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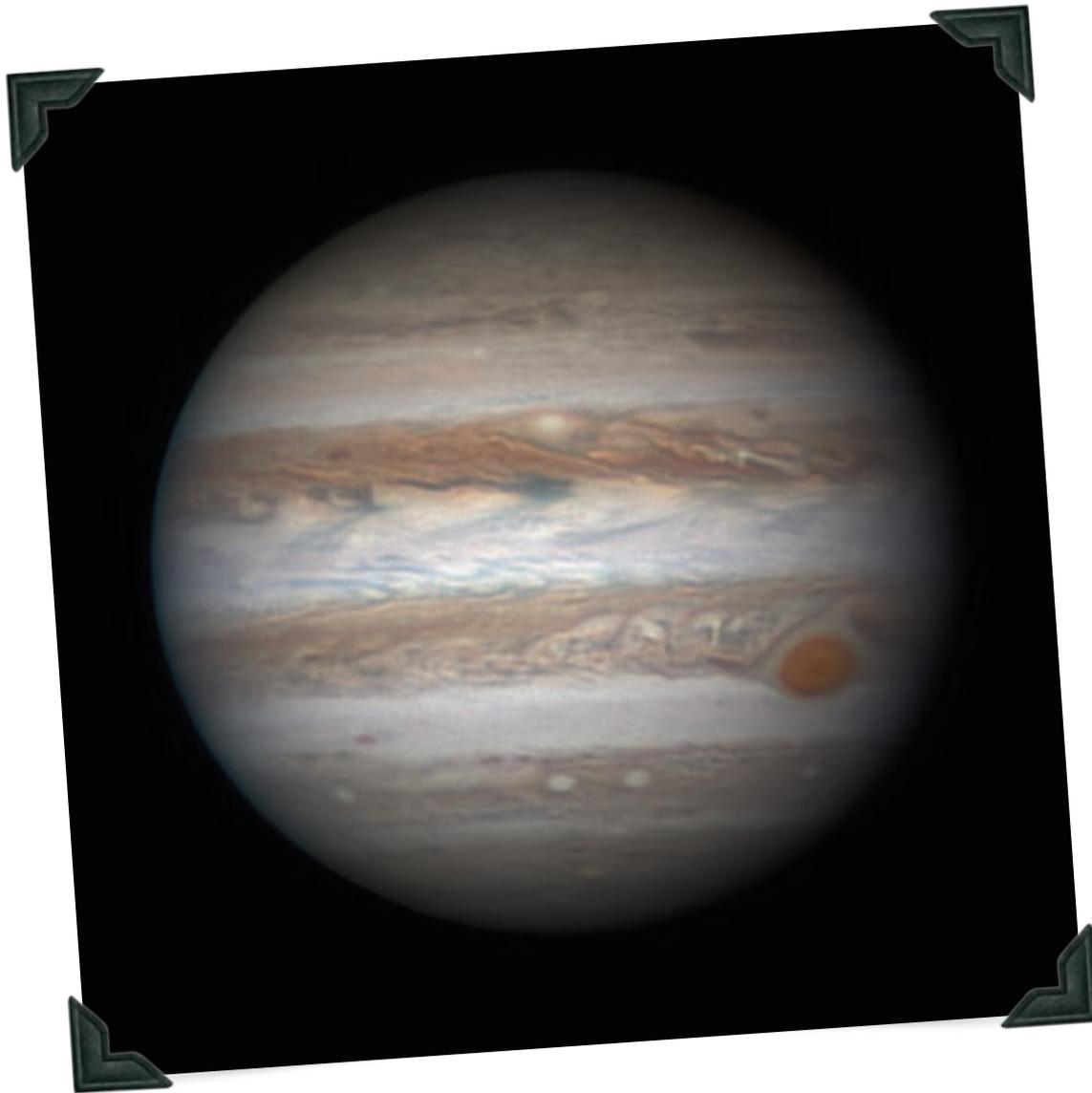
EXPLORATION MILESTONES

2015 IN PICTURES





EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.



A New Year for Jupiter

THE *JUNO* MISSION WILL enter orbit at Jupiter this coming July. To support *Juno*, amateur astronomers around the world are photographing Jupiter's changing face. This photo was taken by Christopher Go from the Philippines, who has been photographing planets since 2003. *Juno* carries a camera, JunoCam, whose sole purpose is to capture photos for public release. The JunoCam team is using amateur astrophotographers' images such as this one to make up-to-date maps of Jupiter and is inviting the public to select spots on those maps for JunoCam to image. 🪐

—Emily Stewart Lakdawalla

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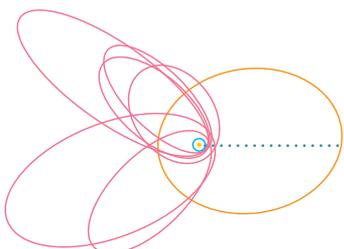
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ON THE COVER: In 2015, we citizens of Earth accomplished new feats in space exploration: we visited Pluto and Charon, entered orbit at Ceres, and brought a rocket's first stage to a gentle, upright landing at Cape Canaveral. Following the 2014 *Philae* landing, *Rosetta* spent 2015 accompanying comet Churyumov-Gerasimenko in its orbit around the Sun, and both passed through perihelion on August 13, 2015. This photo was taken by *Rosetta*'s NavCam just a few months earlier, on May 9, and shows the comet bursting with jets of ice and dust warmed by the Sun. Image: ESA/Rosetta/NavCam/Emily Lakdawalla



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YOUR PLACE IN SPACE



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

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Even More to Celebrate

What an Incredible Time to Be Witnessing Space Exploration!

DURING THE LAST YEAR, we witnessed some amazing feats in space exploration and we shared some wonderful adventures. But 2016 promises to bring even more discoveries and more to celebrate.

35 YEARS OF ADVOCATING EXPLORATION

In October, Planetary Society members and supporters gathered in Pasadena to enjoy our *More to Explore* events. We celebrated 35 years of advocacy and support for the adventure of space exploration. There, our own Neil deGrasse Tyson received The Planetary Society's Cosmos Award for Outstanding Public Presentation of Science. The award was presented to him by none other than the television show *Star Trek's* Lieutenant Uhura herself, Nichelle Nichols, a long-time friend of the Society and supporter of space exploration. For The Planetary Society, and perhaps for me especially, it's essential for us to promote and support the public presentation of science. By understanding our place in space, we can appreciate the importance of avoiding an asteroid impact, the contributions of space technologies to our everyday lives, and the profound nature of being alive at this time in the universe.

WELCOME, ROBERT PICARDO

Speaking of trekking extraterrestrials, you may be familiar with the *Star Trek Voyager* television series. Robert Picardo played The Doctor, and he has joined our board as its newest member. He, too, is a space advocate, and he brings new energy and new ideas. Check out his new monthly e-newsletter *The Planetary Post* on planetary.org.

PICTURES FROM PLUTO

As a kid, I had a poster of the solar system. In those days, Pluto was still unambiguously considered a planet. On this poster, Pluto had ice mounds with sharp peaks resembling icicles

that had been knocked loose and thrust tail-first into the frosty landscape.

As surprising as that may have seemed to me then, real pictures of the real dwarf planet Pluto arrived here on Earth last summer and these images are even weirder than that 1960s-era poster artist imagined. Nitrogen glaciers. Volcanoes that eject ice. Large areas rendered brown by tholins—a term coined by scientist Bishun Khare and our cofounder Carl Sagan to describe complex, carbon-bearing molecules that they had produced in the lab (incidentally, they thought this material might one day be called “star tar”). The higher resolution images we will see in the next few months will be even more striking and more thought provoking, as we discover more about the nature of distant objects that are 40 or more astronomical units from the Sun. *New Horizons'* flyby of the Pluto system is only one of the extraordinary space adventures we shared this year.

FANTASTIC LIGHTSAIL

Of course, we also flew our *LightSail* spacecraft at last and accomplished our test flight mission objectives. Next, we will fly our second spacecraft to higher altitude, where we can stay in orbit longer and do some maneuvering. We have just completed our required rigorous mission review. The *LightSail* team is incorporating some important design improvements to both the hardware and software. Some of these adjustments (or tweaks) are obvious. Several other changes are subtle, but significant. The team is working to meet an important test and integration deadline in March 2016. While the official launch date for the very first Space X Falcon-Heavy rocket is still September of 2016, the actual date may slide into the future. We will be ready either way.

SUMMER ARRIVAL AT JUPITER

This summer, the *Juno* spacecraft will go into

orbit around Jupiter, measuring the planet's gravity with amazing precision. With these data, scientists hope to infer the composition of Jupiter's core. There's evidence that it's made of dense metals, as is our Earth's core.

There's other evidence that Jupiter has sufficient gravity to crush pure, or nearly pure, hydrogen into a cold state dense enough to behave like a metal, forming "metallic hydrogen." Understanding hydrogen at extraordinary pressure might help us understand fusion and the nature of stars, which may in turn enhance our understanding of what it would take to harness fusion here on Earth.

SUPPORTING THE MISSION TO EUROPA

The Europa Clipper mission has just entered "Phase A," an official designation where NASA is now formulating the details of how the spacecraft will achieve its scientific goals. The instruments have been selected and a science team assembled. This means we really are on track to send a spacecraft to explore Europa, to characterize the ocean under the ice and prepare to look for life there. This said, the Clipper's launch date has yet to be specified. For now, NASA will only allude to "the mid-to-late 2020s." Congress wants it to happen in 2022 and has directed NASA to include a lander at the same time. With your support, we will continue to advocate for a safe launch date that is as early as possible.

As I often say, a hundred years from now, humankind will know whether or not there is or was life on Europa—but I want to find out now, while you and I are alive. Mission planners are designing and building a so-called "flagship" mission, with an estimated cost on the order of \$2 billion. That sounds like a lot of money, and it is. But it will be spent over the better part of a decade, so the cost per year, and the cost per person turn out to be quite reasonable, like a cup of coffee per American

taxpayer per year. Not bad for making a discovery that would change the way each and every one of us feels about being a living thing in the cosmos.

A NEW MARS MISSION

In spring 2016, Europe will launch a new mission to the Red Planet. The *Trace Gas Orbiter (TGO)* will help us better understand small concentrations of atmospheric gases that could be evidence of possible biologic or geologic activity on our planetary neighbor. It will also drop off the Schiaparelli lander: a short-lived entry, descent, and landing demonstrator. *TGO* is the first leg of the two-part ExoMars mission, a collaboration between the European Space Agency and Russia's Roscosmos. A couple years later, *TGO* will be followed by *ExoMars 2018*, an advanced rover that will drill two meters below the surface and feature a surface science platform. Stay tuned.

The Planetary Society will continue to advocate for more spacecraft and more missions to Mars beyond NASA's upcoming Mars 2020 rover mission. Furthermore, we will continue to advocate for a Humans Orbiting Mars (HOM) mission in 2033 as a step toward landing later in that decade.

THANK YOU!

Your support has grown stronger than ever this year. With your help, we are working for more sophisticated missions and more international cooperation. We are working to engage more and more of the world's citizens in the adventures and discoveries of space exploration. By understanding other worlds, we will better know our own. With this knowledge we can enhance the lives of people everywhere. Thanks again. The best is yet to come. 🍀

Bill Nye



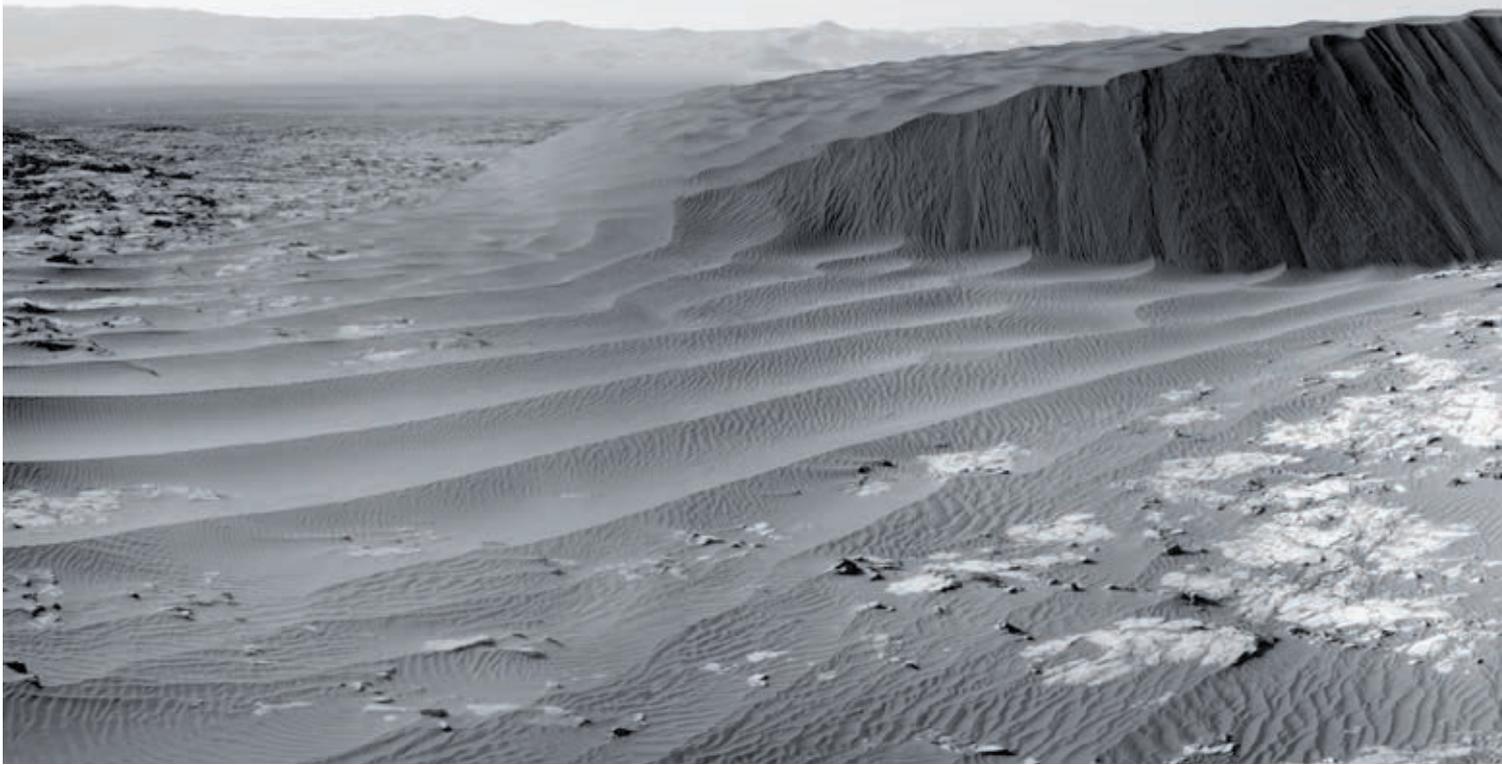
ABOVE Neil deGrasse Tyson receives the Cosmos Award for Outstanding Public Presentation of Science from Nichelle Nichols at The Planetary Society's 35th anniversary More to Explore event.



EMILY STEWART LAKDAWALLA

blogs at planetary.org/blog.

THE YEAR IN PICTURES



ABOVE Curiosity's scientific goal lies among the layered rocks at the base of Gale crater's central mound, but a line of dark sand dunes lies between that peak and the spacecraft's landing site. After more than three years of driving, Curiosity finally reached them, becoming the first rover to study the steep, active slip face of a Martian barchan (crescent-shaped) dune. This photo was taken on December 15.

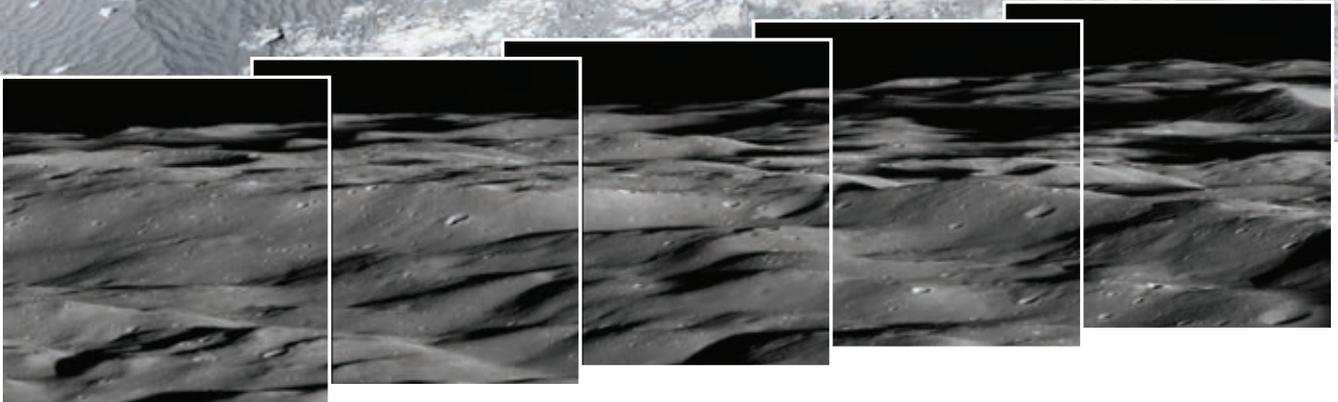
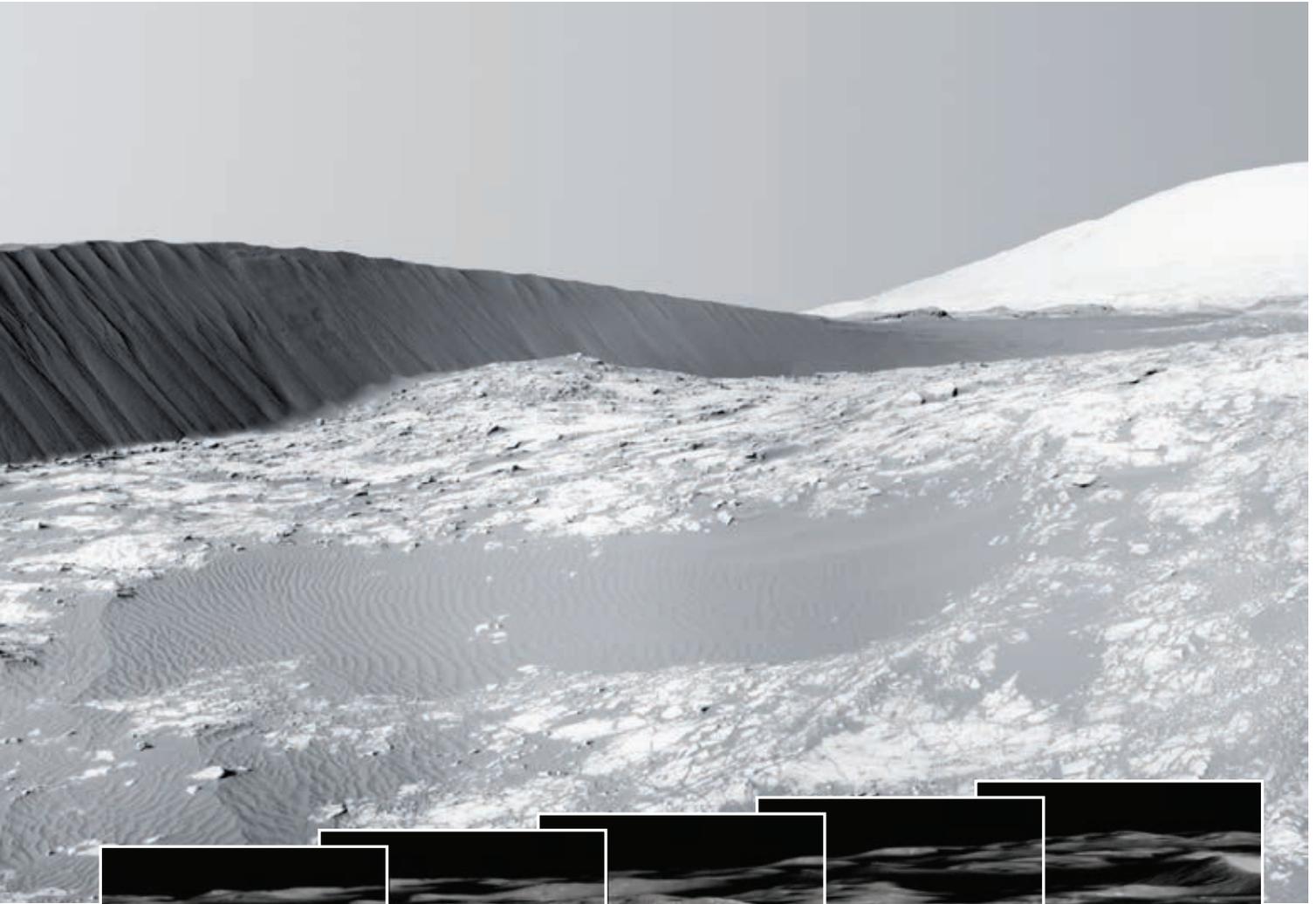
2015 HAS BEEN A YEAR of thrilling arrivals, particularly for dwarf planets, with *Dawn* entering orbit around Ceres and *New Horizons* shooting past Pluto and Charon. Against all odds, Japan's *Akatsuki* achieved orbit at Venus, and DSCOVR (Deep Space Climate Observatory) finally began monitoring Earth. On Mars, *Opportunity* and *Curiosity* reached their own new horizons—sedimentary horizons, that is.

It has also been a banner year for private spaceflight, with the launch and flight of The Planetary Society's *LightSail* test mission, and SpaceX's successful landing of its Falcon-9 first stage rocket only six months after a catastrophic launch accident.

This year we said goodbye to one solar

system mission when we deorbited *MESSENGER* at Mercury, but a host of other spacecraft continue their long and productive missions. China's *Chang'e 3* and *Yutu* continue to deliver data from the surface of the Moon while *Lunar Reconnaissance Orbiter* works on from orbit. Europe's *Rosetta* watched comet Churyumov-Gerasimenko pass through and beyond perihelion as four orbiters continued their observations of changes in Mars' surface and atmosphere. *Cassini* recorded the shifting seasons of Saturn and its moons, and the *Voyagers* forged deeper into the space beyond our Sun's heliosphere. With so many spacecraft exploring so many places, we are in a golden age of planetary exploration! 🌟

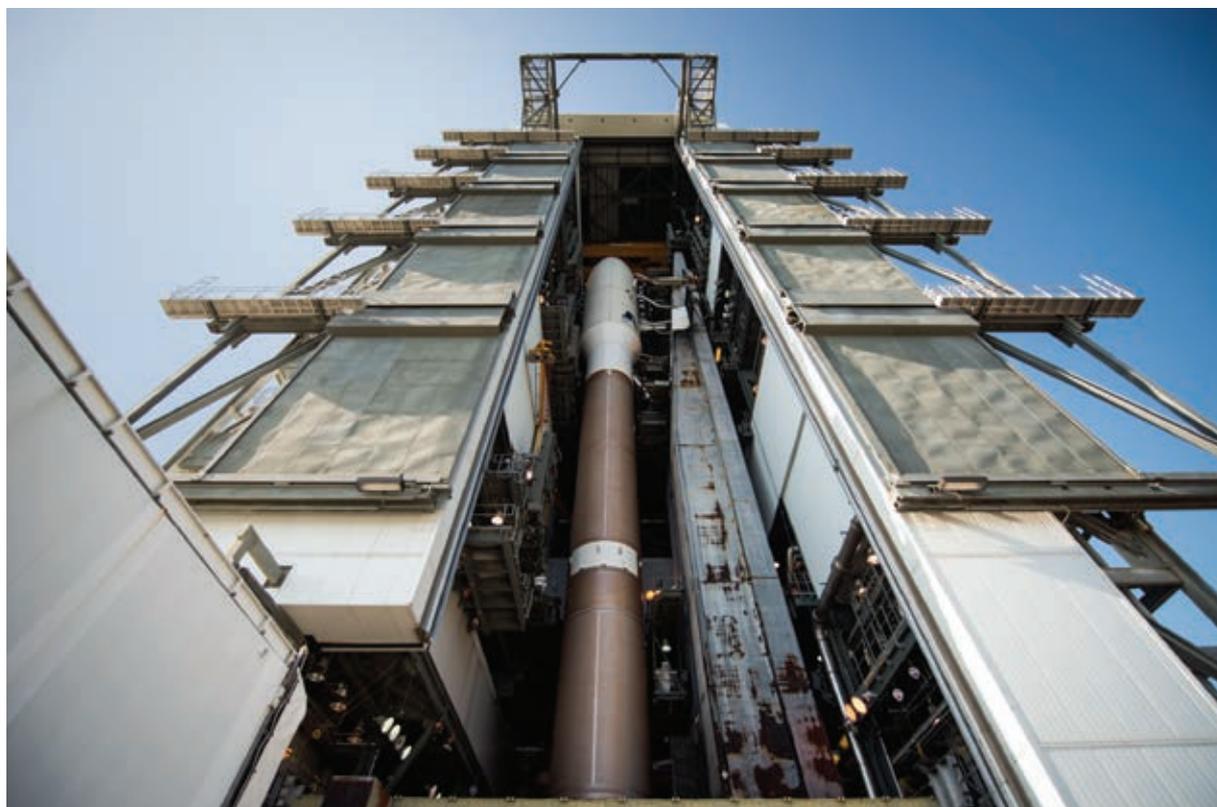
Image: NASA/JPL/Thomas Appéré



ABOVE MESSENGER *dipped closer and closer to Mercury's surface in early 2015, taking high-resolution photos and improving the detail in its composition and gravity maps. Periodically, MESSENGER burned fuel to kick itself into a higher orbit, but the Sun's gravity kept changing the shape of the spacecraft's orbit,*

pushing it inexorably downward. MESSENGER took this oblique photo sequence across the crater Verdi on March 6 from an altitude of only 17.7 kilometers (11 miles)—an airplane-window view onto Mercury. On April 30, mission controllers crashed MESSENGER into Mercury.

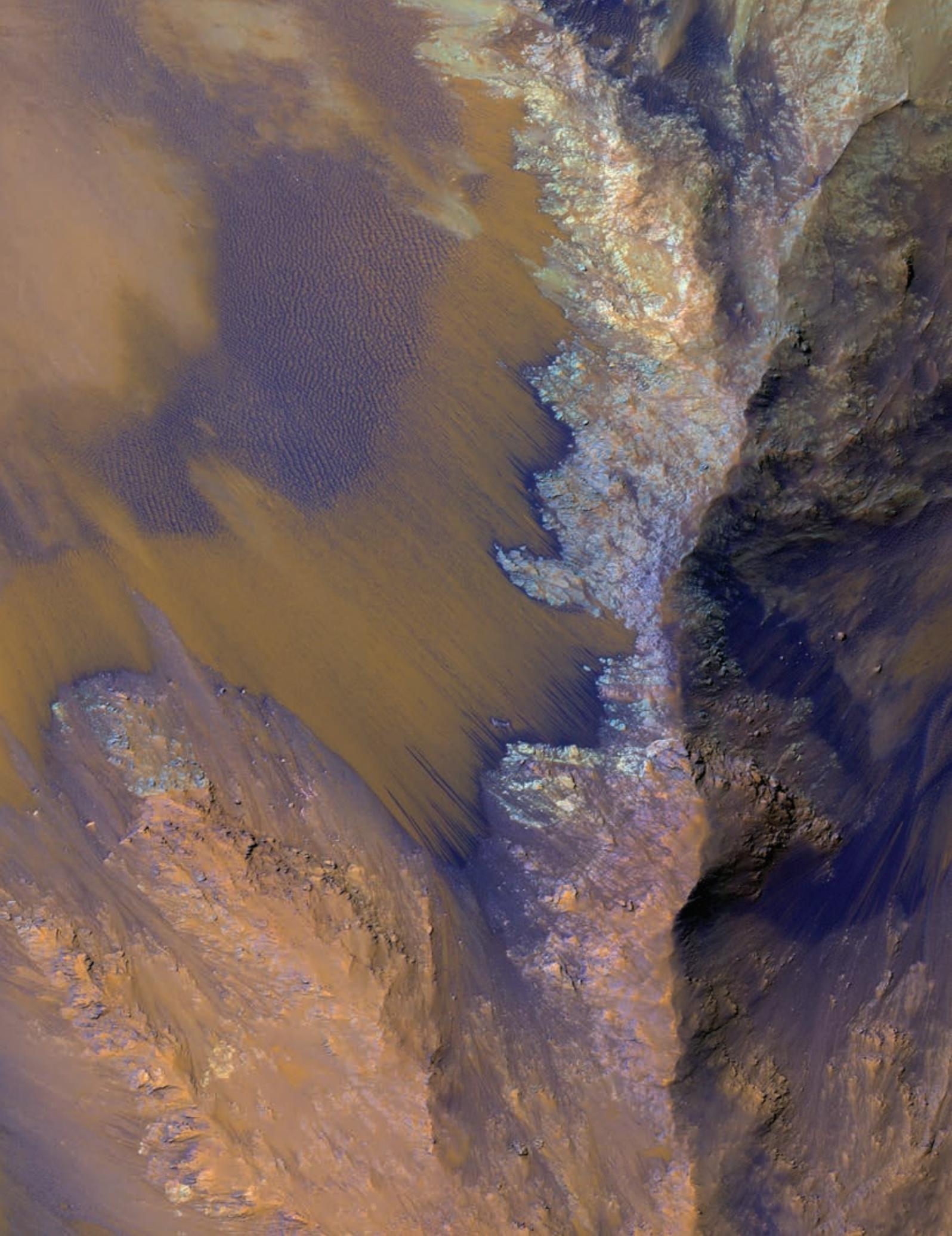
THE YEAR IN PICTURES



TOP In the early morning hours of May 20 at Cape Canaveral, Florida, launch bay doors opened to reveal the Atlas V rocket that would later carry LightSail, The Planetary Society's citizen-funded spacecraft, to Earth orbit.

BOTTOM A landscape of peaked mountains, hazy skies, ground fog, and glacial nitrogen ice greeted New Horizons at the end of its decade-long journey to Pluto. When the spacecraft took this photo, it had already flown beyond Pluto, beginning its journey to an even more distant world in the Kuiper belt, 2014 MU69.

OPPOSITE PAGE Mars Reconnaissance Orbiter celebrated its tenth year in space in 2015. Its longevity has helped it discover and study numerous ways in which Mars' surface changes over time. The dark streaks on the red slope in this image from Coprates Chasma are recurring slope lineae, which appear seasonally and may be seeps of very salty water.



THE YEAR IN PICTURES

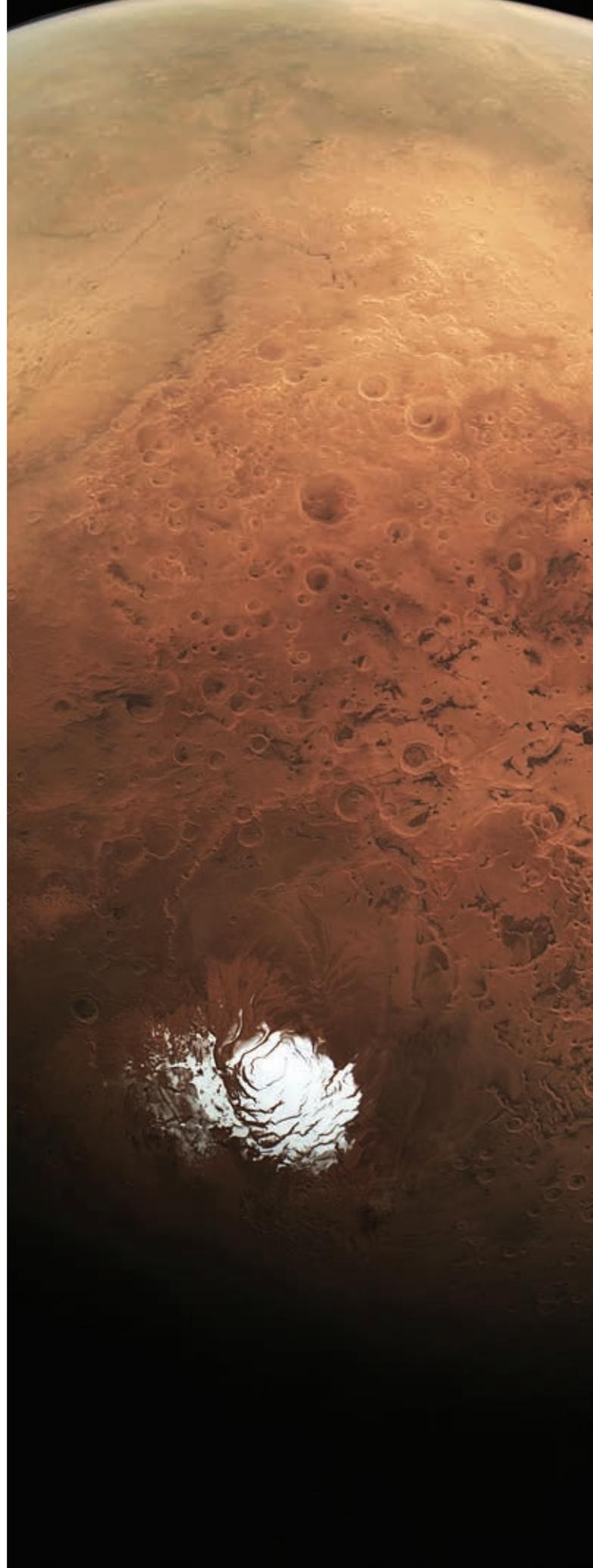
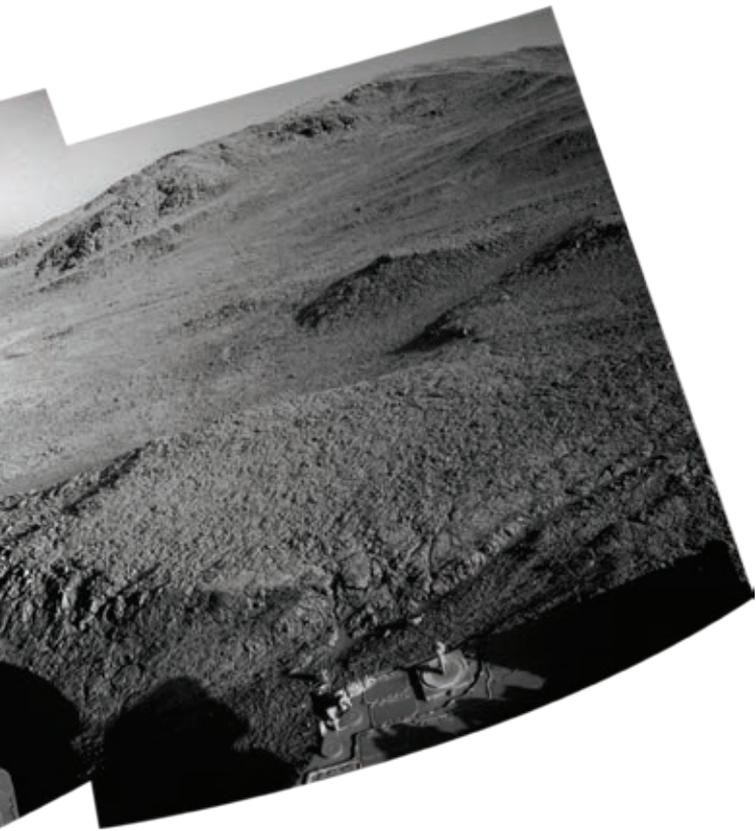


TOP Opportunity surpassed a marathon distance on Mars on March 24, having rolled a total of 42.2 kilometers (about 26 miles) across the Martian surface. The long-lived rover is now enjoying the scenery across the broad expanse of Endeavour crater while scouting Marathon Valley for clay minerals, which bear evidence of ancient habitable environments.

ABOVE LEFT Cassini spent 2015 in Saturn's equatorial plane, which allowed for numerous flybys of the ringed planet's moons. This view of Enceladus, taken on August 17, shows both cratered north polar terrain and the smoother south. Late in 2015, Cassini flew very close to Enceladus three times—its last close encounters. The mission will end in 2017.

ABOVE CENTER Over the course of its 11 Earth years there, Cassini has watched the shadows of Saturn's rings move from the northern part of the globe, across the equator, to their present position in the planet's south. Half a Saturn year is all that Cassini will get—it is running low on fuel and set to plunge into Saturn in 2017.

ABOVE RIGHT We knew Pluto would be interesting, but the varied surface of its binary partner Charon was a big surprise. Charon's pole is stained by reddish carbon-rich gunk; its impact craters have a mix of dark and bright splashes, hinting at subsurface heterogeneity. Its entire southern hemisphere is a smooth plain bounded by a steep scarp, maybe a sign of an ancient volcanic eruption of molten water ice.



ABOVE The Deep Space Climate Observatory (DSCOVR) took up its position between Earth and the Sun on June 7 and began returning regular global portraits of our home planet. Twice a year, as in this photo from July 16, the Moon passes in between DSCOVR and Earth.

RIGHT Mars Express typically shoots images while it is close to Mars, achieving high-resolution, stereo, color views of the Red Planet's surface. But an unusual imaging session from near the top of its elliptical orbit on February 25 permitted it to take in a large swath of the Martian southern hemisphere, from Hellas basin (upper left) to the south polar cap, seen here at the end of southern summer.

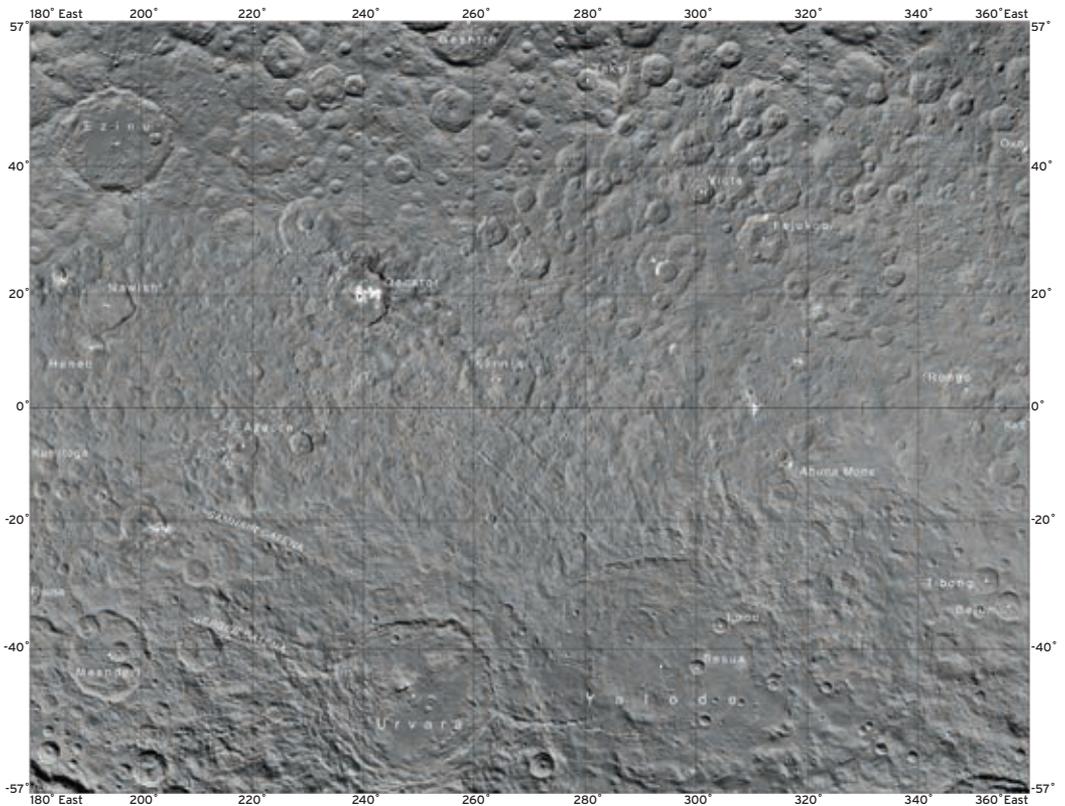
THE YEAR IN PICTURES



TOP After losing its main engine five years ago, Akatsuki achieved something that has never been done before: it successfully entered a planet's orbit using only its attitude control thrusters. Akatsuki took this photo five hours after orbit entry on December 7. The ultraviolet image reveals fine details in Venus' cloud structure. Akatsuki will use photos like this to track Venus' winds and monitor its weather.

CENTER Dawn arrived into orbit at Ceres on March 6, and has already produced our first global atlas of the asteroid belt's largest resident. With the global map complete, Dawn can now focus on Ceres' weird geologic features, like the bright spots in Occator crater, the bizarre pyramid of Ahuna Mons, and the parallel fractures of Samhain and Gerber Catena.

BOTTOM On December 21, SpaceX turned science fiction into reality by launching a spacecraft, ORBCOMM-2, and then bringing the first stage of its Falcon 9 rocket to a gentle, upright landing on a landing pad at Cape Canaveral.



Images: Venus: JAXA; map: NASA/JPL/UCCLA/MPS/DLR/IDA; Landing Image: SpaceX



IN THE SKY

In February and March, planets are spread across the predawn sky, from bright Venus in the East, to Saturn and Mars in the South, to Jupiter in the West. Note how they fall roughly in a line because they all orbit generally in the same plane. Throughout the spring, bright Jupiter rises in the midevening East. On March 8 or 9, depending on location, there is a total solar eclipse visible from parts of Indonesia and the Pacific Ocean, with a partial solar eclipse visible from eastern Asia, much of Australia, and Hawaii.



RANDOM SPACE FACT

Jupiter's moon Ganymede is larger in diameter than the planet Mercury, but has only about half its mass.



TRIVIA CONTEST

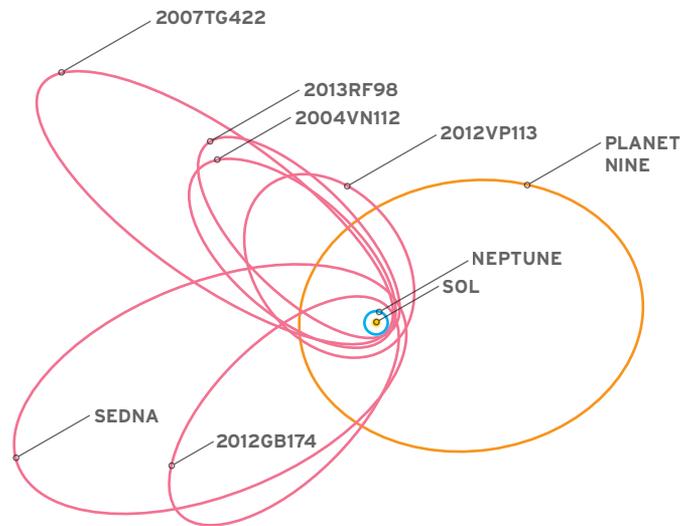
Our June Solstice contest winner is Claire Little of Oakland, California. Congratulations! **THE QUESTION WAS:** What five spacecraft are on escape trajectories from our solar system, i.e., they will leave and never return? **THE ANSWER:** *Pioneer 10, Pioneer 11, Voyager 1, Voyager 2, and New Horizons.*

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

What material forms the bulk of Mars' seasonal polar caps (the ones that grow in the winter and dissipate in the summer)?

E-mail your answer to planetaryreport@planetary.org or mail your answer to *The Planetary Report*, 60 S. Los Robles Ave., Pasadena, CA 91101. 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, 2016. 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.



CALTECH SCIENTISTS Konstantin Batygin and Mike Brown have found evidence of a giant planet with a bizarre, highly elongated orbit in the outer solar system. The object, which they've nicknamed Planet Nine, is about 10 times the mass of Earth and orbits about 20 times farther from the Sun than does Neptune (which orbits the Sun at an average distance of 4.5 billion kilometers or 2.8 billion miles). In fact, it would take Planet Nine between 10,000 and 20,000 years to make just one full orbit around the Sun.

The researchers discovered the planet's existence through mathematical modeling and computer simulations but have not yet observed the object directly.

Brown notes that the putative ninth planet—at 5,000 times the mass of Pluto—is sufficiently large that there should be no debate about whether it is a true planet. Unlike the class of smaller objects now known as dwarf planets, Planet Nine gravitationally dominates its part of the solar system. In fact, it dominates a region larger than any of the other known planets—a fact that Brown says makes it “the most planet-y of the planets in the whole solar system.”

Batygin and Brown report on their findings in a paper entitled, “Evidence for a Distant Giant Planet in the Solar System” in the January 20, 2016 issue of the *Astronomical Journal*.

To read more, go to planet.ly/planet9. 🌌

ABOVE The six most distant known objects in the solar system with orbits exclusively beyond Neptune all line up mysteriously in one direction (magenta). They also tilt nearly identically away from the plane of the solar system. Batygin and Brown show that a planet 10 times as massive as Earth, with an orbit anti-aligned to those six worlds (orange), is necessary to maintain this configuration.

Illustration: Loren A. Roberts/Caltech/R. Hurt (IPAC)



NADIA DRAKE *writes for*
National Geographic.



How Can We Write About Science When People Are Dying?

PARIS WAS horrific.

Yet as I watched that horror unfold, in a city that was once known as “The Paris of the Middle East,” dust clouds were falling onto a street streaked with blood. Beirut had been hit by one of the deadliest bombings since the Lebanese civil war ended in 1990.

It was a story that was both a world away and yet deeply personal. My mother’s family came to the United States from Lebanon when she was a teenager. Decades earlier, my great-grandmother had left Syria and moved

to a small fishing village north of Beirut (later, my grandparents would honeymoon near Aleppo, if you can even imagine a time when that was possible).

In other words, the blood that ran through that street also runs through me.

It was hard, in the face of such unrelenting violence, to focus on work. I found it incredibly difficult to try and describe bodies in the solar system when bodies on Earth were falling to the ground.

I felt utterly useless.

I stewed and stewed, and stewed some more, and emerged briefly and wrote to Kareem Shaheen, a friend who's based in Beirut and covers the Middle East for the *Guardian*.

"I wish there were something I could do to help, or something that would at least make a difference. Want to swap jobs for a bit?" I suggested, half joking.

His response was, in a nutshell, that science has the power to redeem and inspire, and that casting our eyes to the stars can unite every human on Earth. Then he echoed a sentiment I'd heard a day earlier: Keep writing about science. It's important, and it's inspiring.

"There's a unifying beauty to it—you can appreciate the stars and planets whether you're Sunni, Shia, Hindu, Christian, Jew, atheist or Wiccan," Kareem said. "Finding new things to discover, wondering at what could be up there, us being the universe contemplating itself, setting our sights at conquering a new frontier, that's what we should be doing."

It's true. We can all walk outside and look up and admire the same stars, regardless of the stories we inscribe upon them. Kareem went on to describe how watching Venus cross the face of our Sun helped bring him closer to his dad, and to the threads that connect our planet with the cosmos.

"I was in college and wanted to see the Venus transit but couldn't find any filters to use on my telescope," he recalled. So, his dad went out and found a welding mask that would let Kareem safely observe the sun. As he peered through the mask and into the eyepiece, Kareem saw Earth's sister marching across the great golden disk that powers life on our planet.

"Venus was just a speck in my feeble excuse of a telescope, but it was gorgeous," he said. "Seeing it as a tiny fleck against the Sun was sort of like the pale blue dot idea—of how fragile and vulnerable the thread is—and now, thinking back to it, it drives home how insignificant our differences are in the grand scheme of things."

I'm not an optimist by nature—"realist" is the description I prefer—but I'd like to think that he's right, that sharing the wonder of science, exploration, and adventure can be an antidote, in some small measure, to suffering and destruction.

"I wish there were something I could do to help, or something that would at least make a difference. Want to swap jobs for a bit?"

In retrospect, I should have known this all along. Finding solace in the sights and patterns of the natural world has been a part of me since year one: Before I was old enough to walk or talk, my family discovered that showing me the shimmering moon was often the only way to calm me down.

Sometimes the best thing we can do is be good to one another and share stories of the human mind and spirit at their best.

The last story I published before Paris and Beirut erupted was about how Pluto's heart grew from the crater left by an enormous impact. Instead of turning into another big, ugly scar on the planet's surface, the crater played an important role in the birth of a feature that we see as a symbol of love and compassion. I hope there's a metaphor in there somewhere. 🌱

NADIA DRAKE is a science journalist who grew up thinking about cosmic questions and staring at Saturn through giant telescopes. Her work has also appeared in *Science News*, *Nature*, *New Scientist*, *Proceedings of the National Academy of Sciences*, and *WIRED*. The daughter of SETI pioneer Frank Drake, Nadia lives in beautiful, foggy San Francisco. This piece originally appeared on National Geographic's blog site *Phenomena* on November 19, 2015. It is reprinted here by permission of the author.



CASEY DREIER is director of space policy for The Planetary Society.

More Important Than Ever

Space Exploration Can Bridge Political Divides

OPTIMISM FEELS IN short supply these days. Whether it was the avalanche of bad news that closed out 2015 or the unpleasant politics of a presidential election year dominating the start of 2016, it doesn't exactly feel rosy out there. But we shouldn't ignore the extraordinary counter-narrative happening all around us. It's one in which humanity is progressing—peacefully, cooperatively, profoundly—in its understanding of the cosmos.

EXTRAORDINARY ACHIEVEMENTS

The year 2015 saw the first up-close images of Pluto and Ceres; the discovery of flowing water-brine on Mars; a landing on a comet; confirmation of a global ocean on Enceladus;

will be NASA's best budget in five years.

And after four years of sustained effort by our members to restore NASA's Planetary Science Division budget to \$1.5 billion per year, Congress blew past our goal, allocating \$1.63 billion to the program for 2016. That's \$270 million above the amount originally requested by the White House.

Thanks to this funding boost, the *Opportunity* rover and *Lunar Reconnaissance Orbiter* mission are now fully funded for 2016. The upcoming *Mars 2020* rover got a boost in development funding, planetary science research grants grew with inflation, the plutonium-238 restart project will stay on track, and, in a surprising move, Congress

this year. The Space Launch System rocket grew by nearly 50 percent to \$2 billion. The Commercial Crew program got the full amount requested by NASA for the first time ever; it will get \$1.24 billion to stay on track for its first crewed launches in 2017. Earth Science, Astrophysics, Aeronautics, all saw increases. The only major cut was to the Science Technology Mission Directorate.

IT'S UP TO US

By the time you read this, the president's 2017 budget request will be out, the annual cycle will have begun again, and the 2016 budget will be old news. I hope you continue to stay engaged—or decide to get engaged—with our calls to action. Budgets like 2016 don't just happen; we hear

THE ADVOCACY PROGRAM
2015 BY THE NUMBERS

120,087

Messages supporting planetary exploration sent to Congress and the White House

32,257

Number of Society members and supporters who sent those messages—a new record

\$108,062.22

Amount raised for The Planetary Society's Advocacy Program. The second year in a row we raised over \$100k

1,917

Number of individual donors who gave to the Advocacy Program (thank you!)

the start of a new mission to explore Europa; an astronaut living for a year in space. The list of achievements goes on.

The U.S. Congress must have been impressed, because they provided NASA with a 7 percent budget increase for 2016. At \$19.3 billion, this

added language requiring NASA to include a lander with its upcoming Europa flyby mission in the early 2020s—yes, it's now U.S. law that NASA must land on Europa. Sorry, monoliths!

Nearly every program at NASA will see a budget boost

time and time again about the importance of Society members engaging their representatives (and for members outside of the United States, writing the White House). I feel we've turned a corner with NASA's budget, and it's up to us to continue to push to keep this

budget growing.

And should you ever need extra motivation to make that call to Congress or write that letter to the White House, 2016 has you covered:

In March, ESA's *Trace Gas Orbiter* will launch to Mars. It's Europe's first Mars mission in 13 years, and is designed to detect methane and other intriguing atmospheric gases. It will also deploy a Russian-made test landing system to prepare for the more ambitious *ExoMars 2018* rover.

In July, NASA's *Juno* spacecraft will fall into a graceful orbit around Jupiter to begin a one-year campaign at our solar system's largest planet. *Juno* is the first spacecraft to orbit Jupiter since *Galileo*. It has an onboard camera for

on its eight-year journey to the asteroid Benu and back.

And don't forget humanity's existing fleet of spacecraft: *Lunar Reconnaissance Orbiter*, *Akatsuki*, *MSL Curiosity*, *MER Opportunity*, *Mars Odyssey*, *Mars Reconnaissance Orbiter*, the *Mars Orbiter Mission*, *MAVEN*, *Mars Express*, *Hayabusa 2*, *Rosetta*, *Dawn*, *Cassini*, and the *Voyagers* will be actively exploring the solar system. *New Horizons* will continue to downlink its data from the Pluto flyby. Every day there will be something seen for the first time by human eyes.

ADVOCATING FOR A GREATER CAUSE

All of this will occur in the background of the U.S. presidential election. With your help, we

the issue with any of the candidates yourself.

As you may have already noticed, the presidential election season doesn't exactly bring out the best in politics or politicians. Calling it divisive is an understatement. And the antagonism it generates infects every aspect of politics, potentially resonating for years after major elections.

But I see space exploration as the demilitarized zone of partisan politics. The unique coalition forged by common bonds of space can provide the opportunity for politicians to engage on a personal level to develop the goodwill and trust necessary for functional politics.

Space exploration has the power to bring people together

\$638 million

Amount added by Congress since 2013 to NASA's Planetary Exploration Division

10,000+

Number of times the Society's Humans Orbiting Mars report was downloaded online

2

Number of full-time staff focused on space policy and advocacy at The Planetary Society—the most ever in our history

1

Number of new planetary exploration missions entering formulation in 2015 (the Europa multiple flyby mission, scheduled to launch in the mid-2020s)

the sole purpose of supplying beautiful images for the public.

Come fall, the *Trace Gas Orbiter* will enter Mars orbit and drop its test landing payload. As if that's not enough, NASA's asteroid sample return mission, *OSIRIS-REx*, will launch from Cape Canaveral

are building the best reference guide to each candidate's positions on space exploration. Go to planetary.org/election2016 to see what your favorite candidate has said about NASA, and e-mail us at election2016@planetary.org if you have had a chance to raise

in a way that few other things can. It's as if the better angels of our nature have sprung into being, formed in metal and circuits, and are sending us daily data containing insights into the unknown, forcing us to look outside ourselves and into the cosmos. 🌌



HAPPENING ON
PLANETARY RADIO
planetary.org/radio

A TINY EXPLORER CALLED TWINKLE

A small but talented U.K. team is building Twinkle, a small spacecraft with a big mission: exploring the atmospheres of planets orbiting other stars. planet.ly/twinkle

CONGRESSMAN JOHN CULBERSON: A GOOD DAY FOR SPACE

The newly approved federal budget includes great news for fans of space exploration and development. Texas Congressman John Culberson led the fight for a Europa mission, the SLS rocket, commercial crew and more, and discusses those projects and more on the show. planet.ly/culberson

THE WORLD'S BIGGEST TELESCOPE THREATENED?

Mat Kaplan talks with science journalist Traci Watson about the departure of the great Arecibo radio telescope's director and the funding challenge that could shut down the observatory. planet.ly/arecibo

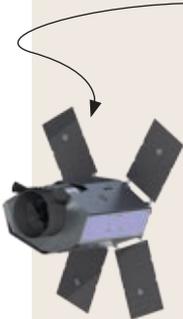
AD ASTRA BUILDS "THE MARTIAN'S" ROCKET ENGINE

Mat Kaplan visits the Ad Astra Rocket Company in Texas, where they are perfecting the VASIMIR electric rocket engine. planet.ly/adastrarockets

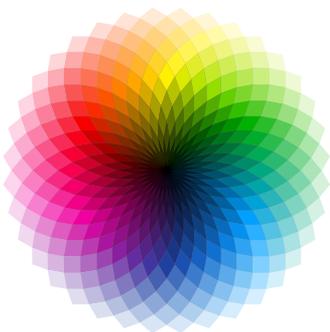
MASTER OF THE MOON ROCKS

Francis McCubbin is the new astromaterials curator at NASA's Johnson Space Center, where the priceless collection includes the *Apollo* moon rocks. planet.ly/mccubbin

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



ON PLANETARY.ORG



MAKING SPACE LOOK RIGHT
COLORS IN PLANETARY IMAGING

Travis Rector takes an in-depth look at the art and science of creating the space images we love. planet.ly/imagingcolors

MISSION UPDATE

PREPARATION FOR FLIGHT Jason Davis recaps the initial round of system-level tests for *LightSail's* primary mission. planet.ly/lightsailprep

PLUTO UPDATES

PRETTY PICTURES FROM A CONFUSING WORLD Emily Lakdawalla reports on discussions about Pluto taking place at the American Geophysical Union conference and Division for Planetary Sciences meeting. planet.ly/confusingworld



DELAYED MISSION
INSIGHT'S PROBLEMS
Van Kane explores the ramifications of canceling the launch of a Mars-bound lander. planet.ly/insightproblems

SPRING 2016
FREE COLLEGE CLASS
Deepen your knowledge with Bruce Betts' weekly *Introduction to Planetary Science and Astronomy* class. planet.ly/bettsclass

CROWD-SOURCING SPACE
CHINA OFFERS DATA Quanzhi Ye details how China will be making *Chang'e 3* probe data available for public use. planet.ly/chinaexploration



MANNED SPACECRAFT
NASA PURSUES DREAMCHASER NASA added a mini shuttle to its fleet of commercial spacecraft capable of traveling to the ISS. planet.ly/dreamchaser



KATE HOWELLS is *The Planetary Society's Volunteer Network Manager.*

Wild, Wonderful Trips for Our Members!

TANZANIA ANNULAR ECLIPSE

AUGUST 23 - SEPTEMBER 3, 2016

Lions, leopards, and elephants, plus the Eclipse. We have room for just a few more members!

MADAGASCAR ANNULAR ECLIPSE

AUGUST 20 - SEPTEMBER 4, 2016

Lemurs and more! Space is limited.

CHILE ANNULAR ECLIPSE EXPEDITION

FEBRUARY 22 - MARCH 4, 2017

With optional Easter Island extension March 4-7, 2017

ALASKA AURORA BOREALIS EXPEDITION

MARCH 2 - 8, 2017

"The Greatest Light Show on Earth"

See Alaska's dazzling night sky, spectacular snow-covered peaks, grizzlies, moose, bald eagles, and Denali (Mount McKinley). Ride the train from Talkeetna to Fairbanks for special lectures in Fairbanks. See the Ice Art Festival and experience the Aurora at Creamer's Field and Alpengrest Observatory.

Join fellow Planetary Society members on these terrific adventures! To learn more, call Betchart Expeditions at 800-252-4910, or visit betchartexpeditions.com.



Building the Mars Generation

AT THE PLANETARY SOCIETY, we love a term that is increasingly being used to refer to today's young people: "The Mars Generation." These are the kids who will grow up to see



humans operating on Mars, and they are the ones who will make it a reality. They are the scientists, engineers, and astronauts of the future—to name just a few of the many people who make space exploration happen.

The term "The Mars Generation" paints an optimistic future for a generation with great potential, and The Planetary Society's volunteers are committed to creating this future. Around the world, our volunteers get out into their communities and work with children, drawing them into the exciting adventure that is space exploration. In schools, at science centers, and out on city sidewalks, the Society's volunteers engage with young people to fuel their natural interest in the world around them, spark their imaginations, and get them looking to the skies.

No matter where they live, our volunteers and outreach coordinators teach local kids that they can have a role in the future of space exploration. They are proud to be doing their part to help the Mars Generation live up to its name.

To learn more about our volunteers' activities, check out planetary.org/blogs/volunteers. To get involved in your community, join us at planetary.org/volunteer.



ABOVE LEFT Outreach Coordinator Cori Charles (far left) brings space down to Earth for these Southern California girls.

TOP RIGHT Kids in a volunteer-run astronomy club in Venezuela.

BOTTOM RIGHT A volunteer's telescope gives this boy a peek at his future.



BRUCE BETTS is director of science and technology for The Planetary Society.

Planetary Deep Drill Field Test

Road Trip to the Salton Sea



The nearly 4-meter-high Planetary Deep Drill (PDD) during its December 2015 field test. Planetary Society staff, shown for scale, are (left to right) Merc Boyan, Andrew Pauly, Bruce Betts, and Mat Kaplan.

NOTHING SAYS “holiday season” like a 4-meter wire-line drill digging its way into tens of meters of rock in a gypsum quarry. So, in December, several of us from The Planetary Society took a road trip to a gypsum mine near the Salton Sea in southeastern California. For several weeks in November and December 2015, the quarry was home to the first field test, sponsored in part by The Planetary Society, of the Honeybee Robotics Planetary Deep Drill (PDD).

The PDD is a prototype of a robotic drill that could bore hundreds of meters into icy planetary surfaces such as the Martian polar caps, Europa, or Enceladus. This revolutionary technique in planetary exploration would allow the sampling of materials that have not been altered or destroyed by surface processes, and it would help us look back in time by digging into geologic strata laid down in the past.

With support from the American Museum of Natural History, the PDD was designed and built by Honeybee Robotics.

Honeybee has lots of experience in building sampling hardware for planetary spacecraft, including several recent Mars landers and rovers. The Planetary Society sponsored this first test of the PDD outside the lab, which basically was a full test of the automated below-ground drilling, the real innovative aspect of this instrument. Everything above ground was human-assisted in the test but would be automated in a future planetary deep drill, including on other worlds.

Why gypsum? Because it has strength properties similar to water ice at cold planetary temperatures, and it is a lot easier and cheaper to mount a first field expedition to a gypsum mine rather than an ice sheet. US Gypsum made their quarry available for the tests. After a safety briefing from US Gypsum personnel, we were off to the drill site, carefully avoiding their giant gypsum-hauling trucks.

As we approached, we saw the PDD drilling next to a U-Haul truck that served as the headquarters and control center for the field

Photo: Kris Zacny

Thanks!

Planetary Society members have helped make these grants—and many other projects—possible! Thank you.

test. The 4-meter drill is lowered on a wire-line and also has an umbilical housing along with power and data cables. When we arrived, the drill was down to more than 13 meters (more than

are also numerous sensors feeding back information about everything from temperature to electric current.

The tests went extremely well. Honeybee is evaluating lessons learned and figuring

Random Space Fact videos at the quarry and on our way back, as well as a science and technology video about the drilling. Media Producer Mat Kaplan recorded a *Planetary Radio* episode about



42 feet) below the surface. Though it was drilling, it was so deep that one could not actually hear the drilling sounds. During the drilling process, the PDD drills 10 to 20 centimeters over the course of tens of minutes, then the human crew reels it up from the hole, cleans out the cuttings, then lowers it again. This gets repeated over and over.

The drill has many sensors, including a visible wavelength camera and a UV light to look for fluorescence. The drill also deploys pads designed to hold it in the bore hole as it drills. These pads not only hold the drilling mechanism in place, but also make for a system that is not very dependent on the surface gravity of a planetary body. There

out how to apply them to future designs and implementations. And now, thanks to a NASA grant, there will be future Earth versions of the Deep Drill that will include an advanced JPL science instrument—a modified-to-fit version of the SHERLOC UV Raman and fluorescence spectrometer, a mineralogy-determining instrument that will fly on the Mars 2020 rover. JPL engineers were out at the site the same day we were learning more about the drill. So, we all can look forward to more field tests, probably in gypsum in 2016, followed by more exotic tests in a Greenland ice sheet sometime in 2017.

On our trip, Planetary Society Creative Director Merc Boyan and I shot several

Planetary Deep Drill, and Communications Coordinator Andrew Pauly collected images and information he shared on The Planetary Society's social media channels. Plus, Digital Editor Jason Davis is doing a follow-up blog with more detail on the field test and lessons learned. You can find links to all these at planet.ly/pdd.

Our expedition to the quarry was a fun and informative trip, thanks to our Honeybee Robotics and US Gypsum hosts, particularly to Kris Zacny, Honeybee's vice president and director of exploration technology. Not long ago it was just an idea, but Planetary Deep Drill has deep drilled into a planetary surface, and that put all of us in the holiday spirit. 🐝

LEFT The PDD suspended above the 13.4-meter-deep hole it drilled into gypsum during the first field test of the system.

MIDDLE In the future, a drill head like this will be caked, not with Earthly gypsum, but with ice from below the surface of Mars or Europa.

RIGHT The drill head and auger motors get hot during the drilling process, so their temperature is closely monitored with an infrared thermometer.



I've been a commercial photographer for 50 years and a Planetary Society member for at least 25 of those years. In March of 2015, I took a trip to Iceland with Betchart Expeditions and The Planetary Society to view the total eclipse of the Sun from a Boeing 757. By sheer luck, we witnessed some rare, level-6 auroral activity one night as well. I took this photo standing in front of a newly built hotel in the northern back country, looking roughly west by northwest. This will not be the last trip I take with Betchart Expeditions! – *Mark Remaley, Valparaiso, Indiana*



It took me a couple of years and a few different cameras, but all of these images were shot through my 8-inch Schmidt-Cassegrain telescope from my backyard: the Sun, Mercury, Venus (in infrared and blue light), the Moon (in hyperreal color), Mars, Jupiter (with Ganymede), Saturn, Uranus, and Neptune! – *Franklin Marek, Slidell, Louisiana*

WANT TO SHARE YOUR SPACE IMAGE? Send us an e-mail with a jpeg attachment (less than 5 MB) 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. Be sure to include your name, contact information, and membership number. We'd also love to learn more about what is most important to you about being a member of The Planetary Society. Questions? E-mail planetaryreport@planetary.org.



Bright Venus reappears nearly two hours after disappearing behind the Moon.
– *Paulene Acalin, Costa Mesa, California*



I worked at The Planetary Society as an intern about 15 years ago. I was inspired by the work and the people and, of course, by space and the night sky. I still take that inspiration with me each time I go out to take photos of the night sky. I hope this photo helps to inspire others to look upwards.
– *Evan Thomas, Ridgecrest, California*



This photo was taken while stargazing in Pennsylvania's Cherry Springs State Park, one of the east coast's best dark sky sites. I'd been chasing a clear, Moonless night for a while, and I was very happy to get what I was looking for!
– *Alex Hengen, Centreville, Virginia*



Looking Up While Drilling Down



Honeybee Robotics' Huey Nguyen monitors the Planetary Deep Drill during its first field test in December 2015.

Our CEO, Bill, asserts that space exploration is inherently optimistic and points out that it's "beyond the horizon that we make discoveries."

So, what could there possibly be in common between gazing deep into the cosmos to find an inspiring future beyond the horizon, and off-roading in the desert to drill 10 meters into a gypsum mine? To create a visionary future, should we be looking up and out into the vast and beautiful depths of space, or should we be looking down past the white dust accumulating on our boots?

The answer is both. Led by our own Bruce Betts, The Planetary Society's Science and Technology program is all about getting into the nitty-gritty details of the technologies we will need to pursue the hard work of space science. The Planetary Deep Drill project that Bruce discusses in this issue is a perfect example. It is being built to help answer one of humanity's greatest questions (are we alone?) by drilling down through the icy crust of another world. The Planetary Deep Drill won't be ready to deploy for years, but developing innovative technologies to answer "the deep questions" requires that we get started well in advance. And early seed investments such as this can often be the most efficient and effective way for us leverage our resources to make the greatest impact.

The financial support of our members is key to these efforts. Projects like Planetary Deep Drill, PlanetVac, Laser Bees, and, yes, *LightSail™* are possible only because you make them happen. Thanks to you, the great journey of discovery literally begins just over the horizon—a few hours away in the harsh Southern California desert.

Onward,

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