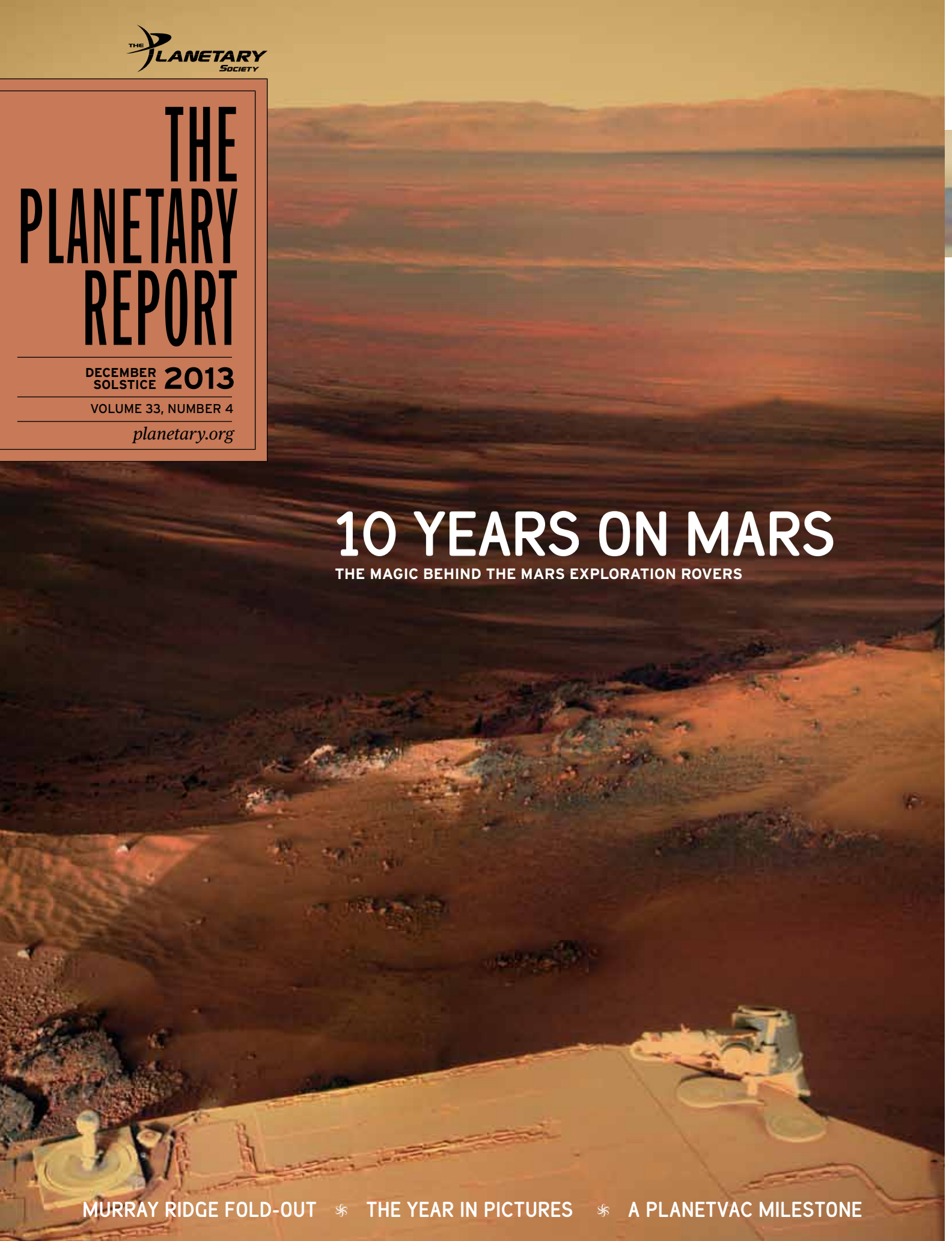
THE PLANETARY SOCIETY

THE PLANETARY REPORT

DECEMBER SOLSTICE 2013

VOLUME 33, NUMBER 4

planetary.org



10 YEARS ON MARS

THE MAGIC BEHIND THE MARS EXPLORATION ROVERS

MURRAY RIDGE FOLD-OUT ✻ THE YEAR IN PICTURES ✻ A PLANETVAC MILESTONE

ON THE COVER: In this sunset view from sol 2847 (January 27, 2012), *Opportunity* gazed backward toward the distant peaks of Endeavour crater's far rim. The setting Sun casts very long shadows from the low-standing ridge on which the rover stands. In fact, *Opportunity*'s own shadow is visible as a blurry speck atop the ridge's shadow. To read more about how this image was processed, go to bit.ly/1i3qgl5. *Image: NASA/JPL/Cornell University/Arizona State University/Don Davis*

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The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 85 South Grand Avenue, Pasadena, CA 91105-1602, 626-793-5100. It is available to members of The Planetary Society. Annual dues in the United States are $37 (U.S. dollars); in Canada, $40 (Canadian dollars). Dues in other countries are $57 (U.S. dollars). Printed in USA. Third-class postage at Pasadena, California, and at an additional mailing office. Canada Post Agreement Number 87424.

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Murray Ridge

In October 2013, *Opportunity* paused at the base of Solander Point and focused its stereo panoramic camera eyes. Murray Ridge filled the frame and seemed to touch the sky. The ridge (shown here in false color) rises majestically, and is named for Planetary Society Cofounder Bruce Murray, who will always be affectionately known by many as the Admiral of the Solar System. There's a beautiful nuance or two in the christening.

Murray was among the first generation of cosmic explorers and a pioneer in planetary imaging and comparative planetology. He later served as director of the Jet Propulsion Laboratory (JPL) during the golden age of planetary exploration, and as a professor at Caltech, where he ushered hundreds of students into the fields of planetary science and geology.

He drew much of his exploration inspiration from Captain James Cook, the British explorer who sailed the seas of Earth in search of new lands in the mid-1700s. The MER team named Endeavour Crater after *HMS Endeavour*, the British Navy research vessel that Cook helmed on his first voyage of discovery in the Pacific Ocean. *HMS Endeavour* took Cook to parts then unknown; likewise, Endeavour Crater is the MERs' "ship," carrying the mission back in geologic time to environs unknown.

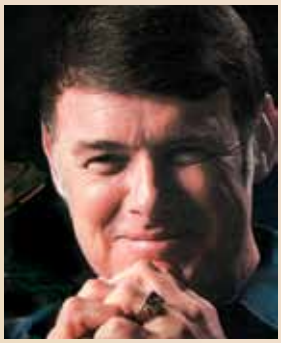
Murray worked out the geologic history of Mars using photographs taken by *Mariner 4* in 1965, an "experiment" for which he lobbied hard. Now *Opportunity* is in large part using imaging to help us understand the geologic history of this part of the Red Planet, enabling scientists to make the first true comparisons of ancient Martian and Earth environments.

It is a tribute as endearing as it is fitting, for here, on and around Murray Ridge, *Opportunity* will write the next chapter in the legendary book of the MERs. Before the Martian winter takes hold, the rover will follow Murray Ridge to the south, where orbital data indicate there is a pot of scientific gold waiting to be found: clay minerals and more evidence of past flowing water—more of what the MERs came to Mars to find a decade ago.

—A.J.S. Rayl

Image: NASA/JPL-Caltech/Cornell/ASU

Murray Image Library



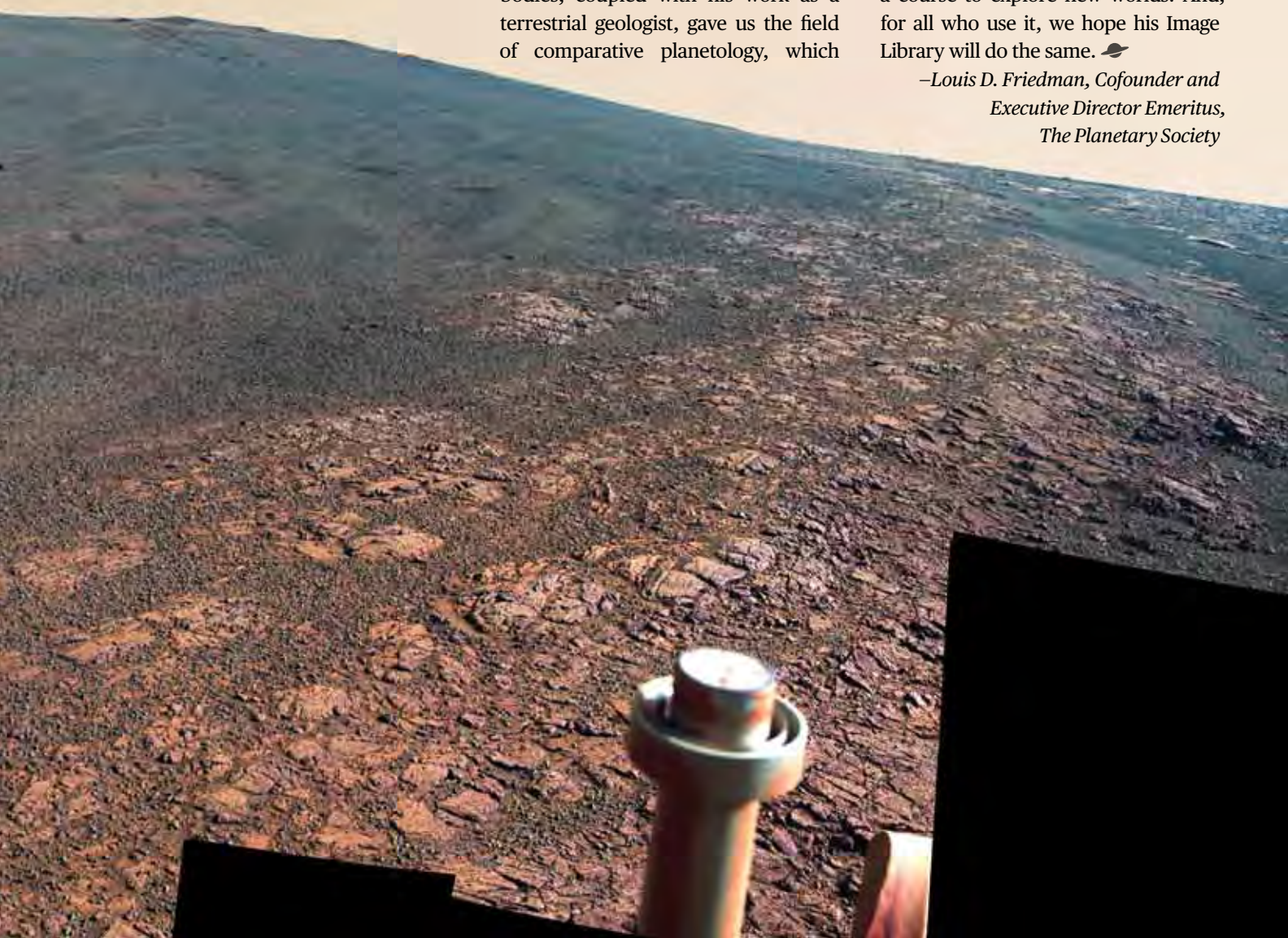
THE PLANETARY SOCIETY's Bruce Murray Space Image Library is an outstanding memorial to Bruce and a tribute to his legacy. Perhaps more than anyone, he was responsible for the development of imaging as a key part of planetary exploration. The spacecraft images we now have–close looks at all the planets, scores of moons, as well as asteroids and comets–have profoundly altered the way we view our own world.

Bruce literally wrote the textbook on terrestrial planets (*Earthlike Planets: Surfaces of Mercury, Venus, Earth, Moon, Mars* with Michael C. Malin and Ronald Greeley, 1981). His analysis of images from these bodies, coupled with his work as a terrestrial geologist, gave us the field of comparative planetology, which has helped us understand our own planet as one of many.

These spectacular images of other worlds–ancient rivers on Mars; storms on Jupiter, Saturn, and Neptune; ice cracks on Europa; lakes on Titan; volcanoes on Io; and much more–have captured the hearts and imaginations of the public, and created a yearning for further planetary adventures.

Bruce said he wanted "to be remembered as an explorer and as a teacher." The Space Image Library will honor that wish. Together with Carl Sagan, Bruce recognized the importance and significance of planetary exploration. As they joined together to create The Planetary Society, they set us on a course to explore new worlds. And, for all who use it, we hope his Image Library will do the same.

–Louis D. Friedman, Cofounder and Executive Director Emeritus, The Planetary Society



BILL NYE *is chief executive officer of The Planetary Society.*

A Sharpened Focus

Your Society is Moving Forward

THE WINTER SOLSTICE in the Northern Hemisphere has come, giving us a chance to reflect on our progress these last few months. Thanks to you, our Society is growing in numbers and in influence. We have a great many new members: welcome and thanks for your support.

In the last few months we've refined our vision and our mission and crafted new statements to express them. Our vision is that one day we want everyone everywhere to "know the cosmos and our place within it."

Although I've been a Member of our Society for 33 years (tempus fugit), I would be the first to admit that our mission has always been broad and, well, a mouthful. I often explained that we "seek other worlds and other life." For me, our mission has always been to explore and see where the journey leads.

Over the last few months, we honed this feeling into a mission statement that I feel really expresses what we're all driving at: "Empowering citizens of Earth to advance space science and exploration." These straightforward sentences are helping my staff and me to home in on what's important for us to work on. To advance space science, we need science missions flying in space. In short, we can tell people that we advance science in space as we explore. It's optimistic; it's our mission.

HONORING BRUCE MURRAY

In November, a remarkable memorial was held at Caltech in honor of our late co-founder, colleague, and dear friend Bruce Murray. Several of us spoke, including Bruce's longtime friend and Planetary Society Cofounder Lou Friedman, Planetary Society President Jim Bell, Jet Propulsion Laboratory Director Charles Elachi, and me. As you may know, Bruce is credited as the man who insisted that a camera be carried onboard spacecraft, starting with *Mariner 4* in 1964.

Because of Bruce's insight and vision with regard to images, we have created the Bruce Murray Space Image Library (see page 3). I think of Bruce every day. It was an honor to work with him. He changed the world.

CARL SAGAN'S LEGACY

November was also the month when Carl Sagan and his widow Ann Druyan had their writings and notes archived in the United States Library of Congress. There was a wonderful ceremony held in the library's venerable main building in Washington, D.C. The event was hosted by Seth MacFarlane, who hosted the Oscars and came to fame through his animated television series *Family Guy*. He has become close with the Sagan family, as he is a science enthusiast and an executive producer of the twenty-first century version of the television series *Cosmos*, which will have a great many references to Carl and will be hosted by our own Neil deGrasse Tyson.

There were many remembrances at the ceremony. I pointed out that virtually every climate model in use today has its roots in the computer model that Carl helped create for analyzing Earth's climate after a war of nuclear weapons, the eerily named "nuclear winter." The physical and chemical processes he identified in the early 1980s are still the significant parameters assessed today in any climate analysis.

I also mentioned the meeting I had with him at my tenth college reunion, where he changed my life directly. After listening to my description of my television work and plans for the future, he advised me to focus my television show on pure science, because kids "resonate to pure science." And so, my

career took a new, sharper focus, which led to a great many successes. Thank you again, Professor Sagan.

While we're talking about transition, I am delighted to announce that we have another new Board member: Fillmore ("Fill") Wood has joined us. He is a space enthusiast, a lawyer, and a person who understands the nonprofit world and the challenges of sustaining our organization while we do good work now and in the future. Lon Levin and Wally Hooser have taken new positions as treasurer and secretary; and Jim Bell and Heidi Hammel have signed on for another term as our Society's president and vice president. Thank you, all!

LIGHTSAIL

On another note, I am delighted to share with you some very good news: we are getting much closer to flying our first *LightSail®* spacecraft. The Board of Directors and I agree; our LightSail program is the most ambitious project we've ever undertaken. Because our founders felt The Planetary Society works best when it does not accept substantial funding from aerospace corporations or space agencies, the LightSail project really stretched us. When I say or write "us", I am referring to you. You built our *LightSail*s, and you are going to see them fly. Keep an eye out for more exciting news.

With *LightSail*s, humankind will have harnessed the energy of the Sun in an innovative yet straightforward fashion, and in the vacuum of space. Thank you very much for your strong and steadfast support.

LAUNCH SUCCESS!

As I write, I am still riding high after witnessing the completely successful, textbook-perfect launch of NASA's *Mars Atmosphere and Volatile EvolutioN (MAVEN)* spacecraft. It is on its way to Mars and it's taking the most direct route we can manage. It was quite a sight to see it launch, poke through a layer of clouds, streak through the blue for a few moments, then penetrate another cloud deck, another blue path, then another cloud, until it completely disappeared. *MAVEN* will help us assess what happened to the climate of Mars. It will help us know how we fit in here in our solar system.

The Indian Space Research Organization's *Mangalyaan* spacecraft has also begun its trip to Mars. It's a big step for our Indian colleagues, and an important step in international cooperation, which no doubt is the future of space. The two space agencies will be exchanging data about Mars and its environment. We'll learn how to work together to lower the cost of our missions to our neighboring worlds, and how to improve the exploration and science returns we reap from them. For example, think about how much more likely an asteroid-deflecting mission will become, and how much lower the cost will be, when we have multiple agencies watching the skies and working together to save the planet for humankind. *Mangalyaan* and *MAVEN* are products of one species. For me, it's an inspirational connection.

Finally, my friends, we have a sharpened focus at The Planetary Society today. Our political advocacy is sophisticated and accurately targeted. Our projects are bearing fruit. I can't get over how many strangers mention the great work of our journalists, our bloggers. The future is looking up and out, farther and deeper into space. Together, we can learn more about the universe, and together we can change the world.

Bill Nye

ABOVE *It was a picture-perfect launch on a beautiful Florida day. As an Atlas 5 rocket carrying NASA's* MAVEN *spacecraft blasted off from Cape Canaveral on November 18, 2013, this flock of great egrets took to the skies as well.*

Photo: Bill Engalls, NASA

HAPPENING ON PLANETARY RADIO

planetary.org/radio

ON THE ROAD

THE AMERICAN GEOPHYSICAL UNION

Emily Lakdawalla and Casey Dreier report from the AGU conference in San Francisco, and Bill congratulates China on *Chang'e 3*'s successful landing. bit.ly/planetary-2013-12-16

COMET ISON: MUCH MORE THAN A MEMORY

Maybe it wasn't "the comet of the century," but ISON left a significant scientific legacy, according to Karl Battams of NASA's Comet ISON Observing Campaign. bit.ly/planetary-2013-12-09

ALYSSA RHODEN AND THE RISE OF THE EUROPA UNDERGROUND

Alyssa Rhoden wants help launching a Europa mission. bit.ly/planetary-2013-11-25

TEN YEARS A-ROVING

What a long, wonderful trip it has been for *Spirit* and *Opportunity*, the Mars Exploration Rovers. Planetary Society journalist A.J.S. Rayl has followed the mission since it began. bit.ly/planetary-2013-12-23

AMY MAINZER, ASTEROID HUNTER

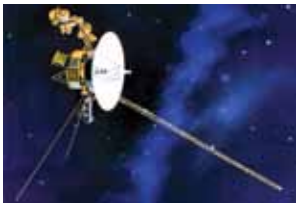
Take a spacecraft that can no longer survey the realm of galaxies, and repurpose it to discover thousands of much nearer asteroids and comets. Amazing! JPL's Amy Mainzer discusses. bit.ly/planetary-2013-12-30

Find these shows and our entire archive of *Planetary Radio* at *planetary.org/radio*!

ON *PLANETARY.ORG*

MEDIA

MOONRISE REVISITED Andy Chaikin shows us a forensic recreation of the famous photograph from *Apollo 8*. bit.ly/planetary-2013-12-19



LOOKING TO 2014

Emily Lakdawalla looks forward to all the missions that will come in 2014. bit.ly/planetary-2013-12-31

BOOKS

SPACE BOOKS! Emily reviews several new books on space specifically for kids. bit.ly/planetary-2013-11-13

MEDIA

GOOD MORNING, MOON A new video for Marian Call's astronaut wakeup song, "Good Morning Moon!" bit.ly/planetary-2013-10-21

MARS MISSION FAMILY PORTRAIT

Jason Davis updated his graphic showing every spacecraft that has been sent to Mars. bit.ly/planetary-2013-12-18

OPINION

THE NEW SPACE RACE

Planetary Society cofounder Louis Friedman shares a *Los Angeles Times* op-ed piece on the changing face of international cooperation. bit.ly/planetary-2013-12-13

GRAND CANYON VS. MARS

Incredible photos of special conditions creating mists and clouds on two different worlds. bit.ly/planetary-2013-12-10

ART & SCIENCE

A 1971 MARS GLOBE

Space artist Don Davis recalls how he painted a globe of Mars using data from *Mariner 4*, *6*, and *7*. bit.ly/planetary-2013-11-29

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.

THE YEAR IN PICTURES

THIS YEAR THE SUN reached the peak of its 11-year activity cycle, and spacecraft activity across the solar system is also at a historic maximum. Robots continued to explore Mercury, Venus, the Moon, Mars, Saturn, and the very edge of the heliosphere, while others cruised toward future encounters with asteroids, comets, Jupiter, and Pluto. We unexpectedly lost one explorer, *Deep Impact*, but we gained four new ones: NASA's *Lunar Atmosphere and Dust Environment Explorer (LADEE)* and *Mars Atmosphere and Volatile EvolutioN (MAVEN)*; India's *Mars Orbiter Mission*; and China's *Chang'e 3* lunar lander.

Closer to home, great strides in private space flight were made this year, with successful launches of *Dragon* and *Cygnus* capsules to the International Space Station, and the first powered flight for Virgin Galactic's *SpaceShipTwo* suborbital vehicle. Humans in space made headlines, too: Chinese astronauts broadcast lessons to millions of school kids on Earth from their orbiting space station, while a Canadian astronaut became a sensation on the Web with his music videos shot in orbit. Not everything returned to Earth from space was a good thing, though. The Chelyabinsk super bolide warned us of the danger posed to Earth by undiscovered near-Earth asteroids.

The following pages contain just a few of the images that mark significant events of 2013. They cover only January through October; please visit **planetary.org/yip** for a link to an addendum of pictures from the year's final months.

BELOW *Two years after its launch, NASA's* Juno *spacecraft swung past Earth on October 9, getting a gravity assist on its way to Jupiter.* Juno *took advantage of the opportunity to test out several science instruments, as well as JunoCam, a camera included on the spacecraft for the sole purpose of taking pretty pictures of Jupiter for public outreach. The JunoCam team put their raw data on the Web for enthusiasts to process, and this image is one result. It is just a hint of the amazing imagery to come from Jupiter.* Juno *will enter orbit on July 5, 2016.*

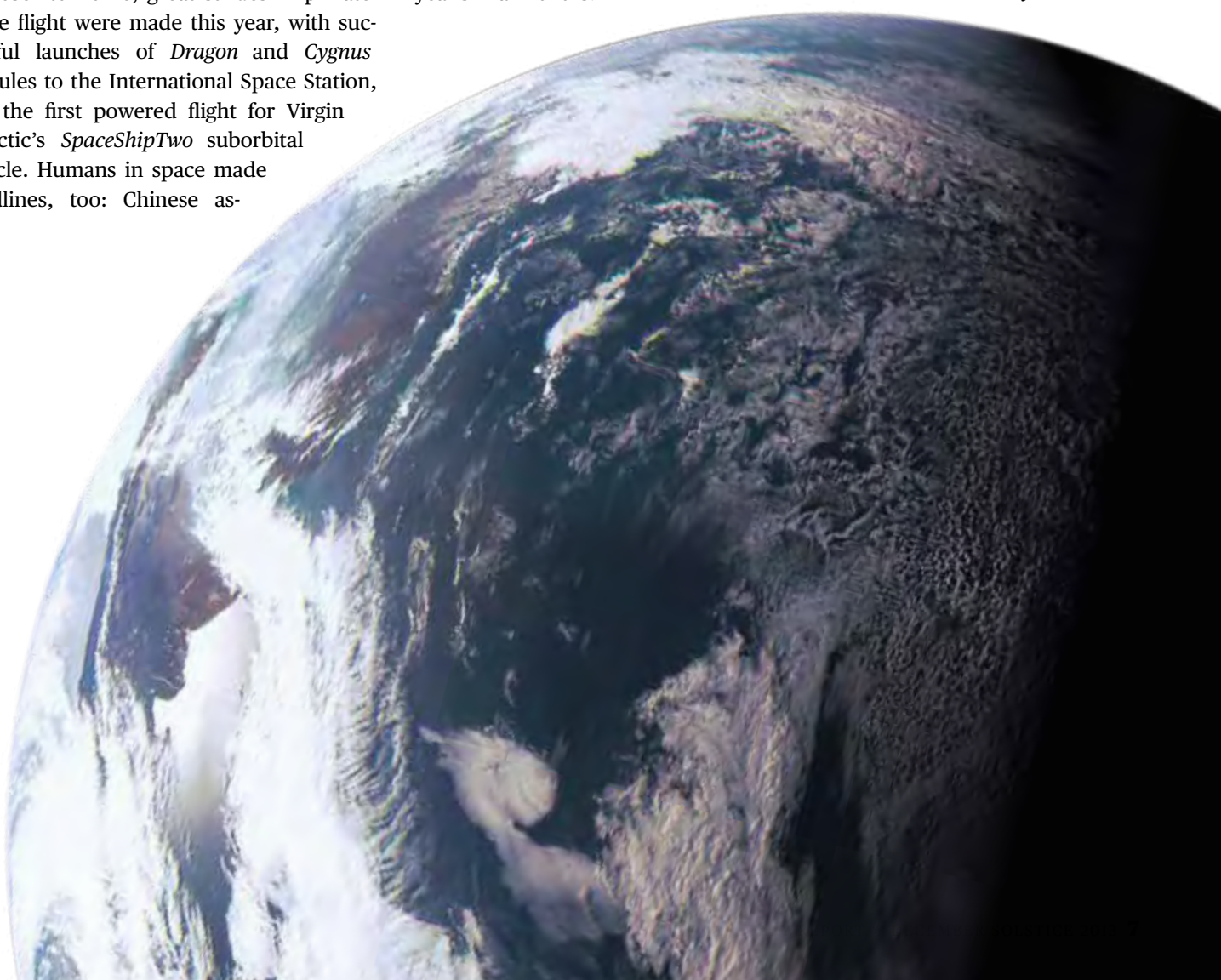
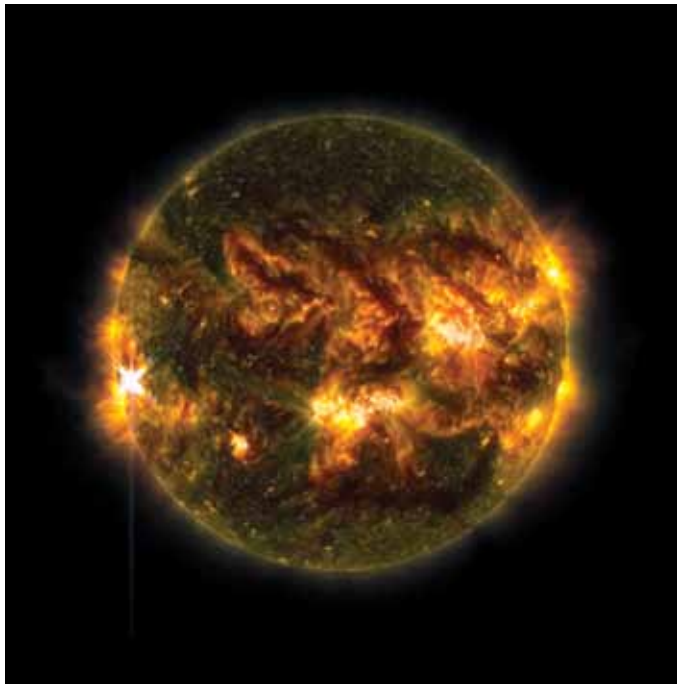
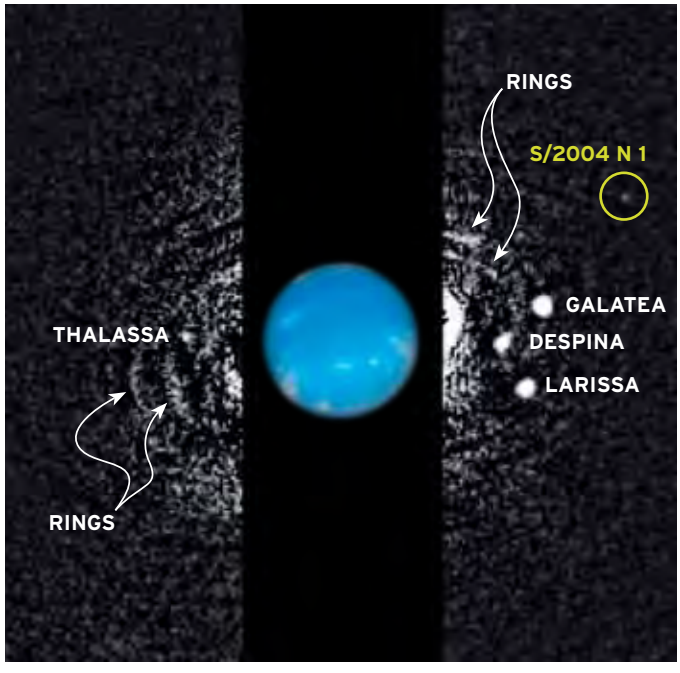


Image: NASA/JPL/MSSS/Gerald Eichstädt



ABOVE *In 2013 the Sun reached the maximum of its 11-year cycle of activity. It was a relatively quiet maximum compared to past ones, but there were two large groups of X-class solar flares (the most powerful in the solar flare classification scheme); one occurred in May, and one in October. The flare pictured here occurred on October 25.*

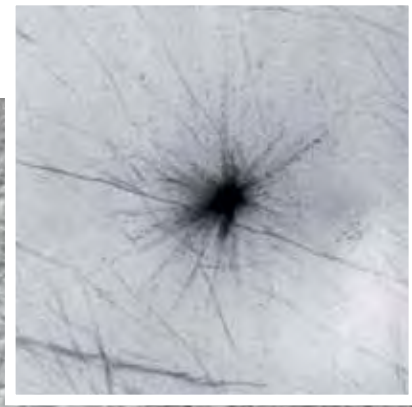


LEFT *It's not common to discover a new moon among the orderly orbits of regular satellite systems. The SETI Institute's Mark Showalter achieved that this year, using new image processing techniques to uncover the presence of S/2004 N1 in nine-year-old Neptune data from the Hubble Space Telescope. The moon is probably only 15 or 20 kilometers (about 9 or 12 miles) across and is too small and dim to be visible in archival* Voyager *images.*

Images: Sun: NASA/GSFC/Emily Lakdawalla; Neptune: NASA/ESA/SETI Institute

THIS PAGE *Most deep-space missions are now operating far beyond their initially planned lifetimes. For both* MESSENGER *and* Mars Reconnaissance Orbiter*, that extended time has allowed them to re-examine particularly intriguing spots. At Mercury,* MESSENGER *is following up to discoveries of enigmatic features called "hollows," which are often found within craters. The photo at right, taken on July 29, is a high-resolution targeted observation of de Graft impact crater, which is 68 kilometers (42 miles) in diameter. The browns, oranges, and blues identify differences in the composition of rocks exposed in the crater's rim and peak.*

Meanwhile, repeat imaging by Mars Reconnaissance Orbiter*'s Context Camera has identified more than 200 craters that have appeared on Mars in the time we have been photographing it from orbit. Scientists use the High Resolution Imaging Science Experiment (HiRISE) camera to obtain higher-resolution views (below and inset). In a dozen of these fresh craters, HiRISE has spotted a brilliant blue-white spot at the center: fresh, nearly pure ice that had been lying just below the surface before the impact. Until now, all such ice-centered craters had been discovered in the northern hemisphere. The photo at bottom is the first to show fresh ice exposed in a southern hemisphere crater, located at 71 degrees south latitude.*



Images: Top: NASA/JPL/CIW; bottom and inset: NASA/JPL/UA

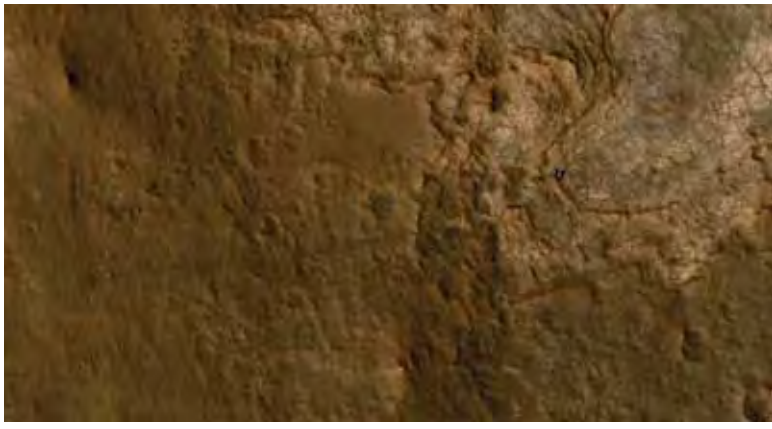
LEFT AND BELOW *Early in the morning of February 15, an industrial town in Russia's Ural mountains received a rude reminder that Earth orbits in a cosmic shooting gallery. The brilliant flare of a meteor lit up the predawn sky like daylight, and left a doublet of cloudy trails in its wake. A few minutes later, the shock wave from its passage reached the ground, shattering windows, damaging more than 7,000 buildings and injuring at least 2,000 people with flying glass. The asteroid that caused the damage was likely about 20 meters in diameter, too small to be seen by surveys, and arrived from a direction that made it undetectable before it hit. These amazing photos were captured by a nature photographer who had been outside to capture photos of the serene wintry landscape near his home.*

RIGHT, TOP AND CENTER *Two private space companies achieved major milestones this year: Virgin Galactic and Orbital Sciences Corporation. Orbital Sciences Corporation launched its* Cygnus *cargo craft on September 18. The spacecraft successfully berthed at the International Space Station on September 29, making Orbital the second private supplier after SpaceX to complete a trip to the station. In this photo, taken by astronaut Karen Nyberg on October 22,* Cygnus *has been filled with trash, detached from the station, and is about to be released to burn up in Earth's atmosphere.*

In the Mojave Desert, Virgin Galactic's SpaceShipTwo *had its first supersonic flight on April 29. Its rocket fired for 16 seconds. Virgin Galactic hopes to begin carrying paying passengers on suborbital flights late in 2014.*

RIGHT, BOTTOM *On September 6, NASA's* Lunar Atmosphere and Dust Environment Explorer (LADEE) *spacecraft departed Earth from an unusual port: Wallops Island, Virginia. It rode into Earth orbit atop Orbital Sciences Corporation's Minotaur V, a converted intercontinental ballistic missile, on the rocket's first flight. The nighttime launch was visible from a large swath of the northeastern U.S. seacoast, including Boston, Philadelphia, Washington, D.C., and, seen here, New York City.* LADEE *arrived safely at the Moon on October 6.*

Images: Marat Ametvaleev



ABOVE, TOP *Mars is red on the outside and gray on the inside.* Curiosity *drilled into a Martian mudstone on May 19, retrieving powdery rock and delivering it to the rover's analytical laboratory instrument. The analysis confirmed that this had been a habitable environment in Mars' deep past. Since then, the rover has embarked on a nine-kilometer journey to the base of Mount Sharp, a trip that will take about one Earth year.*

BOTTOM *While* Curiosity *prepared to drill,* Mars Reconnaissance Orbiter *caught a photo of the rover working at a spot called "Yellowknife Bay." This photo was taken on January 14.*

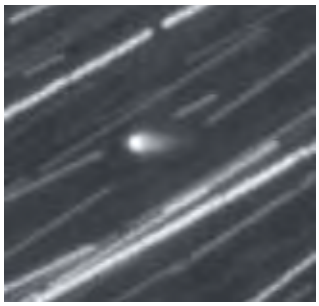
Images: Left top: NASA; Middle: MarsScientific.com and Clay Center Observatory; Bottom: Ben Cooper; Right top: NASA/JPL/MSSS; Right bottom: NASA/JPL/UA/Emily Lakdawalla

WHAT A YEAR FOR IMAGES! VOTE FOR YOUR FAVORITE!

Go to **planetary.org/yip** *and tell us which of these pictures you like best and why. Also, be sure to look at the "bonus" images that Emily added as this magazine went to press.*

Stay tuned…we'll publish the image with the most votes in the March Equinox issue of The Planetary Report. *In the meantime, visit the Bruce Murray Space Image Library at* **planetary.org/image**; *we're adding new pictures every day.*

ON THE WEB

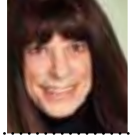


COMET ISON ARRIVED AND LEFT Deep Impact *has performed two close flybys of comets–Tempel 1, in 2005, and Hartley 2, in 2011. This year, the venerable spacecraft performed the first space-based imaging of a newly discovered comet named ISON. This was the last scientific data that* Deep Impact *returned to Earth. Contact with the spacecraft was lost in August, and the mission was declared officially over in September.*

Astrophotographer Damian Peach merged six of his photos of comet ISON, taken over an eight-week period, into this montage showing the evolution of the comet as it approached perihelion. The comet broke up during its close approach to the Sun on November 28.

GAZING ON NORTHERN POLES Cassini *arrived at Saturn when it was high summer in the southern hemisphere. In the nearly ten years since its arrival,* Cassini *has watched as the Sun crossed the equator and the ring plane, bringing light to the northern poles of the planet and its moons.* Cassini *took the photos for this mosaic from a position high above Saturn's ring plane on October 10. The northern summer sun has now lit up all of Saturn's north polar hexagon.*

Images: top: NASA/JPL/UMD; center: Damian Peach; bottom: NASA/JPL/ISS/Gordon Ugarkovic



A.J.S. RAYL *is a science journalist who focuses on space science and flight.*

The Magic of MER

Still Roving After All These Years

LEFT Spirit *and* Opportunity, *NASA's Mars Exploration Rovers (MERs)—and the team behind them—represent one of the most remarkable successes in space exploration history. "MER is a study in how to run a landed mission on Mars," sums up John Grotzinger, Mars Science Laboratory/*Curiosity *project scientist. Here, perched atop a rock called Jibsheet,* Spirit *looks out over a Martian sunset on March 19, 2005. The Jet Propulsion Laboratory created this synthetic view using Virtual Presence In Space technology, which combines visualization and image-processing tools with Hollywood-style special effects.*

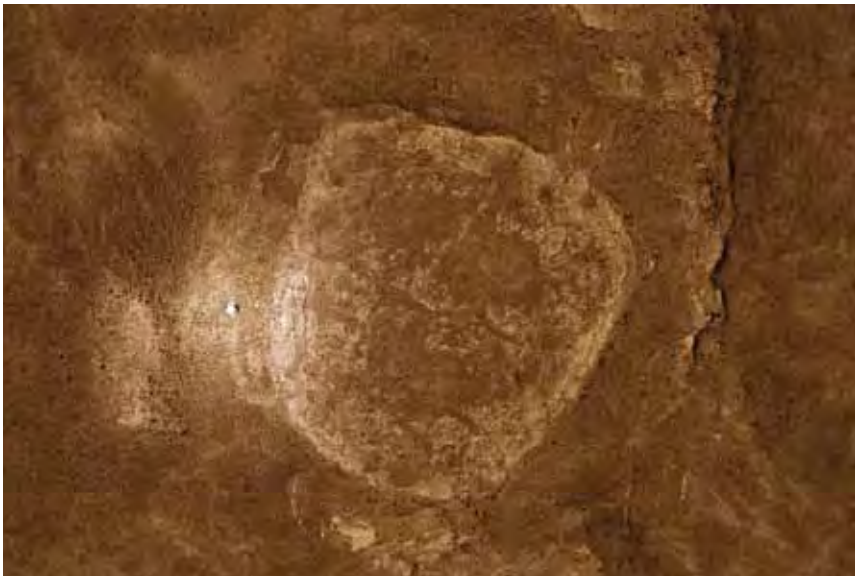
Image: NASA/JPL-Caltech/Cornell

THE MARS EXPLORATION ROVER (MER) mission has established and broken so many records, made so many important findings, and survived so long that it is already a legend in the annals of space history. But in January 2014, MER—initially funded as a three-month tour—will celebrate an achievement never even dreamed possible: 10 years of surface operations. For all that's gone wrong in our world over the past decade, the first overland expedition on the Red Planet has gone spectacularly right.

Spirit and *Opportunity* have touched heartstrings around the world with their fearless explorations, life and death struggles, and uncanny tenacity. They are international cultural icons, starring in their own IMAX movie, TV commercials, and classrooms worldwide. The big-eyed, one-armed, six-wheeled, solar-winglet-sporting robot field geologists established the "look" for extraterrestrial rovers, from Disney's cartoon everydroid, *WALL-E*, to China's lunar robot, *Yutu (Jade Rabbit)* rover.

Most important, they are giving Earthlings an unprecedented view of Mars in breathtaking, 360-degree color panoramas and textbook-changing science discoveries. It's a bounty to which *Spirit* contributed almost up to her last communiqué in 2010, and which continues to grow as *Opportunity*, the longest-lived robot on Mars, roves on.

Designed and built at the Jet Propulsion Laboratory (JPL), home to all of NASA's Mars rovers, *Spirit* and *Opportunity* are superb machines. Yet the reason for MER's extraordinary success extends equally to the team that has operated them on the Martian surface. Led by the mission's charismatic commander



TOP *At an eroded volcano called Home Plate,* Spirit *was the first to find in-situ evidence of carbonates—solid evidence that near-neutral water (like Earth's) once existed on Mars. In this orbital view captured by* Mars Reconnaissance Orbiter's *High Resolution Imaging Science Experiment (HiRISE) instrument,* Spirit *is the white dot at left of Home Plate.*

BOTTOM *While* Mars Global Surveyor *revealed the trails left by Mars' many dust devils,* Spirit *first showed them to us from the ground—and made movies of them! To watch this dust devil grow and blow across the plain inside Gusev crater, go to* 1.usa.gov/1evsPtU.

in chief of science, Principal Investigator Steve Squyres, of Cornell University, the MER operations team has evolved into such a well-oiled human machine that everyone sings the praises of the mission these days. But it wasn't always like that.

"There was a time when it seemed like nobody believed we could do this besides us, the MER team," Squyres reflects. In the still of the night, it's not 10 Earth years on Mars he thinks about. "It's all the years, all the work by so many people to try and just make this thing happen…it's a miracle we even got to Cape Canaveral."

As a journalist covering the MER mission, I remember that time; the doubt and uncertainty, and through the years I've observed as "miracles," most of them originating on Earth, kept happening.

EVEN BEFORE NASA selected MER for flight in July 2000, the odds were stacked against it. At that point, two-thirds of Mars missions had ended in failure—including two predecessors, *Mars Polar Lander* and the *Mars Climate Observer* in 1999. Although *Mars Odyssey* made it into orbit in 2001, MER was a landed rover, as risky as a mission could be. Crazier still, the project had less than three years to go from blueprints to the Cape. Then, just a few weeks after NASA gave MER the green light, it got even more intense.

It was a hot August afternoon when Squyres answered the phone in his office: "The guys in the Mars Program Office at NASA headquarters wanted to know, 'Can you do two?' I swear to God, I said, 'Two what?'"

Overnight, a single rover became twins. Obviously, two rovers improved the odds, but the challenges doubled. The pressure was enormous. The team had to adapt the 1997 *Mars Pathfinder* landing system, which was designed for *Sojourner* and the size of a small microwave oven, to a pair of vehicles as big as golf carts. During testing, parachutes ripped, airbags exploded, and skepticism swirled around the team. I heard the hushed conversations and saw the raised eyebrows, from NASA brass down.

The twin MERs went through more testing and external reviews than any previous interplanetary spacecraft, but trouble followed them right to the Cape. While *Spirit* was on the pad, the team discovered a potentially fatal flaw in the rovers' pyrotechnic system electronics while changing out an electronics board inside *Opportunity*. The team was still investigating the issue when *Spirit*'s launch window opened, but managed, in the nick of time, to exonerate the pyro system. And somehow the launches—*Spirit* on June 10, 2003, *Opportunity* July 7, 2003—went perfectly. It was only the beginning.

A.J.S. RAYL *is a journalist whose work has appeared in* Air & Space, Discover, Reader's Digest, *and* Smithsonian, *among other national magazines. She recently founded GRoK Technologies, LLC, to transform NASA discoveries into biomedical applications. Her "MER Update" appears monthly at* planetary.org.

ABOVE Opportunity *became the first robotic geologist to examine meteorites on Mars. This false-color picture of Block Island—the largest meteorite yet found on Mars—was assembled from images captured by* Opportunity*'s panoramic camera (Pancam). Analysis by the rover's alpha particle X-ray spectrometer (APXS) confirms that the meteorite is rich in iron and nickel. Block Island is about 60 centimeters (2 feet) across.*

BELOW Opportunity*'s Rock Abrasion Tool (RAT) left these marks (known as RAT holes) inside Endurance crater in June 2004. The rings of bright red tailings around the holes provide further confirmation that the "blueberries," little blue/gray spherules seen here and ubiquitously on Mars' surface, are hematite-rich concretions that formed inside deposits soaked with groundwater.*

En route, the largest solar flare on record erupted and surged toward the twin MERs. Demonstrating their MER mettle, the two American spacecraft shook it off and flew on. Then, in late December, as *Spirit* closed in on Mars, the United Kingdom's *Beagle 2* lander, delivered by European Space Agency's *Mars Express*, lost contact and was presumed to have crash-landed. The MER team soon learned a possible reason—a dust storm was changing atmospheric dynamics.

Just hours before *Spirit*'s scheduled entry into Mars' atmosphere on January 3, 2004, the Entry, Descent and Landing (EDL) team was tweaking the timing of the parachute opening. Once that was done, *Spirit* would be on its own. "We have done everything we know that could be humanly done to ensure success," JPL Director Charles I. Elachi assured reporters.

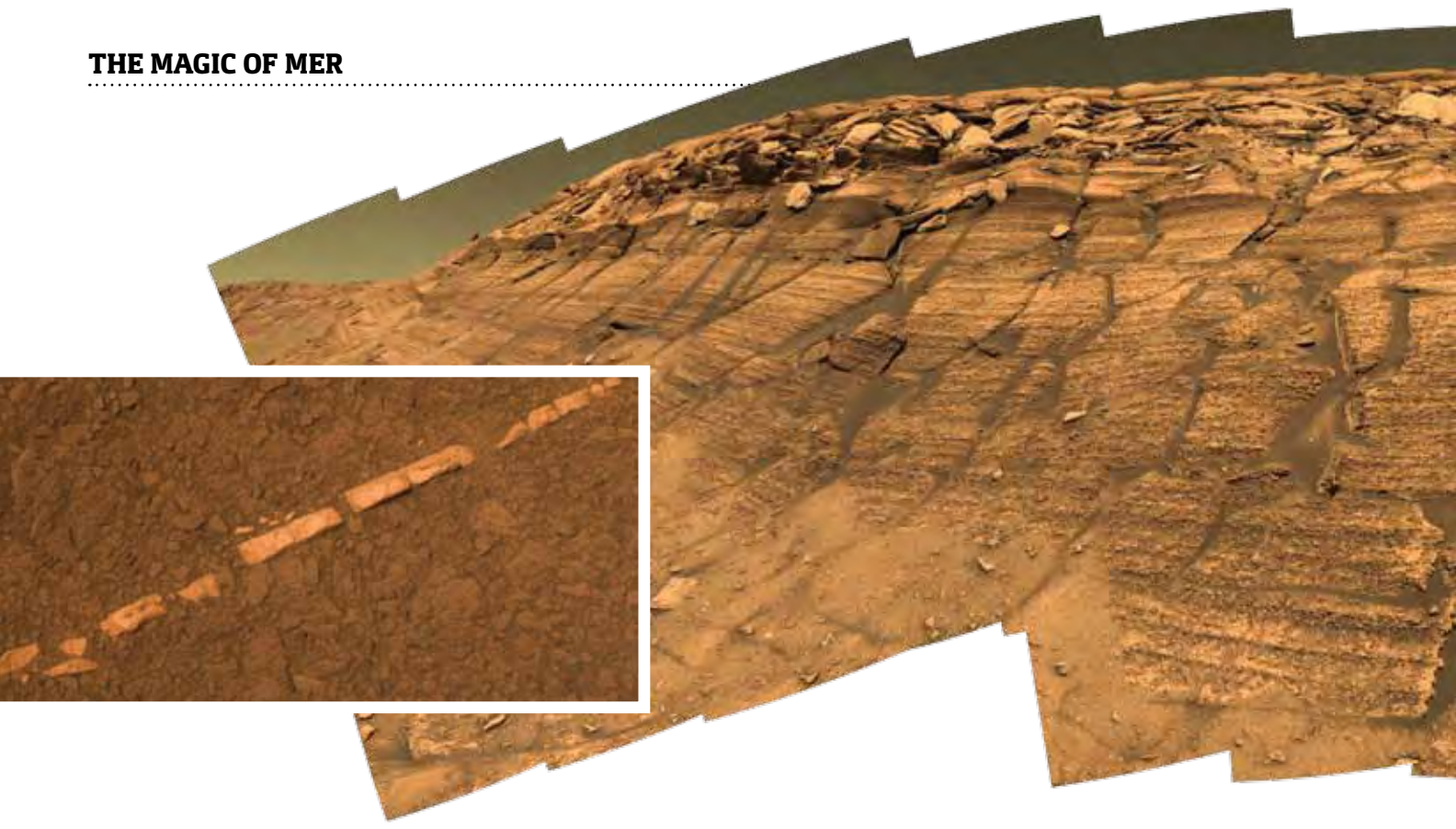
But Mars' reputation as "the death planet" hung like a pall. Ratcheting up the tension was the reality that whatever was going to happen would happen in view of the whole world. For the first time in history, anyone with a Web browser could tap the data flow from Mars, impeded only by the 14-minute transmission time to Earth.

In an omen of the miracle mission MER was to become, *Spirit* made landing look easy, surviving the seven minutes of terror and bouncing down into Gusev Crater at 8:35 p.m. PST, right on time. It then bounced for more than 16 minutes before finally stopping and phoning home to report it had arrived safely. "We're on Mars!" said EDL Manager Rob Manning, making the announcement heard around the world. It was electrifying.

Three hours later, *Spirit*'s first picture postcards streamed in. The whole world was looking. Within 72 hours, the websites of NASA, JPL, and other organizations were slammed with 1.2 billion hits, setting the Internet record then for a single event (this, before social media).

On January 24, *Opportunity* touched down on the other side of the planet in Meridiani Planum, bouncing to a halt inside a small

Images: top: NASA/JPL-Caltech/Cornell; bottom: NASA/JPL-Caltech/Cornell



INSET ABOVE *Homestake, the mineral vein found by* Opportunity *near the edge of Cape York on Endeavor's western rim, is about the width of a human thumb and only 45 centimeters (about 18 inches) long. The rover examined Homestake in November 2011 and found it to be rich in calcium and sulfur, and possibly the calcium sulfate mineral gypsum—another indicator of water. This view, composed of several images taken by* Opportunity*'s Pancam, is the rover team's best estimate of Homestake's natural color.*

ABOVE Opportunity *captured this underlying view of Burns Formation, or Burns Cliff, after driving right to the base of this southeastern part of Endurance crater's inner wall. Again, Virtual Presence In Space technology gives us a synthetic view of how the rover looked in this scenario.*

crater, scoring "a 300-million-mile, interplanetary hole-in-one!" as Squyres exclaimed at the time of landing. When it opened its eyes the scientists nearly launched into space themselves. "What we were hoping, praying we might find after driving many meters was right there—bedrock!" remembers Squyres. Two robot stars were born and NASA got a much-needed boost.

FOLLOW THE WATER

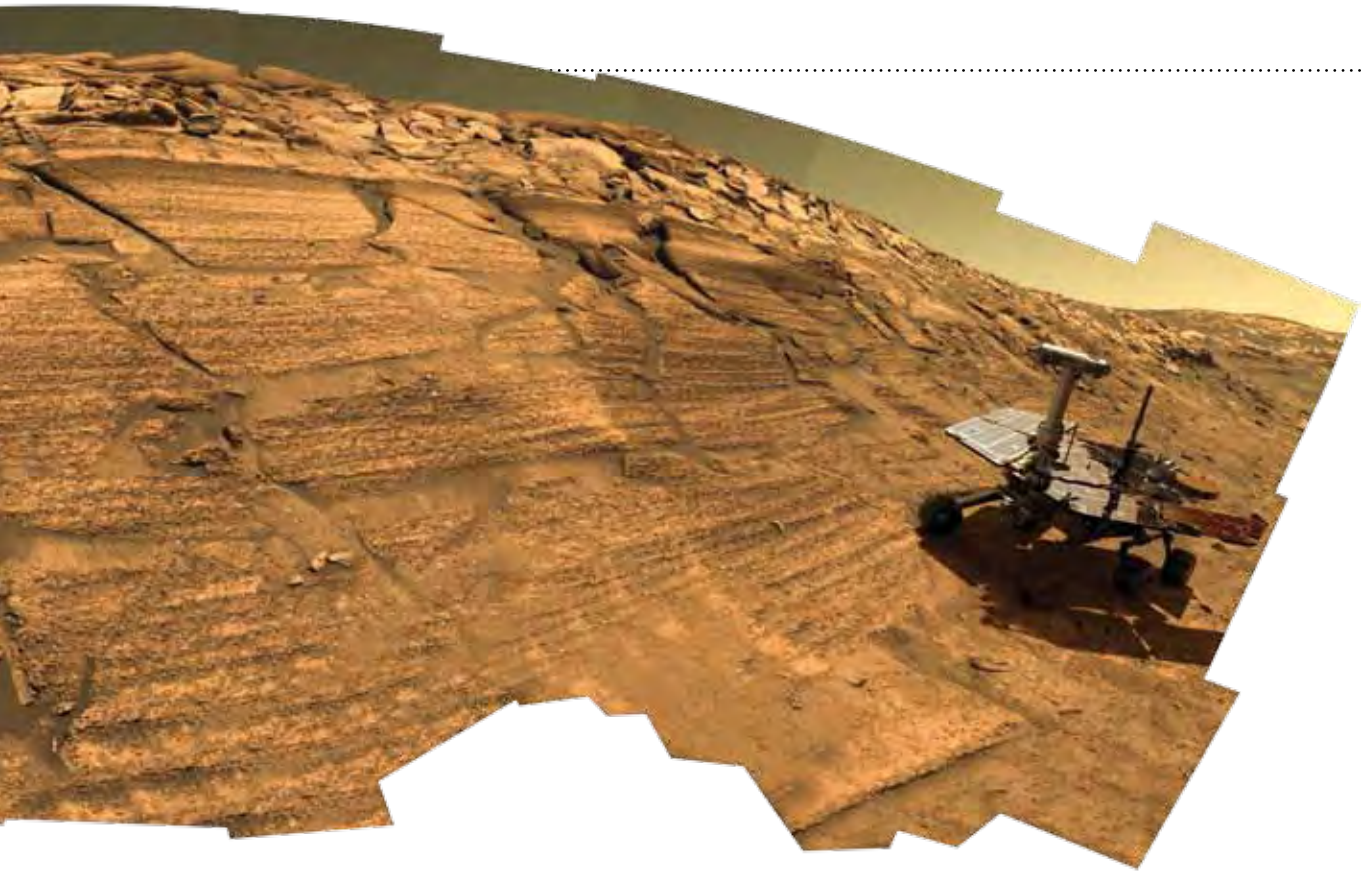
The MERs were sent to "Follow the Water," the first objective in NASA's themed Mars exploration strategy. The layered bedrock all but handed that to *Opportunity* on a silver platter. While the goal was to search for evidence of ancient habitable conditions, mission success required both rovers survive 90 days, travel at least 600 meters, and image and describe the geological environments they found. They had hazard and navigation cameras, and six science tools to help them do the job—the miniature thermal emission spectrometer (Mini-TES) and the Mössbauer spectrometer to identify minerals, a stereo color panoramic camera (Pancam), a microscopic imager to serve as a hand lens, an alpha particle X-ray spectrometer (APXS) to glean the chemical composition of rock and soil samples, and a rock abrasion tool (RAT) to grind into rocks.

Within the 90-day primary mission, *Opportunity* found evidence of ancient salty surface water, while *Spirit* struggled, trudging through soil and lava. But the twin robots just kept on roving and roving, making every day "a little bit like Christmas," as the late JPL Mars rover pioneer and MER engineering chief Jake Matijevic once described life on MER.

Against all odds, *Spirit* crossed two kilometers of treacherous terrain in Gusev Crater to get to the Columbia Hills and not only survived its first, second, and third Martian winters there, but found the evidence for past water it was searching for. Although it had the harder road to rove, *Spirit* made history as the first robot to summit a mountain and take pictures of the planet's notorious dust devils.

At the persistence of Richard V. Morris, of Johnson Space Center, the MER scientists discovered *Spirit* had also returned the first in situ evidence for carbonates on Mars, a sure sign of near-neutral water, like water on Earth. In the hydrated sulfates and nearly pure, opaline silica the rover uncovered at an eroded-over volcano dubbed Home Plate,

Images: inset: NASA/JPL-Caltech/Cornell/ASU; spread: NASA/JPL-Solar System Visualization Team



they found the remains of an ancient, violent, volcaniclastic environment, "probably like what you see in parts of Hawaii and other volcanic centers on Earth," says MER Deputy Principal Investigator Ray Arvidson of Washington University in St. Louis.

In April 2009, as *Spirit* was driving around Home Plate to its next destinations, its left wheels slipped on the crusty edge of a small, shallow, sand-filled crater and sank into the mix of soils. Forever determined, the rover continued working for a year, conducting a radio study to help confirm Mars' core is liquid. Then, just as *Spirit* began making progress getting out of its sandy snare, the mission's fourth Martian winter hit. On March 22, 2010, it checked in, and then presumably went into hibernation mode. The team sent out 1,300 signals during the ensuing 14 months, but never re-established contact. NASA declared the rover's mission over in May 2011. All told, *Spirit* returned 128,224 images, traveled 7.7 kilometers (4.8 miles) across a rugged landscape, and demonstrated MER mettle right to the end. Forever parked near Home Plate, *Spirit* rests silently, a monument to humanity's first overland expedition of Mars.

On the other side of the planet, *Opportunity* found the hematite it came looking to confirm, in and around Eagle Crater where it landed. The mineral, which forms in water, is locked up in small concretions the team nicknamed "blueberries." From Eagle, the rover set out across the Meridiani Plains, becoming the first robot to check out its own heat shield, examine meteorites on Mars, and drive into craters. With the data it returned, the scientists found a paleo-environment where water once flowed across the surface, filling some craters. And they found evidence that the environment changed with the epochs to a time when winds blew more fiercely more often, water disappeared, and fine sulfate-rich layers accumulated into the couple hundred meters of sandstones that form the ground of the plains today.

Opportunity traveled for years over this ground, now known as Burns Formation (named for Roger Burns, professor of mineralogy and geochemistry at MIT), arriving at Endeavour, the 22-kilometer (13.7-mile) diameter crater, in August 2011. Here, the robot field geologist is venturing deeper into Mars' past, to the Noachian Period. Already it has uncovered gypsum and clay minerals at Cape York, solid evidence of near-neutral

BELOW *The pale rock at upper center (about the size of a human forearm) includes a target called Esperance.* Opportunity*'s APXS reveals that Esperance contains more aluminum and silica, and less calcium and iron, than had been detected by the rover in more than nine years on Mars. Preliminary interpretation points to clay minerals due to intensive alteration by water.*

Image: NASA/JPL-Caltech/Cornell/ASU

TOP *MER Principal Investigator Steve Squyres, left, conducts the daily Science Operations Working Group meeting.*

ABOVE *In his office, Squyres pauses to reflect. "We've been entrusted by the government, by NASA, and by the taxpayers, with priceless assets that have been paid for with something now approaching one billion taxpayer dollars," he says. "We are mindful that we're doing this on behalf of everyone."*

OPPOSITE PAGE Opportunity *left these tracks around the outer rim of Endurance while looking for a way into the crater. The MERs were designed to be robot field geologists, surrogates for humans exploring Mars' surface, and they have succeeded beyond everyone's imagination.*

water, unlike the highly acidic ancient water the rover found earlier. "It's been absolutely game-changing," says Squyres.

"BE" THE ROVERS

The entire mission has been game-changing. In part, it's because the rovers are amazing machines. "They're dutiful, intrepid vehicles of exploration that have surprised us all," says MER Project Manager John Callas, of JPL. But the way the rovers tolerated the thermal cycling, the constant expansion and contraction of their metal parts, seems like a miracle if there ever was one.

Spirit and *Opportunity* were built to last, Mars willing. Every instrument, every part, was designed to extend well beyond the 90-day "warranty" required by NASA. "No engineers want to be the ones who built the first instrument or part to fail," says Bill Nelson, chief of MER engineering.

Still, the crucial factor since the rovers landed has been the robots' colleagues, the humans running the show from Earth. Squyres credits MER's original project manager, Pete Theisinger, of JPL, for setting the tone. "On Day One, Theisinger says: 'We're doing this mission to do good science on Mars,'" Squyres recalls. "And everyone embraced that."

Unlike most NASA missions, the MERs were funded with a single principal investigator for the whole payload, as opposed to a PI for each instrument. Focused on the mission objective, Squyres instituted a structure rooted in tried and true principles–respect, equality, integrity, and gratitude–to encourage strong working relationships and lay a foundation for camaraderie and cohesion.

First, he established the rules of the Martian road. The mission would be discovery driven and each study would be a unified effort. Everything was to be shared.

Squyres organized the MER science team based on expertise, not by instruments, because "it's natural to the way scientists think and like to work," he says. He then created a place for everyone, even students working on the mission, to be heard–a daily Science Operations Working Group (SOWG) meeting. And he spread the "king-dom" around, rotating the role of chairperson. "The key thing to realize when you're leading a team of scientists is that you are not a general in the Army giving orders," he says.

Since rovers rove, continued consensus is mandatory. To achieve that, Squyres instituted daily practices that brought all team members together, like inviting engineers to the science meetings and assigning scientists to light engineering roles. This interconnectedness built an incredibly robust rapport that fosters continued consensus between two usually disparate camps.

With the organization, structure, and work practices he put in place, Squyres effectively succeeded in creating a "social order" with "an emphatically flattened hierarchy committed to the notion of unilateral consensus," says science and technology sociologist Janet Vertesi, an assistant professor at Princeton, who completed her PhD thesis on the MER team at Cornell.

Yet, there is something more about MER, something that seems to emanate from a deep bond, a connection between these humans and robots that is unique in planetary exploration. It's not just a matter of anthropomorphizing–projecting human traits onto the rovers–which is natural for humans to do. "It goes the other way too," says Vertesi. Using a codified series of gestures to imitate the rovers in given situations, such as splaying arms out like solar panels or putting hands up like their face is the Pancam, team members often "transport themselves onto Mars and into the body of their rover, something known as technomorphizing," she says.

In other words, MER team members learned to "be" the rovers, or, as Squyres puts it, "experience Mars through the rover." In effect, they learned to see the planet as the rovers see it and acquired a highly attuned sense of what it "feels" like to be *Spirit* or *Opportunity* confronting their worlds.

Photo: A.J.S. Rayl

Some people would dismiss this embodied connection as completely unconnected to the science. "But it is integral to the science," says Vertesi, whose book, *Seeing Like a Rover: Images in Interaction on the Mars Exploration Rover Mission*, will be published in 2014. "Being" the rovers has enabled the MER team to push the robots' limits and imbue *Spirit* and *Opportunity* with the right robot stuff to do things they were never designed to do, like climb a mountain or survive a direct hit by a huge dust storm. It also forged an integrated team of humans and machines that is pioneering another aspect of planetary exploration.

THE EXPEDITION CONTINUES

At Endeavour, *Opportunity* is roving on undaunted, despite the aches and pains of aging. With a front wheel permanently rotated inward eight degrees, it drives mostly backwards now. Because of a broken shoulder joint actuator in its Instrument Deployment Device (IDD), it must hold its arm partially deployed, like it's fishing, and its two mineral detectors are out of commission.

But for now, it's full steam ahead. *Opportunity* is poised to make history again in the geologic record it will no doubt find on Murray Ridge this Martian winter. And when the 10th anniversary rolls around, the MER team will celebrate and then "get up the next day and plan the next sol," says Squyres.

Spirit and *Opportunity* are of their time—and they changed everything. Beyond a rich legacy of scientific evidence that Mars was once habitable, they have given us the gift of exploration and inspired us in ways that heed the call of the human soul.

We are wired to explore and we begin from the moments we are born. "The rovers are another way humans project themselves into an alien environment," Matijevic reflected one night some years ago. They *are* us. And through *Spirit* and *Opportunity*, we embarked on the journey of a lifetime.

Dedicated to Bruce Murray and to the Mars Exploration Rovers team.

Image: NASA/JPL-Caltech/Cornell

BRUCE BETTS *is director of projects for The Planetary Society.*

Planetary Dirt Sampling Success

PlanetVac Passes a Major Milestone

A YEAR AGO in *The Planetary Report*, I told you about PlanetVac, a proposed planetary surface sampling system from Honeybee Robotics that The Planetary Society and its members were supporting. Now I am happy to report to you on Honeybee Robotics' success with the design, construction, and testing of a full PlanetVac system.

PlanetVac is a new way of doing one of the hardest yet most valuable things in planetary exploration: sampling a planetary surface–gathering planetary dirt–and then transferring that dirt to a science instrument or sample return capsule. Current ways of doing this, such as robotic arms, are costly and complex, with lots of moving parts. Wouldn't it be nice to have other options that could be used in different situations?

PlanetVac, which stands for Planetary Vacuum, is a concept that effectively vacuums up planetary regolith (the dirt overlying bedrock) for quick and reliable surface sampling. In practice it actually blows materials up hollow tubes using compressed gas, which usually is already available on landers for pressurizing the fuel tanks. The PlanetVac sampling devices would be built into the lander legs themselves. This planetary surface sampling technique could be used very effectively on Mars, asteroids, or the Moon because of the low pressure on those bodies. The high ratio of the pressure of the compressed gas to the ambient pressure makes this an extremely efficient technique.

Honeybee Robotics had tested single components of the system and found them to be extremely ef-

SAMPLE TUBE

ABOVE *The PlanetVac surface sampling system rests on Mars simulant soil inside a vacuum chamber after testing at Honeybee Robotics.* **LEFT TOP** *A close-up of the sample tube assembly, which is integrated as part of the lander legs.* **LEFT BOTTOM** *The end of the sampling tube that enters the soil.*

Photos: Honeybee Robotics

Thanks! Planetary Society Members have helped make these and other applied planetary science programs possible. Thank you.

ficient. But, would a full system work as predicted on simulated Martian and lunar surface materials in a vacuum chamber? To find out, the Honeybee team, composed of professional engineers, college students, and a high school intern, designed and built a full PlanetVac prototype system and a simplified small lander on which to install it.

The team suspended the whole setup in their large, phone-booth sized vacuum chamber, pumped the pressure down low (for example, to Mars surface pressures), then dropped the lander onto Martian or lunar regolith simulant (Earth dirt was chosen for its similarities to regolith on Mars or the Moon). The system included specially designed lander foot pads with a hollow tube that led up the lander's legs.

After landing, interior tubes were deployed a few centimeters deeper into the soil to increase efficiency. A nice fallback is that the system still works even if an interior tube fails to deploy. Compressed gas running down a lander leg then was used to force the Mars or lunar simulant up the interior sampling tube. One lander leg deposited dirt into a simulated science instrument (a clear box viewed by a camera to watch the process). Another deposited dirt into a simulated ascent vehicle, a rather playful compressed gas-powered rocket (not an accurate simulation) that launched at the end of the process.

The tests were very successful, demonstrating the effectiveness of a PlanetVac system for quick and reliable sampling of planetary surface materials. Also, much was learned in the process, as designs were created and refined and further lessons were learned for improving future designs. Honeybee Robotics is now in the process of writing up the system's details, the tests, and what was learned. They will publish the results in professional journals and present them at engineering and science conferences.

You can learn more about PlanetVac in our update blogs at **bit.ly/TPS-planetvac**. There you can watch videos of the tests and the facility, meet the team, and see many more pictures of the system. Thanks for making this new prototype planetary sampling technique happen!

WHAT'S UP? *by Bruce Betts*

IN THE SKY

Reddish Mars is rising late in the evening in the east in January, but by opposition (when it's positioned on the side of Earth that's opposite from the Sun) on April 8, it is much brighter and rising in the east around sunset. Jupiter is bright and low in the east after sunset in January, getting higher as the weeks pass. The Moon is nearby on February 10. Mercury is very low in the west after sunset in late January and early February, and very close to the Moon on January 31. Yellowish Saturn is up in the pre-dawn east in January, and rising in the middle of the night by March.

RANDOM SPACE FACT

Mars' brightness varies considerably from one opposition to the next because the Earth-Mars opposition distance changes significantly, mostly due to Mars' elliptical orbit. During its April 8, 2014 opposition, Mars will be about as bright as Sirius, the brightest star in the sky. In contrast, during the favorable 2018 opposition, Mars will be more than 3.5 times brighter than Sirius.

TRIVIA CONTEST

Our June Solstice contest winner is John Gorman of Winchester, Massachusetts. Congratulations! **THE QUESTION WAS:** What are the only planets that have been visited (flybys or orbiters) by one and only one spacecraft as of 2013? **THE ANSWER:** Uranus and Neptune both have been visited only by *Voyager 2*.

Try to win a free year's Planetary Society membership and a Planetary Radio T-shirt by answering this question:

What is the name (or one of the common names) of the Milky Way Galaxy arm in which we live?

E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 85 South Grand Avenue, Pasadena, CA 91105. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by March 1, 2013. The winner will be chosen by a random drawing from among all the correct entries received.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science fiction guests, listen to *Planetary Radio* at *planetary.org/radio*.

CASEY DREIER *is director of advocacy for The Planetary Society.*

A Shift in the Wind

The Public Calls for Planetary Exploration

In early December, Planetary Society CEO Bill Nye released an open letter to the president of the United States, asking him to make exploration a top priority for NASA. Bill's video has almost 1 million views to date. To read the letter in full, please go to bit.ly/planetary-2013-12-05.

IT LOOKED LIKE 2013 would end on a down note.

On November 15, NASA quietly mothballed its Advanced Stirling Radioisotope Generator (ASRG) program. ASRGs were to be the next generation plutonium-238 power sources; they are four times more efficient than existing Radioisotope Thermoelectric Generators, and able to power low-cost missions deep into the solar system [see "Power From the Isotopes" in the September Equinox 2013 issue of *The Planetary Report*].

A few weeks later, NASA announced a sudden restructuring of the grant programs that fund planetary science research. These programs are the only source of funding for planetary scientists in the United States, and many fear there will be gaps in support that will drive scientists—particularly scientists early in their career—out of the field.

We also learned that *Cassini*'s extended mission at Saturn is at risk. According to articles in *Wired* and *SpaceNews*, the White House's proposed planetary science budget cannot sustain science operations of both *Curiosity* and *Cassini* beyond 2014. *Cassini* may be prematurely terminated (crashed) if funding does not improve soon.

These were only the latest consequences of the White House's cuts to planetary science at NASA. An unfairly applied sequester cut and a delayed budget left the program with significantly fewer resources in 2013, despite strong congressional support.

But then things began to change for the better.

The Planetary Society's Fall letter-writing campaign to Congress and President Obama generated over 45,000 e-mails in support of planetary exploration. Bill Nye joined us and released an open letter to the president arguing for a restored Planetary Science budget. The video of Bill reading this letter has been seen over 900,000 times and is the most-viewed item of all time on the Society's YouTube page.

Europa roared back into the news in December with the discovery that it may have huge plumes of water vapor erupting from its surface. The proposed and still-unfunded Europa Clipper mission [see "Turning the Tides" in our March Equinox 2013 issue] can be modified to fly through these plumes and analyze their chemistry. On the same day this news was released, the Society put out an official call for a Europa flagship mission. Our call featured a strong statement of support from Rep. John Culberson (R-TX), who is next in line to serve as chairman of the powerful House Appropriations Subcommittee that oversees NASA (bit.ly/planetary-2013-12-12).

Congress also agreed to a budget that partially reverses the effects of sequestration, the across-the-board cuts to nearly all federal programs. This means fewer congressional standoffs and, we hope, a return to a normal budgeting process. Draft bills that restore some funding to planetary science may be passed as early as January 2014.

The fortunes of NASA's Planetary Science program seesawed this year, but the Society's advocacy program was there for every peak and trough. Thank you to the tens of thousands of you who took the time to stand up for planetary exploration to make 2013 end on an up note. Here's to a brighter 2014.

STROKKUR GEYSIR

EXPERIENCE ICELAND

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Iceland Total Solar Eclipse and Aurora Borealis
MARCH 15-23, 2015

Start planning now! Join your fellow Planetary Society Members for a spectacular expedition:

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- Witness the total solar eclipse from the air—on a plane east of Iceland.
- Experience stunning night skies, courtesy of the Aurora Borealis.

You'll enjoy lectures about geology, volcanism, the Aurora (including a visit to a new Japanese site for study of the "northern lights"), the Icelandic sagas, and the total eclipse. You'll be in expert hands, accompanied by veteran Betchart and Planetary Society expedition leader Bob Nansen and local Icelandic naturalist Siggi Tomasson.

Join us on this exciting adventure!

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When I saw this double rainbow on my way home from work in Orange County, California, I was drawn by its beauty and rarity. What came to mind immediately was how our human impulse to understand and explain such phenomena has put us on a path to an ever deeper understanding of the processes that shape the universe. This ongoing quest for knowledge is the drive to fulfill our collective purpose—to be that part of the cosmos that understands itself. I was glad to have my camera with me to capture this image, an event that I have witnessed only a handful of times in my life.

From an early age, I have been an avid reader of scientific science fiction and a great fan of science, particularly astronomy. When *Cosmos* came along, Dr. Sagan's lucid presentation helped crystallize in my mind the vision of humankind's continuing, tireless quest for knowledge. We are, in essence, a species of scientists.

Precious few human beings directly participate in this endeavor. The rest of us support their efforts and cheer them on. It takes a vast infrastructure for a sentient species to fulfill its destiny.

My membership in The Planetary Society is a valuable way to stay in touch with those fellow human beings who share this understanding.

—Henry Towers, Westminster, California

Planetary Society Members are united in their love of space exploration—which has its origins in Earth's skies. Thank you for sharing your views with us! To see more, go to **mysky.planetary.org**.

WANT TO SHARE YOUR SPACE IMAGE? Send us an e-mail with a jpeg (less than 5 MB) attachment of your image to *planetaryreport@planetary.org*. Please use the subject line "MySky" and include a short caption (such as where you took the image and, if appropriate, with what equipment) and credit line for the image. Please include just one MySky image per submission. Also, be sure to include your name, contact information, and membership number (it's on your membership card and on the mailing label of your magazine). We'd also love to receive a picture of you and to learn more about what is most important to you about being a Planetary Society Member. Questions? E-mail *planetaryreport@planetary.org* or call 626-793-5100, extension 218.

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Thank You for "Empowering Citizens of Earth to Advance Space Science and Exploration."

The Hubble Space Telescope has detected water vapor above the south polar region of Europa, providing the first strong evidence of water plumes erupting from the Jovian moon's surface. In this illustration, based on Hubble's spectroscopic measurements, the plume rises about 200 kilometers (124 miles) above Europa's icy crust.

This year, you and I, as Planetary Society Members, have done so much to further space exploration. I can hardly wait for the coming year.

Together, you and I are embarking on fabulous voyages of discovery—whether it's via our twin *LightSail* spacecraft, sending our names and messages to distant worlds (including an asteroid), roving Mars and preparing for a future sample return, searching for Earth-like planets, seeking an alien signal, or protecting our pale blue dot from incoming asteroids. I am proud to be a Member of this international group of space explorers.

On this page and throughout this issue, we chose pictures to tell these stories, to capture the passion, wonder, and joy we find in exploring the cosmos and searching for life beyond Earth.

Planetary Society Cofounder Bruce Murray understood the power of pictures. He made them a focus of this magazine from the first issue. I hope you will enjoy the photos in this issue and also explore our tribute to Bruce—the Bruce Murray Space Image Library—at *planetary.org*.

Wishing you joy in 2014,

Andrea Carroll
Chief Development Officer
andrea.carroll@planetary.org
626-793-5100 x214

Your gift makes a difference.
To give, go to ***planetary.org/donate***

Illustration: NASA/ESA/K. Retherford/SWRI