

THE PLANETARY REPORT

DECEMBER SOLSTICE 2017

VOLUME 37, NUMBER 4

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THE YEAR IN PICTURES

HIGHLIGHTS FROM 2017



RICHARD CHUTE is The Planetary Society's chief development officer.

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As our famous CEO might say, consider the following ...

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ON THE COVER: For those lucky enough to have seen it, the North American Eclipse on August 21, 2017 was a life-changing moment—especially for those viewing a total solar eclipse for the first time. Screams of delight, tears, and cheers erupted across the United States as the eclipse followed its path of totality across the continent. Science was done, people came together, and everyone—even those seeing a partial eclipse—had fun watching Earth's Moon pass in front of its star. Planetary Society Web Editor Tanya Harrison photographed the eclipse from an altitude of 11.6 kilometers (38,000 feet) on board special Alaska Airlines Flight "Solar 1." Read Tanya's account of her experience at planet.ly/chasingtotality.



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The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016, 626-793-5100. It is available to members of The Planetary Society. Annual dues are \$50 (U.S. dollars) for members in the United States, as well as in Canada and other countries. Printed in USA. Third-class postage at Pasadena, California, and at an additional mailing office. Canada Post Agreement Number 87424.

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BILL NYE is chief executive officer of The Planetary Society.

A Busy Year-End

Our Reach Is Expanding, and We're Ready to Fly

MY FIRST TRIP to Australia was spectacular. In late September, I went with my colleagues Erin Greeson and Andrew Pauly to this year's International Astronautical Congress in Adelaide. I presented some technical aspects of *LightSail 1* and *LightSail 2*, and I spoke about how The Planetary Society, as the world's largest non-governmental space organization, connects people all over the world with space exploration. The presentation was very well received.

During the opening ceremony, Australia's Education Minister Simon Birmingham announced that his country is establishing its own space agency. Australia's Canberra complex has always been an indispensable part of the Deep Space Network, which keeps us in touch with spacecraft all over the solar system and beyond. While there, we were taken on wonderful tours of South Australia with Science and Information Technology Minister Kyam Maher. In the outback, one can really get a sense of how wide open and trackless most of that continent is, and how well-suited to observing the southern sky. I am certain that the new space agency will lead to new opportunities, technological advances, and prosperity for Australia and the world. Congratulations, Australia!

At the Congress, we made sure to attend the talk given by SpaceX CEO Elon Musk. He presented a plan to build the Big Falcon Rocket (BFR), a rocket large enough to go to Mars, that could also be used to make intercontinental and transcontinental trips here on Earth. In its ultimate embodiment, the BFR's fuel would be made from scratch using renewably produced electricity to evolve methane from atmospheric carbon dioxide and water. It's visionary. Our talks were both about new kinds of spaceflight; each technology uses (or will

use) sunlight to either propel a *LightSail* or produce a fuel for chemical propulsion. I'm no captain of industry, but I like to think that our talks were so well attended because we each presented new ideas for interplanetary flight.

MORE GREAT NEWS

Speaking of engaging people from all over the globe, I hope you'll try your hand at what we're calling our #SpaceHaiku. People like you have been submitting space-themed haiku-style poems (in English). Check them out on Facebook/Planetary or at planetary.org. Remember, a haiku has just three lines. The first line has five syllables, the second line has seven, and the third line has five again. In traditional Japanese fashion, a haiku refers to nature and the world around us. A haiku seldom rhymes (but I confess I don't mind if they do). People around the office got started on these, and it has proven to be a lot of fun. Now and then, one of these poems really gives you pause for thought. I'm not saying this one will, but you can get the idea:

*With our haiku hands
What's written may be in sands
Of Mars, one day soon*

Send in a #SpaceHaiku of your own.

Since our beginning, The Planetary Society has emphasized the international nature of space exploration and the terrific benefits inherent in international cooperation. I'm proud to announce that our own global community outreach coordinator, Kate Howells, has been asked to join Canada's Space Advisory Board. This is a big step for Kate and for us. She will provide our perspective on the best use of Canada's intellect and treasure to advance

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space exploration. With Kate's new role, we are represented on the board of a space agency outside of the United States. Our international reach is expanding!

LOOKING FORWARD

As another amazing year for you and your Society winds down, I hope you feel our excitement for the year ahead. As I write, our *LightSail 2* spacecraft's batteries are charged up, and its internal clock is running. SpaceX is preparing to flight-test its first Falcon Heavy rocket. We're ready to fly. As soon as we get the go-ahead from NASA, we will ship *LightSail 2* to Cape Canaveral to be loaded atop the second Falcon Heavy rocket. Thanks to you and your support, our very capable little spacecraft will maneuver, tack to build orbital energy, fly higher, and help us learn more about sailing on sunlight. The world will be watching what you have made possible.

And thanks to you, our diligent advocacy work in Washington, D.C. is proving to be more effective than ever. Today, we have three full-time people focused on space policy and advocacy, with two based in Washington, D.C. As I've written here in the past, Washington is essentially a small town that runs on relationships. There may be millions of people in Washington's metropolitan area, but the key people for us are the congressional staffers who analyze, think through, and ultimately write the space policies that become laws and produce budgets. The House of Representatives voted to increase NASA's planetary science budget to a record \$2.1 billion, in no small part due to our well-targeted, credible advocacy. Our policy people, Casey Dreier, Jason Callahan, and Matt Renninger, will be more involved than ever in helping NASA



shape its planetary exploration plans.

With all this, I hope you'll continue your support of space exploration. Thanks to you, we are doing more to connect people everywhere with space. Write to us. You are always free to send letters to the editor (at right). Tell us what you hope for in space. For my part, I feel strongly that we want to look for life out there. Such a discovery would be profound, changing the way each and every one of us feels about being a living thing in the cosmos. One big aspect of this search is the search for extraterrestrial intelligence (SETI). Check out Jason Davis's story on the Society's history of work in this field on page 13. With the discoveries made during my lifetime, we've come to realize the vital nature of really knowing our place in space. It's up to us to advocate for good policies, create innovative ways to explore, and educate the world about the importance of space to our lives. For example, the work we do now could help prevent Earth from getting hit by an asteroid or comet. It's a real threat, and you and I are uniquely positioned to ensure that proper programs get put in place.

It's an exciting time. Let's change the world. 🌍

Bill Nye

ABOVE South Australia's Minister for Science and Information Technology Kyam Maher and Planetary Society CEO Bill Nye discuss Earth science and space exploration at the Nilpena fossil site.



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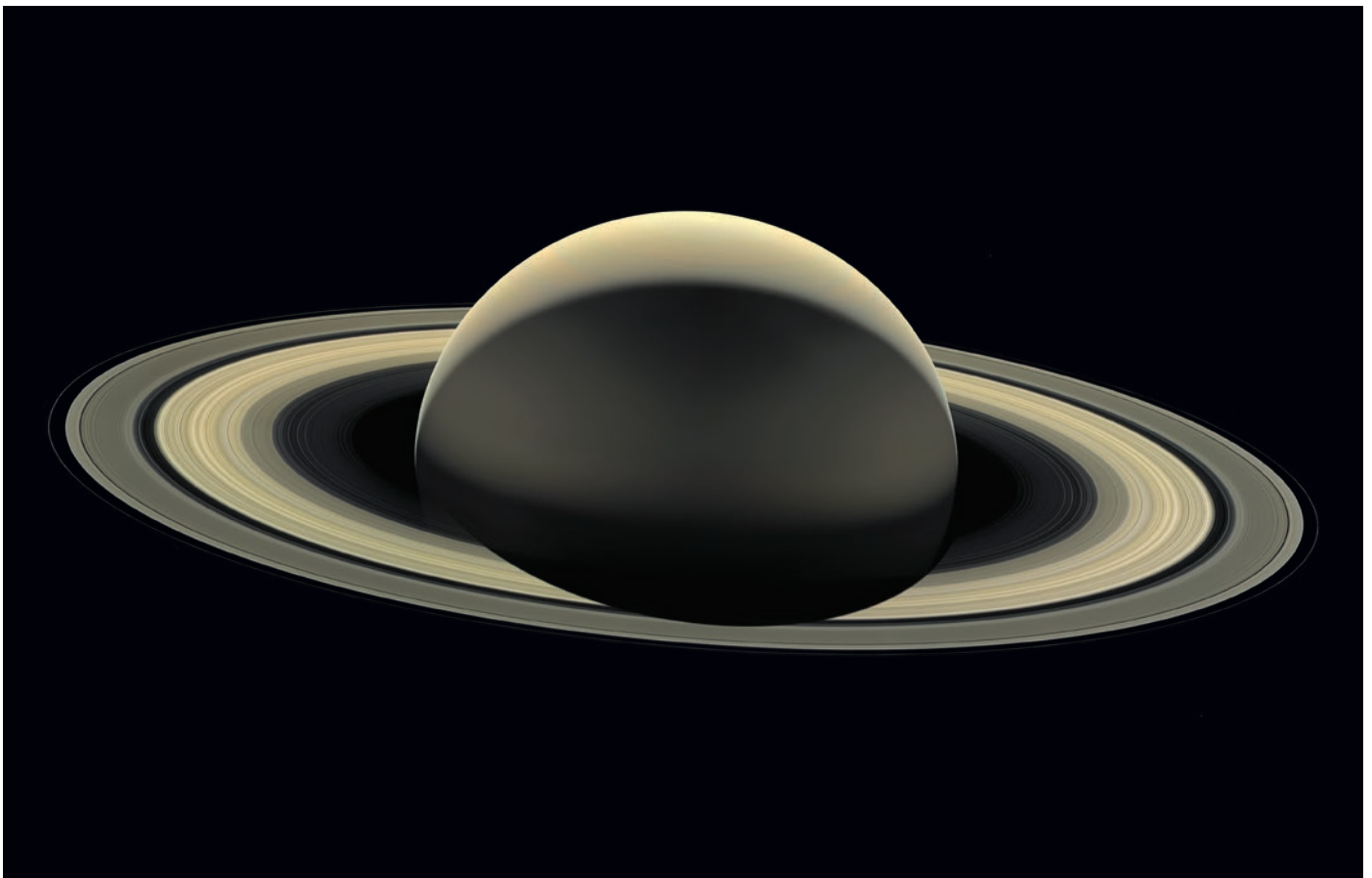
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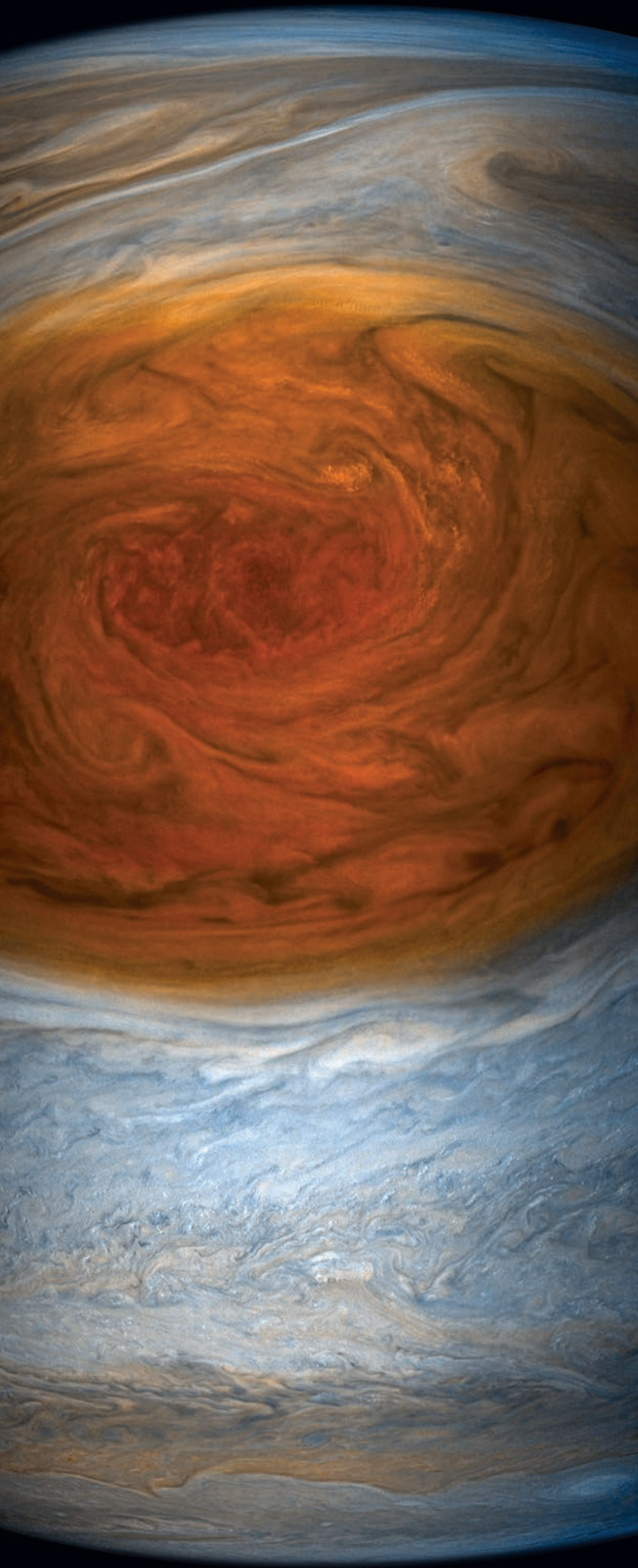
THE YEAR IN PICTURES

SOLAR SYSTEM EXPLORATION has been at a peak for a decade. This year marks the beginning of a contraction, hopefully a temporary one. There were no planetary launches in 2017. (At least one Chinese lunar launch, *Chang'e-5*, had been expected this year, but a Long March 5 rocket failure for an Earth orbiter has delayed those plans.) In mid-September, *Cassini* ended its long and fruitful mission by plunging into Saturn, and *Dawn* stopped collecting data at Ceres. Still, the solar system remains a busy place, with spacecraft exploring the realms from Venus to Jupiter, and beyond Pluto. 🚀



ABOVE *On its last inbound orbit of Saturn, Cassini used its cameras to take several snapshots of favorite views. One of these was a 6-by-2-frame mosaic of the whole planet and its ring system. Space imaging enthusiast Ian Regan assembled the mosaic into this poignant view.*

This page: NASA/JPL/SSI/Ian Regan; opposite page: Jupiter: NASA/JPL/SwRI/MSSS/erald Eichstädt/Seán Doran; Mars: NASA/JPL-Caltech/Univ. of Arizona

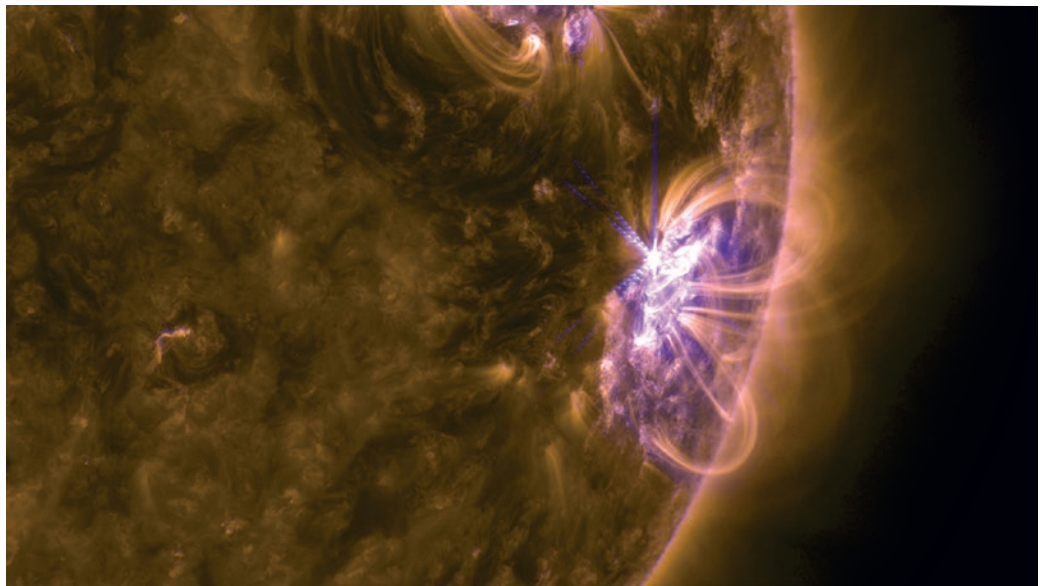


BELOW OSIRIS-REx returned to Earth's vicinity for the first time on September 22, 2017. Flying past Antarctica bent the spacecraft's path to match the inclination of its target asteroid's orbit around the Sun. The mission took advantage of the close encounter to test out most of the instruments. This photo was taken by the spacecraft's color MapCam five days after the flyby, capturing Earth and Moon in the same frame.

PREVIOUS SPREAD, LEFT
Juno's path across Jupiter took it closer than any spacecraft has ever gone to the giant planet's Great Red Spot. In this JunoCam image, the spot looms large because the spacecraft was less than 10,000 kilometers (about 6,000 miles) above the cloud tops during the mission's July 11 perijove. (For context, the entire planet is 140,000 kilometers, or about 87,000 miles, across.)

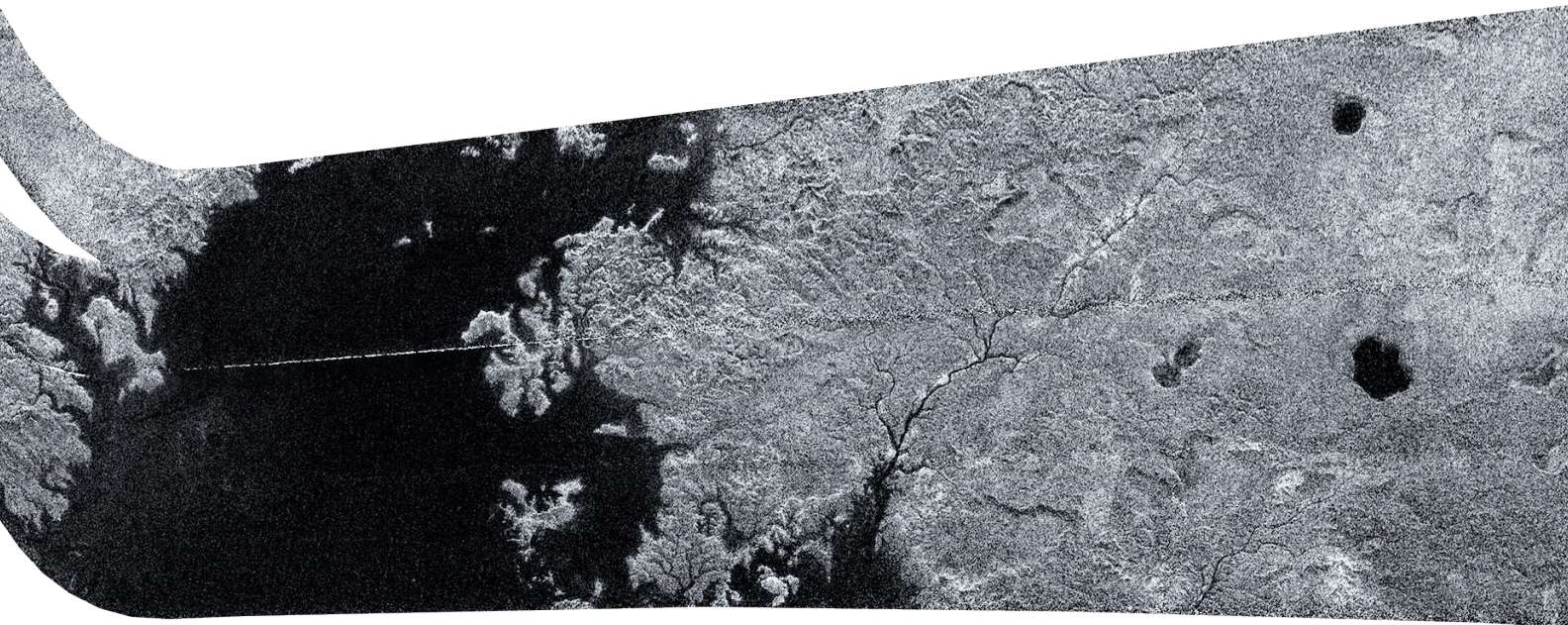


PREVIOUS SPREAD, RIGHT
These parallel furrows coursing down a dune in Hellas Planitia were captured by HiRISE aboard Mars Reconnaissance Orbiter on August 17. They are thought to form when blocks of carbon dioxide ice that forms on dune crests in winter break off and slide down the slope atop a layer of carbon dioxide gas.



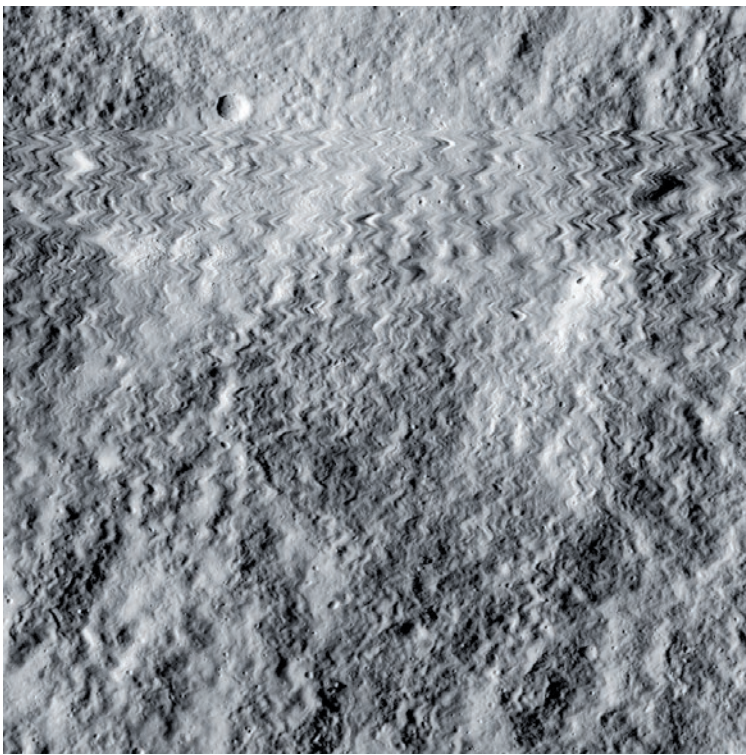
ABOVE Although the Sun is near the low point of its 11-year sunspot cycle, 2017 has seen some impressive sunspots, including one (active region 2673) that produced seven flares in a one-week period in September. This photo, taken on September 8, is the second-largest and second-to-last flare of that series. The image blends two ultraviolet-filter views.

Earth Image: NASA/GSFC/JA; Sun Image: NASA



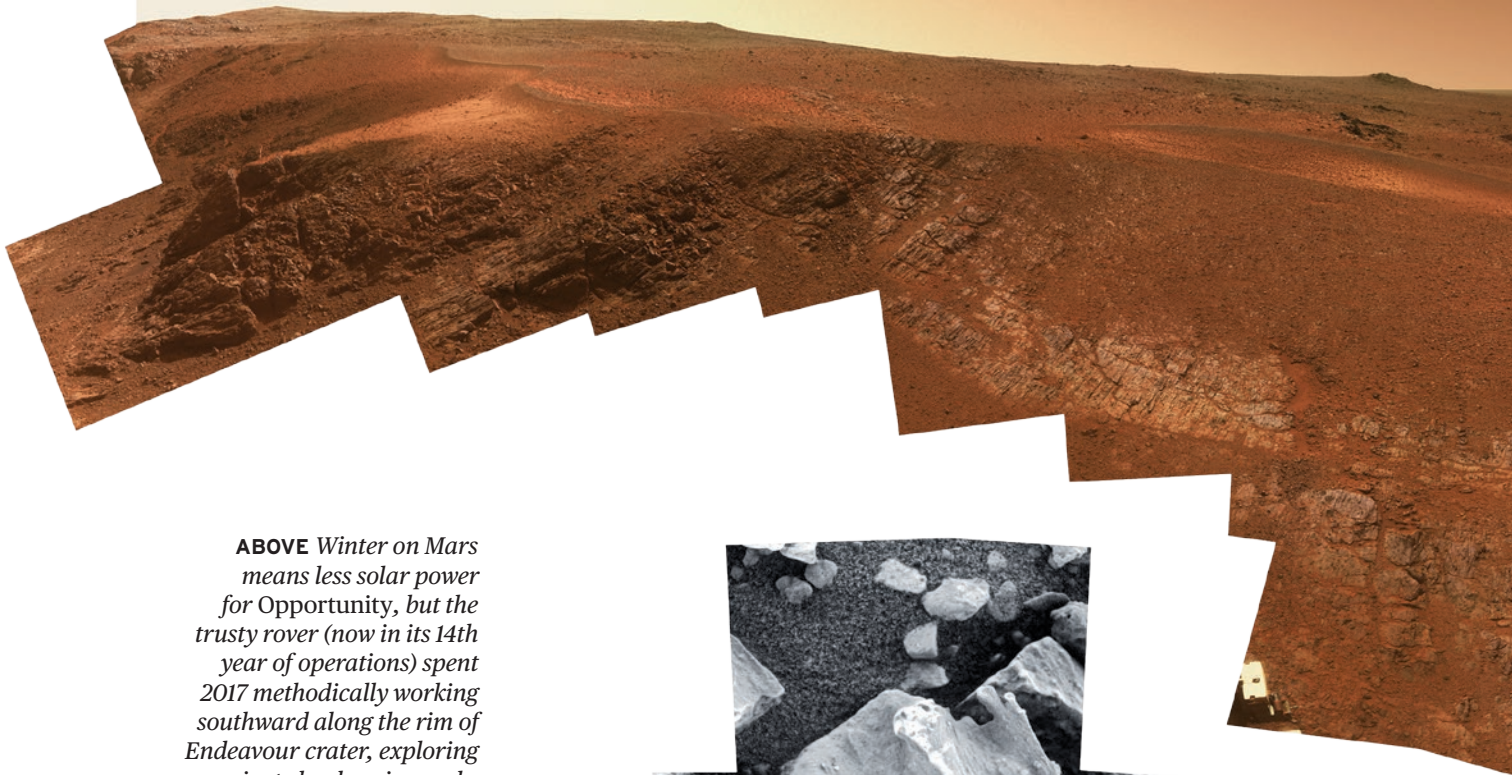
ABOVE Cassini gave us nearly 14 years of data on Titan's changing weather. The spacecraft used its last Titan flyby to perform radar scans across lake-filled terrain, including taking its last photo of the moon's northern lake, Ligeia Mare. In the past, a mysterious island has appeared and disappeared in images of this lake (bubbles? floating hydrocarbon material?). In this observation, the mysterious island was not present. Perhaps one day a new spacecraft explorer will allow us to look for changes in this lake again.

LEFT The unusual, wavy appearance of this lunar terrain is not an actual feature on Earth's Moon. The image records the moment on October 10 when one of the two narrow-angle instruments that make up the Lunar Reconnaissance Orbiter Camera was struck by a tiny meteoroid as it scanned across the lunar surface. The impact caused the camera to vibrate back and forth about 60 times per second. Engineers calculated the camera was struck by a particle that was less than a millimeter in diameter moving at 7 kilometers (about 4 miles) per second. The camera suffered no damage from the impact.



Ligeia Mare image: NASA/JPL; Earth's Moon image: NASA/GSFC/ASU

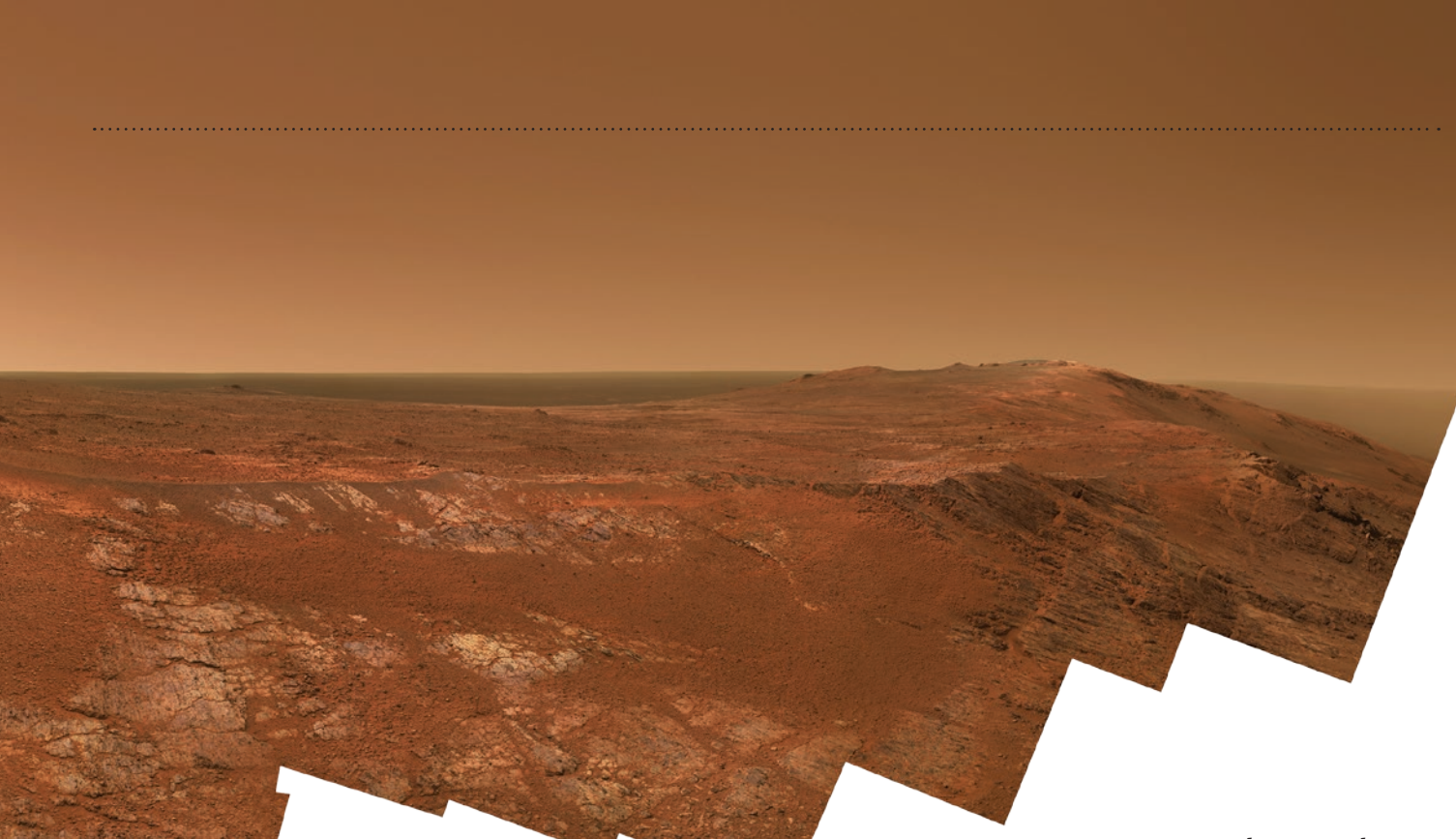
THE YEAR IN PICTURES



ABOVE Winter on Mars means less solar power for Opportunity, but the trusty rover (now in its 14th year of operations) spent 2017 methodically working southward along the rim of Endeavour crater, exploring ancient clay-bearing rocks there. This view, taken on sols 4643 to 4654 (February 14 to 26) at a site called Rocheport, encompasses fascinating rocks in the foreground, the receding rim of Endeavour in the middle ground, and the floor of the crater in the distance.

RIGHT Atop Endeavour crater's rim, wind picks up sediment and scours rocks. This striking photo is an Opportunity Microscopic Imager perspective on a cobble of ancient rim rock whose surface has been fluted by the sandblasting effect of wind. Opportunity studied these rocks at the beginning of the rover's descent into Perseverance Valley.





RIGHT Throughout 2017, Curiosity has been unable to drill at all, due to a balky motor.

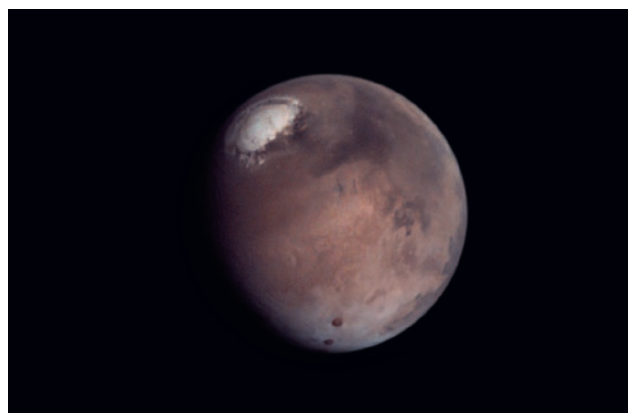
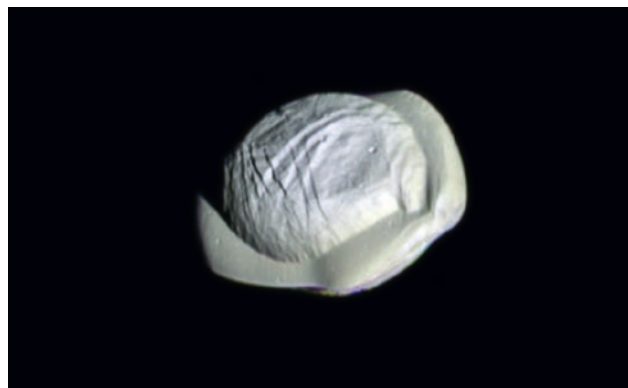
The motor is supposed to extend the drill forward into rocks, but its brake is sticky. On sol 1780 (August 9), the rover's engineers managed to extend the drill fully. The mission team now hopes to drill again, using the arm to press the drill into rock rather than the stuck motor.



BELOW At last, more than five years after landing, Curiosity reached a major landmark that had enticed geologists since before landing. Once known as Hematite Ridge, Vera Rubin Ridge was informally named by the mission in honor of the astronomer who died at the end of 2016. The rocks atop the ridge are different from the lakebed materials deposited in the Murray mudstones below it. Curiosity took this panorama on sol 1812 (September 10, 2017).



Curiosity drill: NASA/JPL/MSSS; Vera Rubin Ridge: NASA/JPL/MSSS/Thomas Appéré



TOP Cassini's final orbits took it quite close to Saturn's rings, giving the spacecraft the opportunity to image the moons embedded within them. *Pan*, pictured here, is about 25 kilometers (about 16 miles) across and orbits within the Encke gap, near the outer edge of the A ring. Its fractured surface and soft equatorial belt indicate a highly porous world made of barely connected ring particles. Most viewers likened its shape to the savory, filled, boiled pastries of their own cultures—ravioli, pierogis, dumplings, and so on.

BOTTOM Mars Express' Visual Monitoring Camera (VMC), otherwise known as the "Mars Webcam," has been watching Mars approach its northern summer solstice, seeing the northern polar cap bathing in around-the-clock sunlight. In this view, the Sun has just risen on the Tharsis montes, whose reddish peaks rise above pale morning clouds.



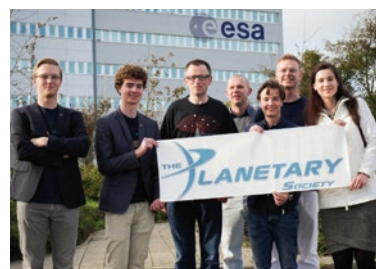
KATE HOWELLS is The Planetary Society's global community outreach manager.

Only the Beginning...

IN EARLY OCTOBER, our European volunteers gathered to represent The Planetary Society at an open house public event held by European Space Agency's Space Research and Technology Centre in Noordwijk, the Netherlands.

There, ten thousand visitors were treated to a presentation about The Planetary Society, and they were able to learn more about us at a booth staffed by volunteers from the Netherlands, Denmark, Luxembourg, Poland, Germany, and Ukraine.

"It was the largest Planetary Society event in Europe by a wide margin," said Marvin Janssen, outreach coordinator for Belgium, the Netherlands, and Luxembourg, "and I'm sure that our presence will only grow in size from this point on."



LEFT Volunteers from across Europe gathered to represent The Planetary Society at Open Day, a public event held by European Space Agency's Space Research and Technology Centre in the Netherlands. **RIGHT** Dutch volunteer Marcel-Jan Krijgsman spent the day sharing the passion, beauty, and joy of space exploration with the open house's many visitors.

Ukrainian outreach coordinator Valeria Koveza was glad to have made the trip from Kiev. "Seeing ESA labs and facilities was definitely a lifetime opportunity," she said. "But the most astonishing experience for me was seeing the enthusiasm and curiosity of the public. Talking to them was mesmerizing."

Dutch-Indian volunteer Vikram Radhakrishnan shared this sentiment: "It bodes well for the future of astronomy and space exploration when the excitement for these fields of science is instilled in so many people."

Asked whether the event was a success, Dutch volunteer Marcel-Jan Krijgsman replied, "Let me put it like this: I'm still a bit hoarse from speaking nonstop with people about *Lightsail*, space advocacy, my telescope, my little Mars rover model, and astronomy. It was great to see and speak to so many curious people."

This is only the beginning for The Planetary Society's volunteer activities in Europe. We continue to expand our outreach work in countries around the world, and our volunteer network is leading the way.

To sign up for volunteer opportunities in your community, go to planetary.org/volunteer. 🌟



JASON DAVIS is a journalist and digital editor for *The Planetary Society*.



Is There Anybody Out There?

A Taste of Our Web Feature on the Past, Present, and Future of the Search for Extraterrestrial Intelligence

IN 2015, A RUSSIAN BILLIONAIRE named Yuri Milner announced a new initiative to help bolster the search for extraterrestrial intelligence, known as SETI. Milner pledged \$100 million over the course of 10 years to the initiative, dubbed Breakthrough Listen, which funds efforts to search for life beyond Earth.

The Planetary Society has supported multiple SETI projects over the years, practically since our founding in 1980, and we still help fund an optical SETI program at Harvard University. The SETI community is small, and Milner's philanthropy has the potential to alter the scientific landscape. Two years after Breakthrough Listen began,

we thought the time was right to turn a journalistic eye toward SETI. How has the field changed? What future technologies might improve SETI research? And where do groups like The Planetary Society fit in? These are the questions that drove our research.

The result is a three-part feature story called "Is There Anybody Out There?" which covers the past, present, and future of SETI. We posted an accompanying episode of *Planetary Radio*, infographics, and even an archival video of Planetary Society cofounder Carl Sagan, movie director Steven Spielberg, and Harvard physicist Paul Horowitz flipping the switch on a Society-funded SETI program

ABOVE *In the nearly five decades since modern SETI began, the field has moved forward despite a sporadic history of inadequate funding and political resistance. In 1979, Australia's Parkes Observatory was part of an international network of instruments NASA planned to use in its own SETI search. But it took more than a decade of advocacy from The Planetary Society and a who's who of respected scientists before NASA's program received funding and went online in 1992.*

called the Megachannel ExtraTerrestrial Assay (META) in 1985.

“Is There Anybody Out There?” also builds on our small reporting team’s commitment to bringing you the space stories that matter most. While we do this regularly at planetary.org, in the pages of *The Planetary Report*, and through programs like *Planetary Radio*, I’m also passionate about



LEFT In 2015, Russian physicist and venture capitalist Yuri Milner, flanked by board member Stephen Hawking, announced Breakthrough Listen, a new SETI project by his company, Breakthrough Initiatives.

deep-dive, investigative stories you won’t find anywhere else. We started this trend last year with our “Horizon Goal” series on NASA’s human spaceflight program, and I hope you’ll find “Is There Anybody Out There?” equally interesting.

You can find and read the complete story at planetary.org/seti. In the meantime, here’s a small excerpt to get you started. -JD

About two thousand years ago, just before the start of the Common Era, the Romans conquered Spain. The Roman Empire was

powered by money, and the currency of the time was silver. Fortunately for the Romans, there were ample silver mines in their new Spanish territory.

It takes a lot of energy to smelt silver into coins, so the Romans cut down vast swaths of Spain’s forests to burn the wood for fuel. A byproduct of the smelting process is lead, which the Romans used for plumbing. For the first time, our species was engaged in large-scale industrial manufacturing—and also large-scale pollution. Signs of all this can be found in Greenland’s ice cores.

Pete Worden, executive director of Breakthrough Initiatives, recently told me Roman silver mining is arguably the first time the impact of humans on the planet would have been noticeable from outer space.

“If you were sitting at a nearby star and had the ability to take a spectrum of the atmosphere, with technology that we can imagine in the next few decades, you would detect these things that are, at least from our understanding, clearly industrial pollutants,” he said.

A popular science fiction notion, as portrayed in the novel (and movie) *Contact*, by Planetary Society cofounder Carl Sagan, is that intelligent life might pick up our stray TV transmissions. But that’s not possible with Earthling-level technology. If aliens in orbit around Proxima Centauri, our nearest stellar neighbor, broadcast us episodes of *I Love Lucy*, we wouldn’t hear them, unless they put a lot more power than ours into their transmitters.

We are, however, on the verge of being able to pick up missile detection radar-level signals. And if something as noisy as the Arecibo Observatory planetary radar in Puerto Rico, which is used to zap near-Earth

JASON DAVIS’ interest in spaceflight started early. He recalls watching space shuttle Discovery’s 1988 return-to-flight mission following the Challenger accident and playing a videocassette of the launch over and over, memorizing countdown and ascent procedures. Jason is now a digital editor for *The Planetary Society*. He covers the Society’s LightSail mission, as well as other science and technology projects, at planetary.org.



meetings, blustering congressional representatives, and unexplained signal detections. Now, a surge of cash has given SETI fresh life. New arrays of powerful radio telescopes are rising in South Africa and Australia, which could help revolutionize the field. Meanwhile, other new projects promise to realize the dream of watching the entire sky for signals, all of the time.

Is there anybody out there? We may be closer to the answer today than ever before.



In 1978, during one of his many appearances on the television talk show *The Tonight Show*, Planetary Society cofounder Carl Sagan discussed SETI at length with host Johnny Carson. In a pre-Internet era when most Americans had only a few channels, Sagan and Carson spent 15 minutes on prime-time television discussing everything from *Star Wars* (“I felt very bad that, at the end, the Wookiee didn’t get a medal,” Sagan said) to how aliens might send us a signal using prime numbers.

“The remarkable thing is, for all the history of mankind, people have wondered about intelligence elsewhere—I think it’s in religion

TOP LEFT Paul Horowitz is shown here in 1995 with the Billion-channel ExtraTerrestrial Assay (BETA) equipment at Harvard University. Whereas META was groundbreaking in its ability to search 8 million slices of radio frequency at once, BETA searched a quarter-billion slices.

LEFT A precursor to META was Suitcase SETI, a portable spectrum analyzer that could be installed on large radio telescopes.

TOP RIGHT In 1978, Johnny Carson devoted a full 15 minutes of *The Tonight Show* to a conversation about SETI with guest Carl Sagan.

asteroids, were aimed in our direction, we’d definitely hear—assuming we were listening and pointing in the right direction.

But in the end, it might not be our radio traffic that gives us away. Intelligent beings might already know we’re here, thanks to the way we’ve tinkered with our planet’s ecosystem.

The question of whether or not we are alone in the universe lies at the heart of many reasons we explore space. But for more than half a century, one branch of science has tried to answer the question more directly. SETI, the Search for Extraterrestrial Intelligence, started as a fringe science, surged to a taxpayer-funded endeavor, and then receded into a privately funded effort.

The field’s history involves semi-secret



ABOVE LEFT After donating \$100,000 to fund the building of Project META, then-Planetary Society Board Member Steven Spielberg was given the honor of throwing the switch to begin META's search operations in 1985.

ABOVE RIGHT The Planetary Society still funds Harvard University's Optical SETI program. Here, then-graduate student Jason Gallicchio is seen reflected in the telescope's primary mirror.

INSET In 1999, SETI@home—an Internet-connected SETI project that allows the public to use their personal computers to help search observation data for alien radio signals—went online from the University of California at Berkeley. Planetary Society members helped provide the funds needed to launch SETI@home.

and philosophy, legends—but this is the first time that we have the competence and ability to actually do such a search, and we are just beginning,” Sagan said.

In 1981, NASA and The Planetary Society funded Suitcase SETI, a portable spectrum analyzer that could be installed on large radio telescopes like the one at Arecibo. Suitcase SETI eventually grew into Sentinel, an all-sky search using a 26-meter radio telescope at Harvard University. Next came META, the Megachannel Extraterrestrial Assay, funded with a significant donation from Steven Spielberg, who was then a Planetary Society board member.

These projects were led by Paul Horowitz, a Harvard physicist and electrical engineer. Horowitz said META was able to pick through 8 million slices of radio frequency at a time, which made it the most advanced SETI search ever when it came online in 1985. Yet when compared to modern processing capabilities, its performance was paltry.

“I had that thing (the META computer) in a double rack, and at the top, it said, ‘META supercomputer—75 million instructions per second,’” Horowitz said. “Now, your cell phone is better than that.”



During a decade of operations, META found 37 “candidate events”—strong signals of unknown origin. None have ever repeated. The Society launched a southern hemisphere clone of the project named META II, and META eventually evolved into BETA (Billion-channel ExtraTerrestrial Assay), which increased the processing capacity of the Harvard telescope to a quarter-billion channels at once. BETA operated until 1999, when a storm damaged the antenna’s drive gear.

Around the same time, Horowitz’s group, motivated by Charles Townes, who invented the laser, started tinkering with optical SETI searches. Visible light has a higher frequency than radio waves, allowing more data to be encoded over any given period of time. Like radio waves, visible light also filters through our atmosphere, making it a logical portion of the spectrum for SETI searches.

In 2006, Horowitz and The Planetary Society launched an optical SETI search, dubbed OSETI, using a 1.8-meter telescope at Harvard. This search is still in operation, completing a full survey of the sky visible from Massachusetts every 200 nights.



LEFT *This artist's concept shows the newly discovered rocky planet in the habitable zone around nearby Ross 128.*

A New Target for SETI

In mid-November, European scientists announced the discovery of a rocky, Earth-size exoplanet in orbit around the star Ross 128, which is only 11 light-years away. The researchers think the planet, Ross 128 b, has a temperature range that could allow liquid water to exist on its surface, meaning it could potentially harbor life. Ross 128 has already been the target of SETI searches (which ended up as false alarms). This new discovery ensures that scientists will return to take a closer look. Read the full story at planet.ly/ross128b.



ABOVE *Carl Sagan closed an archival Planetary Society video promoting SETI by saying, "I think even if there is a plausible argument for a few, we ought to keep looking. I'd even go further than that. If there is a plausible argument that there isn't anybody out there—bearing in mind that we can be wrong—we ought to keep looking, because the question is of the most supreme importance. It calibrates our place in the universe. It tells us who we are. And so, it is worthwhile trying to find other civilizations ... no matter what."*

Meanwhile, in the late 1980s, The Planetary Society, NASA, and the National Science Foundation helped fund a West coast SETI effort called SERENDIP at the University of California, Berkeley. SERENDIP, as its name implies, looks for serendipitous SETI detections by piggybacking on traditional astronomical observations made by large radio telescopes. The program went through many upgrades and relocations over the years, and was still running at Arecibo when the telescope was damaged by Hurricane Maria in September.

SERENDIP originally processed data in real-time, but Berkeley soon began archiving the data and sifting through them using computer algorithms. There were more data available than could be processed using supercomputers, said Dan Werthimer, who is now chief scientist of the Berkeley SETI Research Center. Werthimer and three other engineers and scientists designed a program to allow home computers to help with the data crunching.

"We had this wild and crazy idea to use volunteers to analyze our data, but we took

it around to various people, and nobody seemed to think it would ever work," Werthimer told me. "The Planetary Society said, 'Hey, this wild, crazy idea? We want to get behind it.' And they gave us the money to launch the project."

In 1999, Berkeley launched SETI@home, and since then more than 8 million people have downloaded the program and donated spare computing power to help search for intelligent life. The open-source software, BOINC, on which SETI@home is based, is now used for other projects. This led to what Werthimer calls "the democratization of supercomputing," which allows users to choose individual programs to assist.

Andrew Siemion, the director of Berkeley's SETI Research Center, credits The Planetary Society's involvement with SETI@home for helping to keep the field alive prior to his arrival at Berkeley as a student in 2004.

"Science is about standing on the shoulders of giants," he said. "Frankly, we would not be here today were it not for the support specifically of the Planetary Society." 🐾

Go online and read the complete story at planetary.org/seti



WHITNEY PRATZ is *The Planetary Society's* partnerships manager.

There Goes the Sun

An Eclipse Adventure Diary

FRIDAY, AUGUST 18

Our eclipse-viewing journey begins with a welcome dinner in Twin Falls, Idaho. The Planetary Society and Betchart Expeditions are sending science experts and hundreds of travelers to Bald Mountain (Baldy), Idaho, or Rendezvous Peak near Jackson Hole, Wyoming, to enjoy the 2017 North American Eclipse. While most of us are new to each other, introductions quickly give way to a room full of excited space enthusiasts and (mostly) fellow Society members. We spend the weekend getting to know each other while we raft the Snake River and learn about California Condors and the

an excited line has formed to begin the ascent. On the gondola and chairlift rides up, we see fire smoke resting in the valleys. The sky above is a crisp blue. At this altitude, we quickly get hot in the Sun as we spread out across Baldy's Peak and settle in. The syzygy (alignment of the Sun, Moon, and Earth) begins subtly, like nothing special.

MONDAY, AUGUST 21 - 11:00 A.M.

When the Moon eclipses the Sun a little more than halfway, the temperature drop becomes unmistakable. We're sitting on the mountainside. There's less than a fingernail of Sun



ABOVE Total solar eclipses are not rare on Earth, but this past summer's eclipse was the first total solar eclipse to cross the U.S. from its Pacific to Atlantic coasts. These snapshots from Whitney's eclipse adventure show: the author and friends waiting for totality, rafting the Snake River, working hard for that perfect shot, and a distant bison herd.

difference between hawks and falcons at the Birds of Prey National Conservation Center.

SUNDAY, AUGUST 20 - 7:00 P.M.

Planetary Society Vice President Heidi Hammel preps us on the science of eclipses and shows us all the stages to expect: Bailey's beads, the diamond ring, and the arrays. Because we have a 4:30 a.m. departure, we get into bed early.

MONDAY, AUGUST 21 - PRE-DAWN

We arrive at the ski lodge, mindful of the hundreds of thousands of other people who are gathering in the path of totality. By 8:00 a.m.,

left visible and, still, our star's energy is too much for us to remove our eclipse glasses. In the seconds between 99 percent eclipse and totality, I remember the many times someone had said how different the experience becomes at totality and, as I remove my safety glasses and look through my binoculars, I see what they mean.

The eclipse is every beautiful sunrise and sunset you've ever seen, packed into 90 seconds, but the colors are all new. I realize that I'm looking straight at the Sun in an ink-blue night sky at 11:30 a.m., and that crickets and birds chirp as if it were early

Snapshot photos by Joanne Rosenbaum and Leo Bridges



evening. Icy breezes carry gasps and cheers.

Solar flares bounce at the disk's edge in red and deep pinks, the arrays glimmer, and two planets peek out on the left side. Before we're ready, the diamond ring reappears.

MONDAY, AUGUST 21 - 9:00 P.M.

We compare our experiences over dinner. Those who weren't witnessing their first eclipse mostly agreed that this one, at high altitude and with less atmosphere, was the best they'd seen. We all agree that, while the experience was brief, it felt much longer because of how vividly we remembered each second.

AUGUST 22-26

We spend the rest of the week exploring along our route from Idaho to Jackson Hole, Wyoming. We learn the paleontological history of both states; 20 full horse skeletons were discovered in the now-famous Hagerman Fossil Beds in Idaho. On the bus between stops, Dr. Spencer Wood explains how the landscape formed millions of years ago. Expedition leader Bryan Bates speaks on the flora, fauna, and human history of all the areas we visit and teaches us how to use a hunting tool invented by Native Americans. We strain to differentiate pronghorns from the tall grasses that obscure them. In the distance, a herd of bison eludes our cameras and binoculars as we drive in and out of Grand Teton and Yellowstone National Parks.

FRIDAY, AUGUST 25, 7:00 P.M.

On our last night, we toast our week together, then watch the sunset over Jackson Lake, Wyoming. The rocky, sharp edges of the



Tetons stand out against pillows of clouds and soft light. We load onto our bus together for one last time.

Then, there they are: the bison. It's almost dark and the herd we'd only seen as specks in the distance is now crossing the road. An enormous bull stops in the middle of the road and looks both directions at the waiting cars. Despite numerous warnings to stay away from wildlife throughout the parks, people exit their vehicles to get closer. He stands like a mountain, inhaling and exhaling, tail twitching. As the adult bison take turns jumping over a single-beam wooden fence and their babies gather the courage to run under it, we're gasping, cheering, and crying, much like we did on the mountaintop. Once the herd's final baby has made its way across the road, the bull moves on, his slow, heavy steps disguising just how dangerous he could be. For the first time on the trip, we lower our cameras and phones.

By the end of the week, we've bonded as eclipse chasers, bison enthusiasts, and friends brought together by an awe-inspiring few minutes that, while not a rare occurrence on Earth, created a truly once-in-a-lifetime experience for each of us.

If you haven't yet joined a Betchart Expedition, I highly recommend it. It's not a mode of traveling I'd ever experienced, but I welcomed the change. Accommodations are set. The experts are top-notch. All you do is show up and learn. Check out upcoming trips at betchartexpeditions.com and in the Betchart Expeditions insert in this magazine. You won't regret it! 🐾

ABOVE LEFT To satisfy popular demand, Betchart Expeditions hosted two eclipse-viewing trips. These travelers prepared to experience the celestial event atop Rendezvous Peak near Jackson Hole, Wyoming.

ABOVE RIGHT This composite image taken over two minutes of totality shows off the beauty of the Sun's arrays and colorful solar flares. Society friend Jarred Donkersley captured the images in this view from Idaho's Sawtooth National Forest.



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

Closeout!

LightSail 2 is Ready to Ship

THE PLANETARY SOCIETY has reached a major *LightSail* milestone. After eight years of work, our *LightSail 2* spacecraft is closed up and ready for delivery. *LightSail 2* aims to provide the first demonstration of controlled solar sailing in a CubeSat, or any small space-

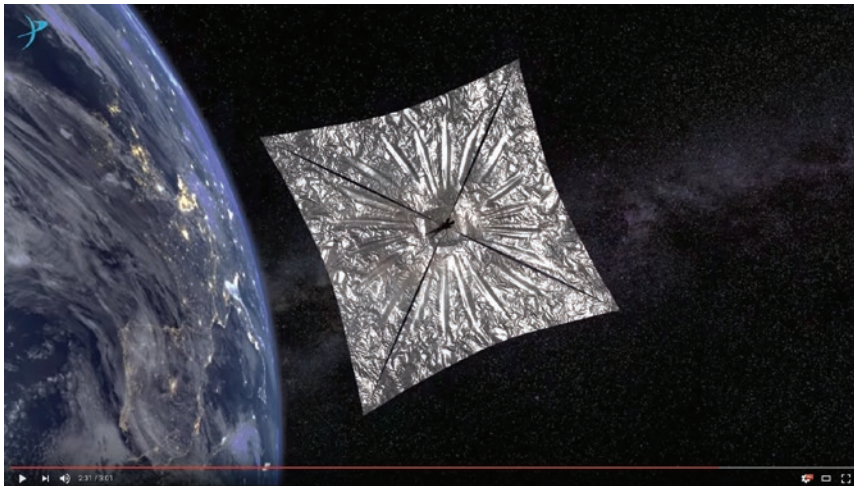
lated key mission activities in a large facility at California State Polytechnic University San Luis Obispo. The DITL included communications, antenna and solar panel deployment, and full boom deployment. The test went well, and we learned things that led us to create modifications, which were then tested.

In March 2017 we held the *LS2* Pre-Ship Review (PSR), and it went very well. The PSR brought together the *LightSail* team and some external reviewers at Planetary Society headquarters in Pasadena to evaluate the spacecraft's status and its readiness to ship. Pre-Ship Reviews are fairly standard in the spacecraft industry. It is a chance to thoroughly review the spacecraft's many software and hardware updates and tests.

The bottom-line result from the review was that *LS2* is in excellent shape; we could have shipped then if we needed to. But, because we had the time, we identified and addressed some minor issues and ran additional tests. Those tests included going back to UCLA for another magnetometer calibration test to ensure *LS2* will be able to orient itself properly as it sails around Earth.

As a final "let's-make-really-sure" activity, in August we carried out one final Day in the Life/Operational Readiness test to run the spacecraft and the spacecraft team through their paces by using *LS2* to simulate key mission moments. It went great.

In September and October, engineers re-configured *LS2* into its flight-ready state for what is likely to be the last time. The procedure, known as "closeout," set the spacecraft's software to start the mission on the next boot and physically secured all deployable structures, including the antenna and solar panels.



ABOVE We have reached a milestone in our eight-years-long *LightSail* story. We are finished working on and testing *LightSail 2*. We are ready to ship our flight-ready spacecraft and make this scene a reality.

craft. Here's a review of what has happened in the last few months of this project and what will happen in the future.

THE LAST YEAR IN THE LIFE OF LIGHTSAIL 2

LightSail 2 (LS2) spent 2017 with uncertain launch dates that have continued to slip for its launch on a SpaceX Falcon Heavy rocket. The uncertainty provided an opportunity to perform more improvements, tests, tweaks based upon the tests, and more tests. It is, of course, far better to find issues and fix them on the ground than to try to deal with an issue that may or may not be fixable in orbit.

In December 2016 we carried out another Day in the Life Test (DITL), in which we simu-

Thanks!

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

PROX-1

In May, *LS2*'s partner spacecraft, *Prox-1*, shipped to the Air Force Research Laboratory (AFRL) in Albuquerque, New Mexico. *Prox-1* is a Georgia Tech student-built SmallSat sponsored by the U.S. Air Force's University Nanosat Program (UNP). *Prox-1*'s original mission plan was to deploy *LS2*, track it down, and image it during solar sail deployment. The UNP and *Prox-1* teams conducted a review of the spacecraft and determined that, while the hardware needed for the mission was fully integrated, the flight software required further development. "After discussions between the Air Force and Nanosat program, the two programs decided to scale back some *Prox-1* mission objectives," said *LightSail 2* Project Manager Dave Spencer.

As part of this change, *Prox-1* will still deploy *LS2* but it will not track the solar sail CubeSat down and image it during sail deployment. *LS2* has its own onboard cameras, which will be used to image the solar sail deployment sequence. None of *LS2*'s mission objectives have changed.

OTHER SIGNIFICANT DEVELOPMENTS

In January, we published papers and Planetary Society CEO Bill Nye presented at the International Solar Sailing Symposium in Kyoto, Japan. The papers discussed *LightSail 1*, both the mission and its successful public involvement and outreach, and *LightSail 2*.

We've created a new Academic Resource Center on our website, where you can find *LightSail* schematics, links to peer-reviewed papers, parts lists, and imagery. It can be found at planet.ly/sailresources.



The Planetary Society has continued to coordinate and share information with NASA's Near Earth Asteroid (NEA) Scout mission, a solar sail CubeSat with roughly twice the size and sail area of *LightSail*. NEA Scout is currently scheduled for launch in 2019.

In September, Bill Nye gave a well-received keynote presentation at the International Astronautical Congress in Australia about our *LightSail* program (see page 4). As part of his talk, we released a new, stunning animation of the *LightSail 2* mission that you can find at planet.ly/watchlightsail2.

THE FUTURE

So, what are the puzzle pieces leading toward *LS2*'s launch? First, *LS2* team members will integrate the *LS2* into a P-POD (Poly Picosatellite Orbital Deployer), the device that will actually deploy the spacecraft once in orbit, using a spring mechanism. *LS2* will then be shipped to AFRL in New Mexico, where it will be integrated with *Prox-1* and then go through combined testing: environmental testing such as vacuum tests, thermal tests, and vibration tests, all of which we've already performed on *LS2* as a separate spacecraft. *Prox-1* with *LS2* are part of a set of U.S. Air Force payloads called Space Test Program-2 (STP-2). Eventually, all STP-2 spacecraft will be integrated into a SpaceX Falcon Heavy Rocket. We will fly on the second or third flight of the Falcon Heavy. Launch is currently scheduled for no earlier than April 30, 2018. But that could always change.

You can learn more about the many hardware and software improvements we've made to *LS2*, get extra details from the last year, and find future updates in Jason Davis's blogs at sail.planetary.org/misioncontrol.

LEFT *LightSail 2*, carrying the names of the members and supporters who've made the mission possible, has been "closed out." Its software is now set to start the mission.



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

The More Things Seemed to Change ...

An Uncertain Year Was Ultimately Pretty Uneventful



ABOVE *Matt Renninger, the latest addition to our Space Policy and Advocacy team, used his Planetary Society lapel pin to symbolize the power behind our members' passion for space exploration.*

As we were finishing this issue, President Trump made official what the Vice President announced in October: it is now U.S. policy to send humans back to the Moon and on to Mars. Go to planetary.org/spaceadvocate for more information.

THE FIRST TWO ARTICLES I wrote for *The Planetary Report* this year highlighted two issues for 2017: 1) budget uncertainty, given a new Congress, president, and NASA administrator; and 2) the lack of commitment to the Mars robotic program.

Now we can look back and see how those issues played out.

EXPECTED CUTBACKS DIDN'T HAPPEN

First, it's interesting to see what has not changed (at least, not yet).

We did not see the Earth Science Division excised from NASA, as proposed by the Trump campaign. And while Earth Science was targeted for cuts, they were smaller than expected, ranging from 5 percent to 10 percent below the 2017 level. The Senate blocked the cuts.

NASA's overall budget also did well. Though the Trump administration proposed a \$561 million cut (notably, the smallest-percentage cut proposed for any non-Defense agency), Congress shrugged and moved ahead with its own plans, and, though final numbers were not available at press time, is likely to fund NASA at \$19.5 billion or more in 2018.

What also didn't change by press time was NASA's top leadership. The nomination of Jim Bridenstine as administrator was not submitted until September 1. His confirmation hearing didn't occur until two months later. As a result, NASA has gone nearly a year under the new administration without political leadership.

Other things that did not happen: the Space Launch System and *Orion* did not get cancelled, even after the delay of their first launch to late 2019. It appears Commercial Crew programs

will continue as planned.

Vice President Pence declared at the first meeting of a reconstituted National Space Council that Americans will return to the Moon. But NASA was already focused on the Moon (having forgotten about the Asteroid Redirect Mission before the new administration even took power) and continued planning for its crewed Deep Space Gateway station in lunar orbit.

SO WHAT HAS HAPPENED?

The fact that the National Space Council exists is progress. Its first meeting, on October 5, with CEOs of major aerospace companies, the vice president, and half the cabinet, demonstrates that the Trump administration has significant interest in space.

Thanks to strong congressional support, missions set to launch in the early 2020s are funded in NASA's 2018 budget, including Psyche, Lucy, a yet-to-be-selected New Frontiers mission, the Mars 2020 rover, the Europa Clipper, WFIRST, and more. It also includes critical funding for ongoing Plutonium-238 production and increased support for scientific research. The tens of thousands of Society members who wrote in support of NASA funding should be pleased with this outcome. We are.

MARS EXPLORATION PROGRAM

In the spring, Jason Callahan and I released *Mars in Retrograde: A Pathway to Restoring NASA's Mars Exploration Program* (see the Spring 2017 issue of *The Planetary Report*), which spelled out the lack of Mars missions after the Mars 2020 rover, particularly in regard to Mars Sample Return—the highest-

Photo: Matt Renninger

priority of the planetary community. The report also focused attention on the aging fleet of Mars science orbiters, which provide critical communications support for surface missions.

Following up on *Mars in Retrograde*, our newly expanded Space Policy and Advocacy team made over 40 visits to offices on Capitol Hill to raise awareness of the “Mars problem.”

Our efforts helped secure additional funding for the Mars Exploration Program in the final 2018 budget. This added funding could support both a new Mars orbiter (launching in 2022) and investment in a Mars Ascent Vehicle, or it could go toward Mars Sample Return planning. An orbiter would ensure NASA's presence at the Red Planet into the 2030s, and provide high-resolution surface imaging—crucial for landing site selection for human and robotic missions—and reliable communications infrastructure for surface missions.

On another front, NASA announced a commitment to Mars Sample Return in 2026—under a new, “lean” concept. Still in an early design stage, the intent of the mission is to return only a portion of samples prepared by the Mars 2020 rover. To keep costs down, it would include no additional scientific instrumentation and would depend on a non-NASA partner to provide the Earth-return vehicle. NASA would gamble on the existing, aging communications infrastructure at Mars. The plan calls for modifying the science-driven orbit of the *MAVEN* mission for better communications coverage, and leaning on ESA's *Trace Gas Orbiter* spacecraft to fill in any potential gaps.

This bold plan requires NASA to accept greater risk to advance a top science goal. We are working to get details on the proposal and understand possible long-term impacts on the science community. NASA is poised to take an important step toward one of the most challenging, potentially revolutionary, goals in planetary science. We are closer to sample return than ever before. The Mars program is in much better shape at the end of 2017 than at the beginning.

We enter 2018 with a positive but uncertain path before us. The Moon lies ahead. A new NASA administrator takes the helm. Mars is still a focus of science. The Earth Science Division lives on. Much can still change. But it appears any change will be less disruptive than initially thought.

One additional note: The Planetary Society was able to grow our full-time staff devoted to policy and advocacy this year. This increased capability was due to funds that you, our members, provided. As I look forward to 2018, I am grateful for your continued support. We have big plans for the future, and I am certain you won't be disappointed. 🐾



IN THE SKY

On January 31, 2018, there is a total lunar eclipse visible from Asia, Australia, the Pacific Ocean, and western North America. On February 15, there is a partial solar eclipse visible from parts of Chile, Argentina, and Antarctica. In January, bright Jupiter and reddish Mars rise near each other in the East around 3 a.m. By March they have separated significantly, and Jupiter is rising in the middle of the night and Saturn has joined Mars in the East in the wee hours of the morning. In March, both super-bright Venus and bright Mercury are visible low in the West, soon after sunset.



RANDOM SPACE FACT

During its twenty years in space, the *Cassini* spacecraft traveled the equivalent of nearly 200,000 times around Earth.



TRIVIA CONTEST

Our March Equinox contest winner is Dan Duchnych of Newark, New Jersey. Congratulations! **THE QUESTION WAS:** What was the first lunar rover (wheeled vehicle on the Moon)?
THE ANSWER: The robotic Soviet *Lunokhod 1* in 1970.

Try to win an autographed copy of *Human Spaceflight: From Mars to the Stars* by Louis Friedman, and a *Planetary Radio* T-shirt by answering the question:

Who was the first NASA Administrator (head of NASA)?

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, 2018. 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.



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Jovian Delight

A Final "Year in Pictures" Share

The work of talented citizen scientists has proven essential to showcasing the potential of JunoCAM on NASA's *Juno* spacecraft. Every close encounter with Jupiter has delivered a feast for the eyes, and perijove 9 (October 2017) was no exception. Here, a tremendous northern hemisphere cyclone straddles the boundary between red-brown and grey-blue bands near 40 degrees north latitude. Small clusters of white convective clouds are visible in the swirling arms of the bright cyclone, casting shadows back across the cloud decks (sunlight is coming in from the bottom left). These clusters could be freshly condensed ices of ammonia and maybe even water, lofted upward by the storm's powerful motions. The storm's core, darker and complex, is expected to be deeper than its white spiral arms. White flecks of cumulus clouds are scattered across the image, mostly inside the atmosphere's gray filamentary bands. The spatial scale of this image is 6.7 kilometers (4 miles) per pixel. —Leigh Fletcher, University of Leicester