts, and data boxes provide short facts to help with quick identification. Earth's most precious rocks, minerals, and gems can be anywhere and everywhere in the world — from riverbeds to beaches, cliff faces to fields. The only equipment needed is a backpack, a smartphone, and some good walking shoes — and maybe a small bag to carry home the treasure. For ages 11–15.

Astronomy Lab for Kids: 52 Family-Friendly Activities.

By Michelle Nichols. Quarry Books, 2016, 144 pp., Paperback. $24.99. *www.quartoknows.com*

It can be hard to explain and understand what lies beyond what you see in the beautiful night sky. *Astronomy Lab for Kids* teaches children the basics of outer space in 52 lessons that can be done with everyday items from around your house. Mini astronomers will learn about things such as the size and scale of planets using sandwich cookies and tennis balls, how to measure the speed of light with a flat candy bar and a microwave, how to make a simple telescope with magnifying glasses, and so much more! Children of all ages and experience levels can be guided by adults and will enjoy these engaging exercises. For ages 6 and up.



There's No Place Like Space! All About Our Solar System, Revised Edition.

By Tish Rabe. Random House Books for Young Readers, 2009, 48 pp., Hardcover. $9.99. *www.penguinrandomhouse.com*

A classic revisited. *Au revoir*, Pluto! In this newly revised, bestselling backlist title, beginning readers and budding astronomers are launched on a wild trip to visit the now *eight* planets in our solar system (per the International Astronomical Union's 2006 decision to downgrade Pluto from a planet to a dwarf planet), along with the Cat in the Hat, Thing One, Thing Two, Dick, and Sally. It's a reading adventure that's out of this world! For ages 4–8.

Calendar 2017

For the latest version of the meeting calendar, visit http://www.hou.usra.edu/meetings/calendar.

January

3–7 **229th American Astronomical Society Meeting,** Grapevine, Texas. *http://aas.org/meetings/aas229*

11–13 **16th Meeting of the NASA Small Bodies Assessment Group (SBAG),** Tucson, Arizona. *http://www.lpi.usra.edu/sbag/*

11–13 **Dust, Atmosphere, and Plasma Environment of the Moon and Small Bodies (DAP 2017),** Boulder, Colorado. *http://impact.colorado.edu/dap_meeting.html*

16–18 **ALMA Band 1 Science Workshop,** Taipei, Taiwan. *http://events.asiaa.sinica.edu.tw/workshop/20170116/*

17–20 **Sixth International Workshop on the Mars Atmosphere: Modelling and Observations,** Granada, Spain. *http://www-mars.lmd.jussieu.fr/granada2017*

23–27 **Ices in the Solar System,** Madrid, Spain. *http://www.cosmos.esa.int/web/ices-in-the-solar-system/home*

31–Feb 3 **21st International Microlensing Conference,** Pasadena, California. *http://nexsci.caltech.edu/conferences/2017/microlensing/*

February

20–24 **Formation of the Solar System and the Origin of Life,** Leiden, The Netherlands. *http://www.lorentzcenter.nl/lc/web/2017/864/info.php3?wsid=864&venue=Oort*

22–24 **Frontiers in Theoretical and Applied Physics,** Sharjah, United Arab Emirates. *http://www.aus.edu/ftaps2017*

27–28 **Workshop on Chondrules and the Protoplanetary Disk,** London, United Kingdom. *http://www.hou.usra.edu/meetings/chondrules2017/*

27–Mar 1 **Planetary Science Vision 2050 Workshop,** Washington, DC. *http://www.hou.usra.edu/meetings/V2050/*

March

5–10 **Planetary Systems Beyond the Main Sequence II,** Technion, Israel. *http://planets-beyond-ms.weebly.com*

6–10 **Diversity of Planetary Circulation Regimes,** Les Houches, France. *http://leshouchesplanets2017.zmaw.de/index.php?id=3780*

8–10 **7th International Workshop on Occultation and Eclipse,** Hafshejan & Shahr-e Kord, Iran. *http://iota-me.com/oe.php*

15–17 **UKEXOM2017: UK Exoplanet Community Meeting,** St. Andrews, Scotland. *https://ukexo2017.sciencesconf.org*

19–25 **The 16th Electromagnetic and Light Scattering Conference,** College Park, Maryland. *http://www.giss.nasa.gov/staff/mmishchenko/ELS-XVI*

20–24 **48th Lunar and Planetary Science Conference,** The Woodlands, Texas. *http://www.hou.usra.edu/meetings/lpsc2017/*

20–24 **Science with the Hubble and James Webb Telescopes V,** Venice, Italy. *http://www.stsci.edu/institute/conference/hst5*

20–24 **Astrochemistry VII — Through the Cosmos from Galaxies to Planets,** Purto Varas, Chile. *https://www.iau.org/science/meetings/future/symposia/1187/*

26–31 **Formation and Dynamical Evolution of Exoplanets,** Aspen, Colorado. *http://ciera.northwestern.edu/Aspen2017.php*

April

3–5 **Titan Through Time 4 Workshop,** Greenbelt, Maryland. *http://ssed.gsfc.nasa.gov/titanworkshop/*

10–14 **Asteroids, Comets, Meteors 2017 (ACM 2017),** Montevideo, Uruguay. *http://acm2017.uy*

24–26 **Exoplanet Science with Small Telescopes: Precise Radial Velocities,** Philadelphia, Pennsylvania. *http://web.sas.upenn.edu/smalltrv/*

24–28 **Astrometry and Astrophysics in the Gaia Sky,** Nice, France. *https://iaus330.sciencesconf.org/*

24–28 **Astrobiology Science Conference,** Mesa, Arizona. *http://www.hou.usra.edu/meetings/abscicon2017/*

May

2–3 **European Lunar Symposium — 2017,** Munster Germany. *https://els2017.arc.nasa.gov/*

4–5 **New Views of the Moon — Europe,** Munster, Germany. *http://www.hou.usra.edu/meetings/newviews2017/*

7–12 **Radio Exploration of Planetary Habitability,** Palm Springs, California. *https://aas.org/meetings/aastcs/radiohab*

9–11 **Chondrules as Astrophysical Objects Conference,** Vancouver, British Columbia. *http://chondrules.phas.ubc.ca/*

15–19 **International Conference on Mars Aeronomy,** Boulder, Colorado. *http://lasp.colorado.edu/meetings/marsaeronomy2017/index.php*

15–19 **Fifth IAA Planetary Defense Conference,** Tokyo, Japan. *http://pdc.iaaweb.org*

15–19 **The Applied Space Environments Conference (ASCE 2017),** Huntsville, Alabama. *http://sti.usra.edu/asec2017/*

16–19 **Fifth International Planetary Dunes Workshop,** St. George, Utah. *http://www.hou.usra.edu/meetings/dunes2017/*

22–26 **Astrophysics of Exoplanetary Atmospheres,** Vietri sul Mare, Italy. *http://www.mpia.de/~mancini/ases2*

22–26 **Japan Geoscience Union Meeting,** Chiba, Japan. *http://www.jpgu.org/meeting_e2016/greeting.html*

29–Jun 3 **International Interdisciplinary Workshop on "Accretion, Differentiation, and Early Evolution of the Terrestrial Planets,"** Nice, France. *https://www-n.oca.eu/morby/Accrete.html*

29–Jun 23 **Protoplanetary Disks and Planet Formation and Evolution,** Garching, Germany. *http://www.munich-iapp.de/scientific-programme/programmes-2017/protoplanetary-disks/*

30–31 **iCubeSat 2017 — The 6th Interplanetary CubeSat Workshop,** Cambridge, United Kingdom. *http://www.iCubeSat.org*

June

11–15 **2017 American Astronomical Society Division of Dynamical Astronomy Meeting (AAS-DDA),** London, United Kingdom. *https://dda.aas.org/meetings/2017*

12–15 **3rd Planetary Data Workshop,** Flagstaff, Arizona. *http://www.hou.usra.edu/meetings/planetdata2017/*

13–15 **Meeting of the NASA Small Bodies Assessment Group (SBAG),** Greenbelt, Maryland. *http://www.lpi.usra.edu/sbag/*

13–15 **Dust in the Atmosphere of Mars and Its Impact on the Human Exploration of Mars,** Houston, Texas. *http://www.hou.usra.edu/meetings/marsdust2017/*

18–23 **Origins of Solar Systems: Making a Habitable Planet,** South Hadley, Massachusetts. *https://www.grc.org/programs.aspx?id=12346*

24–Jul 2 **Workshop on Shock Metamorphism in Terrestrial and Extra-Terrestrial Rocks,** Perth, Australia. *http://www.sserviaustralia.org/event/shock-metamorphism-in-terrestrial-and-extra-terrestrial-rocks/*

July

3–7 **13th Asian-Pacific Regional IAU Meeting (APRIM 2017),** Taipei, Taiwan. *http://www.aprim2017.tw/*

3–8 **International Symposium on Education in Astronomy and Astrobiology (ISE2A),** Utrecht, The Netherdlands. *http://ise2a.uu.nl*

16–21 **XVIIIth International Conference on the Origin of Life,** San Diego, California. *http://www.hou.usra.edu/meetings/issol2017/*

24–28 **CHEOPS Science Workshop,** Schloss Seggau, Austria. *http://geco.oeaw.ac.at/links_CHEOPSsw17.html*

August

7–13 **The Third Workshop on Extremely Precise Radial Velocities (EPRV III),** University Park, Pennsylvania. *http://exoplanets.psu.edu/*

15–18 **Accretion: Building New Worlds,** Houston, Texas. *http://www.hou.usra.edu/meetings/accretion2017/*

September

5–7 **Exoplanetary Systems in the PLATO Era,** Coventry, United Kingdom. *http://www2.warwick.ac.uk/fac/sci/physics/research/astro/research/plato_mission_conference2017/*

18–20 **4th Global Applied Microbiology Summit,** Dallas, Texas. *http://appliedmicrobiology.cmesociety.com/*