THE PLANETARY SOCIETY

THE PLANETARY REPORT

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ICY ANALOGUE

COMPARATIVE PLANETOLOGY ON ANTARCTICA

EARTH-LIKE EXOPLANETS ✻ MARS' FADING FORTUNES ✻ PLANETARY DEFENSE UPDATE

KATE HOWELLS *is The Planetary Society's Global Community Outreach Manager.*

Curiosity Unites Us All

IN 1986, The Planetary Society established a volunteer program and invited members who wanted to be more involved to set up displays in local libraries and shopping centers. The Society's goal was to support a wider-ranging program of volunteer-led lectures on space topics.

Now, more than 30 years later, The Planetary Society's volunteer program has grown far beyond those initial dreams. We currently support a worldwide network of passionate volunteers who create and drive innovative educational outreach programs tailored to diverse communities. Wherever they are, Planetary Society volunteers bring the wonders of space exploration down to Earth, growing and nurturing a global community of space advocates.

A fantastic example of today's Global Volunteer Network is the work being done by our volunteers in Pakistan, led by outreach coordinator Roshaan Bukhari.

Roshaan and his volunteers organize presentations on space science and exploration for audiences large and small, reaching people of all ages and demographics. They take telescopes into poverty-stricken neighborhoods, giving kids the chance to glimpse the planets of our solar system. They work with schools across the country to inspire students to learn science and expand their horizons. And they collaborate with local organizations like the Lahore Astronomical Society and the Khwarizmi Science Society to grow and strengthen their local space community.

In every report from our volunteers in Pakistan, we hear the same positive results. They go out into their cities to share their knowledge of the cosmos, and there they find eager learners. Volunteer Muhammad Imran regularly organizes telescope observing nights for kids in his area, and reports back every time with the perceptive and creative questions they have about the solar system. And volunteer Zara Shafique, after visiting her former school to present a lesson on the OSIRIS-REx mission, was moved by the students' curiosity, calling it "an inspiration in itself."

Regardless of where we are, how we live, or what we look like, human beings have curious minds. People from all walks of life share an innate desire to understand the universe we live in. And through the incredible work of our volunteers, The Planetary Society is able to reach more people and inspire more curiosity, bringing the passion, beauty, and joy of exploration to the citizens of our world.

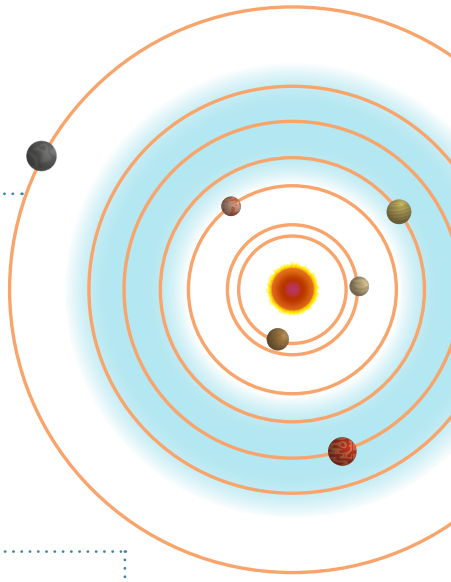
To learn more about The Planetary Society's Global Volunteer Network, check out **planetary.org/about/volunteers**. If you'd like to become a volunteer yourself, go to **planetary.org/volunteer**.

ABOVE *Outreach Coordinator Roshaan Bukhari and fellow Planetary Society volunteers in Pakistan organize space exploration events and telescope viewing for a wide variety of audiences.*

CENTER *Muhammad Imran shares views of the cosmos with children in poverty-stricken neighborhoods.*

RIGHT *Zara Shafique (in yellow) is moved and inspired by the curiosity of students from her former school.*

Photos courtesy of Roshaan Bukhari, Muhammad Imran, and Zara Shafique



DEPARTMENTS

ON THE COVER: Starkly beautiful, Antarctica is the coldest, driest, windiest continent on Earth. Thanks to the Antarctic Treaty, it is also a protected ecozone that supports ongoing scientific research by more than 4,000 scientists from around the world. Here, otherworldly towers of ice appear (about 9 meters, or 30 feet, high) to march up the slopes of Mount Erebus, Antarctica's only active volcano. Some scientists speculate that geologically active, watery moons such as Europa and Enceladus might also sport features like these. *Photo: Michael Carroll*

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

A Very Busy Spring

Advocating for Space Policy and Science Literacy

LIKE MANY OF YOU, I want to see astronauts make it to Mars while I'm still breathing Earth air. Through strong leadership and good space policy, we can realize this dream.

As you'll recall, in 2015 we convened a workshop of experts to examine the practicality of such an audacious endeavor. The resulting analysis showed that we could get humans in orbit at Mars by 2030 if we just apply the resources we have now in a focused fashion. Our experts showed an executable and affordable sequence of missions that would take people out to Mars and back. But to be able to continue to do what it does best, NASA needs support from the U.S. president and his administration.

In this issue, Casey Dreier, our director of space policy, lays out the historical trajectory of Mars exploration—and its future decline, unless funding is confirmed. And, because we are nothing if not optimistic, our feature article balances the tone of this issue. "Antarctica: An Alien Ice World on Earth," describes the extreme conditions scientists must adapt to in order to do planetary science in this harsh environment. Antarctica has a lot to teach future Mars astronauts.

The Planetary Society has delivered a list of five recommendations to the current U.S. administration on how NASA should proceed to keep the pace of Mars and planetary exploration going ever forward. In addition to a white paper, we released an open letter to President Trump summarizing these recommendations. The video "went viral" and became our most-watched ever, generating news coverage in dozens of major global news outlets and more than one million views within a week. You can watch the video at **planet.ly/TrumpLetter**. More people are watching us, learning about us, and supporting us than ever. There's a new movement for space, and you—we—are playing a leading role. Thank you all. By promoting planetary science, we help citizens everywhere know and appreciate the cosmos and our place within it. In fact, science is how we know anything at all about the universe we live in.

In addition to this movement for space, there's an overarching movement for science happening. A group of scientists has organized the March for Science, which will take place on April 22, or Earth Day. I am serving as an honorary cochair for the march, and The Planetary Society is an official partner. I will march at the main event in Washington, D.C., but there will be upward of 400 sister marches around the world. We will assemble with people everywhere, whether they are formal scientists or thoughtful citizens from other walks of life, to march in support of science. We will march to advocate for space, and we will march for unity. When we explore the cosmos, we come together and accomplish extraordinary things. Space brings out the best in us. Science connects us.

This movement for science, science literacy, and space exploration is very important to me. Outside of my job as your CEO, I have been busy with new projects that will deliver science education to millions. My new Netflix show, called *Bill Nye Saves the World*, premieres on Netflix April 21. Two of the thirteen episodes are about space exploration and the search for life. Each show is about a half hour, so instead of the traditional "See you next

LEFT *Bill poses for a giant selfie with member reception attendees at South by Southwest.*

BELOW *Our* LightSail *on display at the London Science Museum.*

week" at the end of each episode, I encourage the audience (you) to "Watch another one!" It's the modern model of television viewing, and it's exciting. I hope you watch and enjoy these shows. The crew and I really are trying to change the world.

Also this spring, my first book for middle-school kids, *Jack and the Geniuses at the Bottom of the World*, will be released. In this book, regular kid Jack and his exceptional, brilliant foster brother and sister are fictional, but very scientific. They travel to Antarctica and have quite an adventure. It's the first in a series that I, along with Greg Mone, my cowriter on the project, have been working on for a few years. I'm hoping to inspire a few young minds.

It's been a busy spring. As I write, I just got back from South by Southwest, the music and film festival held every year in Austin, Texas. There, a new independent film documentary called *Bill Nye: Science Guy* screened before a crowd of industry people and film enthusiasts. As you may infer, it's about me, and my quest to promote science literacy. And I'm proud to say that The Planetary Society is well represented throughout the film, from our co-founder Carl Sagan discussing solar sailing on *The Tonight Show* with Johnny Carson to the successful launch of our *LightSail®1* spacecraft and *LightSail 2*'s successful day in the life test. At the festival, we held a special reception for members from the Austin area. It was very satisfying to see and spend some time with so many young people who are passionate about science.

Finally, I made it to England to visit our *LightSail* engineering model, which has been on display at the London Museum of Science, the world's second most-visited science museum. The staff gave me a great tour of this marvelous public space. It is a great achievement to land our spacecraft in one of the world's most renowned science museums as anticipation builds for *LightSail 2*.

At The Planetary Society, we undertake and support these projects to advance space exploration. By knowing more about the cosmos, we will know more about ourselves. Thank you for your strong support!

Bill Nye

THIS IS YOUR ORGANIZATION, AND WE WANT TO HEAR FROM YOU.

What do you think about The Planetary Society's mission and vision? What is your opinion of our programs and strategies? How do you feel about being a member? E-mail your thoughts to *planetaryreport@planetary.org* or write to Members' Dialogue, The Planetary Society, 60 S. Los Robles Avenue, Pasadena, CA, 91101.

Thanks!

Group photo: Andrew Pauly, The Planetary Society; *LightSail* display photo: London Science Museum

Wonderfully Habitable Worlds?

Scientists Find Seven Earth-like Planets Around a Nearby Star

ABOVE *Scientists using NASA's Spitzer Space Telescope have confirmed four more planets in orbit around dwarf star TRAPPIST-1, bringing the known total of rocky, Earth-size planets in the TRAPPIST family to seven. This view from the second planet in the system, TRAPPIST-1b, shows the evening sky as it might look from the side of the planet facing away from its sun.*

IN MAY 2016, Michaël Gillon of Belgium's University of Liège and his team announced the discovery of three Earth-sized exoplanets around TRAPPIST-1, an ultracool M-dwarf star, using the small TRAPPIST telescope at European Southern Observatory (ESO)-La Silla, Chile. It was an exciting discovery, yet on that day no one could possibly have imagined that less than a year later they would make another significant discovery involving the same system. But here we are: on February 22, 2017, they announced in *Nature* the discovery of seven potentially habitable Earth-like worlds in the TRAPPIST-1 system.

TRAPPIST-1 is a fairly inconspicuous star in our Milky Way. Small (8 percent the mass of the Sun) and cold (half the temperature of the Sun), it is a member of an ultracool dwarf population that represents 15 percent of the star population of our galaxy. In early 2016, Gillon and his team detected the transits (i.e., the shadow of a planet passing between its host star and Earth) of three exoplanets at the inner edge of the habitable zone of their star.

Energized and excited by this discovery, the team requested and received additional telescope time to follow up on this system during the second half of 2016. NASA's Spitzer telescope is one of the instruments they selected for an ambitious program that called for monitoring the TRAPPIST-1 system almost continuously for twenty days. Spitzer and ground-based telescopes allowed the team to detect 34 transits, more than they had anticipated, suggesting the existence of additional exoplanets in the system.

After careful analysis, the data revealed the presence of seven Earth-sized exoplanets (named TRAPPIST-1 b, c, d, e, f, g, and h) in orbit around this M-type star. Because their orbital periods are short (fewer than twelve days for planets b through g), several transits were detected during the campaign. Accurate measurements of those tiny events (which show 0.6 percent dimming of the star) provide a wealth of information about the planets' orbits, sizes, and even masses, by measuring precisely the timings of the transits that are perturbed by the gravity of the other planets.

SO WHAT HAVE WE LEARNED ABOUT THE TRAPPIST-1 SYSTEM?

It's very tight. The most distant planet (h) is at 0.06 astronomical unit (AU) from its star. The closest one is at 0.01 AU. For comparison,

Illustration: Ron Miller

Mercury orbits at 0.39 AU from our Sun. This planetary system is not equivalent to our solar system, but more a minuscule version of it, comparable in size and mass ratio to Jupiter and its Galilean moons.

Similar to our solar system, these exoplanets travel circular orbits, all of which go in the same direction. They probably formed together with their star more than 500 million years ago.

The depth of the transits (how much starlight gets blocked by the planets) provides a measurement of the radius of the planets, which are similar to Earth (b, c, e, f, g) or Mars (d, h), so they range from 75 to 110 percent the size of Earth.

The data are accurate enough to detect mutual gravitational effects, so we can infer the mass of the first six planets and, hence, their density. These are probably rocky worlds that range in density from 60 to 117 percent that of Earth.

Considering the amount of energy they receive from their star, planets e, f, and g might have temperatures suitable for the presence of liquid water on their surfaces, if their atmospheres are similar to Earth's.

WHAT CAN'T WE SAY ABOUT THE TRAPPIST-1 SYSTEM?

This is not the first discovery of a system with this many exoplanets. Kepler-90 is another system with seven exoplanets discovered by transit measurements. Several of those exoplanets are larger than Earth and are probably ice and gas giants. HR8832 and HD10180 have seven planets that were discovered by radial velocity (a shift, or "wobble," in the parent star's light spectrum). In both cases, the exoplanets are massive, at least ten times the mass of Earth. The host stars also have a mass similar to our Sun. What is crucial here is that, for the first time, we have discovered seven temperate exoplanets, six of which we could say are rocky, in orbit around an M-dwarf star. There are many such stars in our galaxy, so there are probably a lot of worlds like these out there!

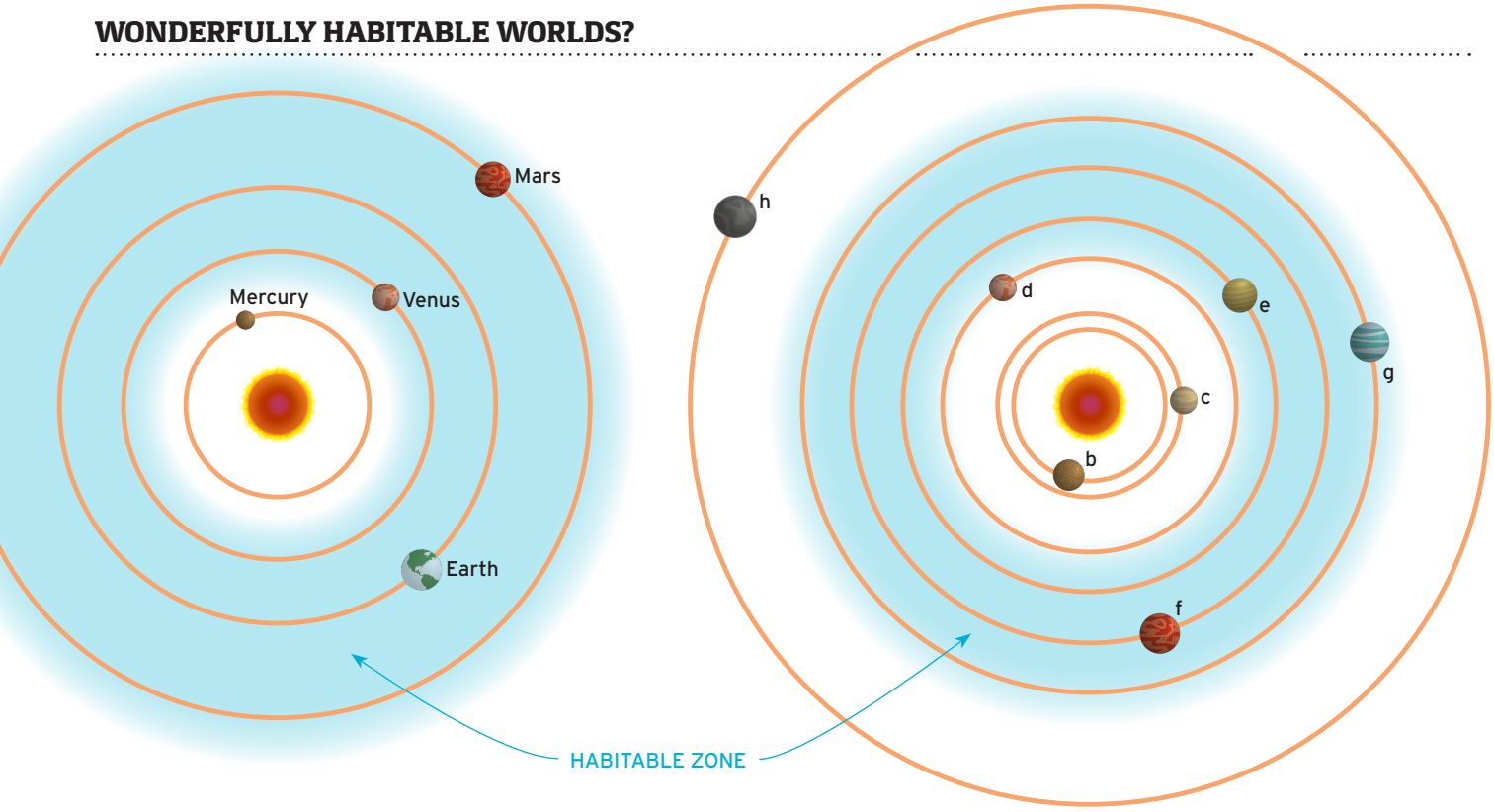
No, we have not yet discovered a cousin of Earth, much less seven of them. The measurements provide interesting information about these exoplanets; however, their locations in the habitable zone of their star do not imply that they are habitable. For instance, Mars and Venus are in the habitable zone of our Sun but are not habitable anymore. In other words, it is too early to say if there are oceans on their surfaces. TRAPPIST-1 is located about 40 light-years from us, so we will probably need the large aperture of the

It all started with beer.

TRAPPIST-1, the star and its seven planets, was discovered with two telescopes—one in Morocco and one in Chile—also named TRAPPIST (Transiting Planets and Planetesimals Small Telescopes). The telescopes were built by the University of Liège and Geneva Observatory. Michaël Gillon and Emmanuël Jehin have nicknamed the new planets after their favorite beers, which are brewed by Trappist monks at Orval Abbey, a monastery in southern Belgium.

Now, based on the success of their first project, the team is building a new observatory called SPECULOOS (Search for habitable Planets Eclipsing Ultra-cOOl Stars) comprised of four telescopes. SPECULOOS is also the name of a famous Belgian cookie.

WONDERFULLY HABITABLE WORLDS?



ABOVE *Top view of our inner solar system and the TRAPPIST-1 planetary system showing the circular orbits of the seven Earth-like exoplanets. The suns, planets, and orbits are not to scale; the entire TRAPPIST set of planets could fit inside Mercury's orbit. The blue area corresponds to the habitable zone of the star where liquid water could exist on the surface of those worlds.*

James Webb Space Telescope or a dedicated space telescope like European Space Agency's Atmospheric Remote-sensing Exoplanet Large-survey (ARIEL) to detect the presence of an atmosphere and derive its composition. Using the Hubble Space Telescope, the team has tried to detect an exosphere on one of the planets, but without success so far.

No, we have not detected life on those exo-worlds. In my opinion, life is the result of a complex cascade of random events, and we don't really know if those exoplanets, located near an ultracool star, are suitable for life. They are very close to TRAPPIST-1 and may be tidally locked, showing the same hemisphere to their star at all times. The existence of life on worlds with temperatures that vary from one hemisphere to the other is difficult to imagine. It will take years of observations and modeling to understand whether life can exist on such worlds.

Last year, astronomers announced the discovery of a potentially terrestrial planet around Proxima Centauri, located only 4.2 light-years away from us. Now these scientists reveal the existence of seven temperate ones around a small star that could live forever. The field of exoplanet research is booming.

A team led by Emmanuël Jehin (coauthor of the *Nature* paper) is currently building SPECULOOS (a TRAPPIST-style telescope on steroids), made of four 1-meter robotic telescopes installed at Chile's Cerro Paranal. With this telescope, the team will survey 10 times more red dwarfs than TRAPPIST did. Soon we could expect the discovery of a dozen systems similar to this one. We will have the opportunity to explore the diversity of atmospheres and climates, and potentially life, on Earth-like worlds out there.

The discovery of these strange new worlds where life could flourish is the beginning of an exciting time for astronomers and biologists–a time when we are beginning to see the unimaginable, a time when life as we don't know it can be imaged and studied. We will probably need to build complex and expensive instruments to understand those worlds. But what an astonishing, awe-inspiring, life-changing prize to win, don't you think?

FRANCK MARCHIS *is senior planetary astronomer and chairman of the SETI Institute's Exoplanet Group. This article originally appeared on his* Cosmic Diary *blog at* **planet.ly/TRAPPISTworlds** *and is adapted and reprinted here with his permission.*

Illustration: Loren A. Roberts based on information from F. Marchis, H. Marchis, and NASA/JPL-CALTECH

A SPECIAL REPORT BY MICHAEL CARROLL WITH ROSALY LOPES

Antarctica

An Alien Ice World on Earth

WHEN ERNEST SHACKLETON searched for explorers to accompany him on a South Polar expedition in December 1913, his ad is said to have read, "Safe return doubtful." Today, Antarctic exploration still holds elements of danger (a well-loved researcher lost his life recently in a snowmobile crash), but the National Science Foundation and other organizations have set in place ways to make the Harsh Continent a safer place. Through their efforts, hundreds of people are able to carry out research annually in the most remote corners of Antarctica's frozen wilderness, from glacial meteorite fields to the Mars-like Dry Valleys.

There are still regions on Antarctica that provide daunting challenges to access. One of these is the world's southernmost active volcano, Mount Erebus. In the 2016-2017 season, only 32 people stayed on the mountain for longer than a day. NASA/Jet Propulsion Laboratory volcanologist Rosaly Lopes and I were among those privileged few.

ONE MUST HAVE a very good reason for going to Antarctica, and an even better reason for going to the Mt. Erebus volcano. We traveled to the southern continent as guests of the National Science Foundation's Antarctica Writers and Artists Program. According to NSF's Peter West, the agency sends just three or four artists to Antarctica each summer season to "help communicate the significance of the science done there—and the challenges of working and doing science successfully in that hostile environment—

A series of ice towers builds along volcanic vents on the flanks of Antarctica's Mt. Erebus.

Photo: Rosaly Lopes

TOP *Erebus is Earth's southernmost non-dormant volcano; it has been active for 1.3 million years. With a summit elevation of about 3,800 meters (12,500 feet), Erebus is the second-highest volcano on the Antarctic continent.*

LOWER LEFT *The remote, forlorn-looking Fang Glacier tent camp. A stay in these unheated Scott tents prepares explorers heading for the summit of Erebus.*

LOWER RIGHT *A typical freezer-style door handle in Antarctica.*

to the general public. Many scientists are good communicators, but art reaches people in a different way than data or graphs."

Seasoned researcher Lopes was a must-go candidate for the trip as she is one of the foremost volcanologists at the Jet Propulsion Laboratory, and an expert on volcanoes of the outer solar system. My appeal to the NSF lay in the fact that I have often depicted volcanic landscapes on other worlds (and written about them as well). Our backgrounds helped convince the Foundation that our expedition to McMurdo Station and, ultimately, to the slopes of Mt. Erebus was a good investment.

Specifically, we journeyed to Antarctica in search of planetary analogs. The concept is one of the most important in the study of distant worlds: Earth exhibits terrain and geology that bear strong resemblance to features we see on other planets and moons. For example, the layered terrain of the Martian poles, put down by periodic dust storms and seasonal winds, looks a lot like the layered terrains in the Icelandic glacier Vatnajokull, where periodic volcanic eruptions drape the ice with ash before winter ices lock them into place.

Many such analogs exist in Antarctica. Its dry valleys are famous for their Mars-like conditions. Sheltered from the Antarctic Ice Sheet by the Transantarctic Mountains, these arid, chilled hollows host subsurface ice, frozen lakes, and rocky gravel, making them the closest Martian analog on the planet, and a prime target for astrobiologists searching for hints about life in the cosmos.

Antarctica also offers analogs to locales farther afield: fractures and pressure ridges sculpt the sea ice in ways reminiscent of Jupiter's oceanic moon Europa. Mt. Erebus, prime target for our little team, builds eerie ice towers around vents on its flanks, perhaps presaging volcanic forms that future explorers will find at the geysers of Enceladus or Triton. In addition, Erebus is one of only six volcanoes on Earth with active lava lakes, making it a close cousin to Jupiter's violent, volcanic moon Io. While these analogs are valuable to planetary scientists, they also serve as a critical tool for astronomical artists, who depict alien vistas at resolutions not yet available from spacecraft.

Crater photo: Carsten Peter

The study of planetary analogs carries far more urgency than just the quenching of our intellectual thirst. Lessons learned help us to better understand our own world, and serve as cautionary tales for our care of Earth's biome. We've learned about terrestrial weather by studying the storm systems of Jupiter. The polar caps and geology of Mars have given us insights into climate change, and the Venusian atmosphere has provided us with critical information about chemicals like chlorofluorocarbons. In many important ways, our study of other planets and moons has been a study of Earth.

TO EREBUS, BY WAY OF MARS

Clearly, Erebus is an important site to study. But to get to Mt. Erebus, prospective explorers require training, and that training takes place in one of the world's most remote outposts: McMurdo Station. McMurdo is the largest base in Antarctica. From a winter population of less than 200, the town's ranks swell to nearly 1,000 at the peak of the austral summer. Perched upon the McMurdo Sound on Ross Island, the community faces roughly in the direction of New Zealand, one of the nearest inhabited spots of land (only Argentina is closer, on the opposite side of the landmass). As is true of all outposts on the southern continent, McMurdo does not sit on United States real estate. No one owns any part of Antarctica. International treaty declares all territory south of 60 degrees latitude as a "zone of peaceful conduct and research." Nuclear waste, military action, and mining are all prohibited. McMurdo began as an American naval air facility, and now it is operated by the National Science Foundation's United States Antarctic Program.

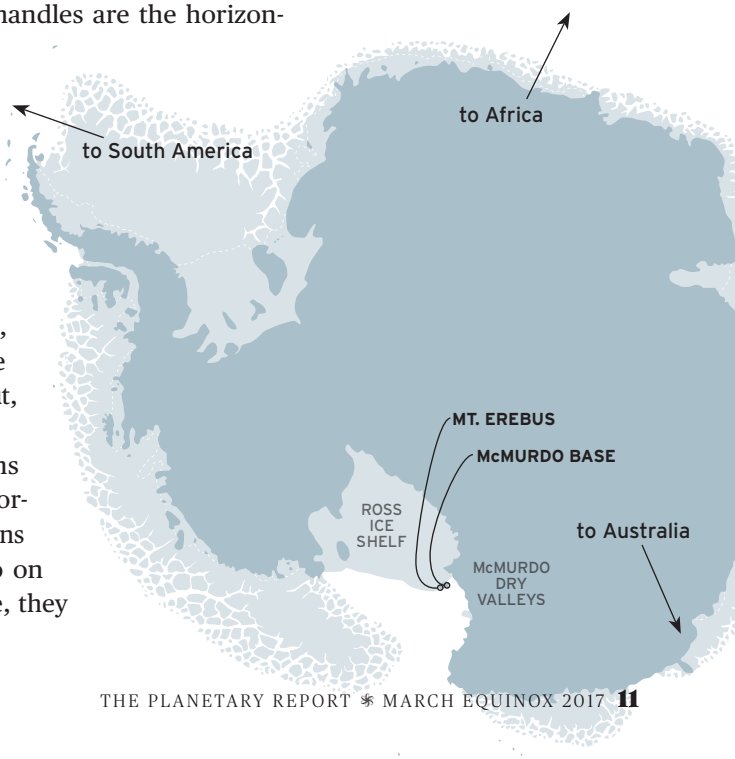
Antarctica is a model of international cooperation. At McMurdo itself, roughly 30 percent of the power is wind-generated, but this power is split with nearby Scott Base, the New Zealand station. New Zealand also shares the heliport at McMurdo, and coordinates research and logistics. In the southern wilderness, cooperation is a matter of survival. Antarctica is the coldest, windiest, driest, deadliest place in the world. An ice sheet up to three miles deep covers the continent, which has a landmass larger than the continental United States. This ice constitutes roughly 90 percent of the world's fresh water. While marine life along the coastlines is varied and abundant, the continent itself is nearly sterile. Science stations from countries as diverse as Japan, Finland, Argentina, Russia, Brazil, and Norway lie across the frigid terrain. Its location at the South Pole makes the continent ideal for research in fields such as astronomy, atmospheric and magnetospheric sciences, paleontology, marine and microbiology, and even meteorite studies.

While Antarctica provides a perfect model for terrestrial cooperation, it's also a model for what may need to take place at Martian settlements. And therein lies perhaps the most dramatic planetary analog of all.

A MARS SETTLEMENT ON EARTH

Anyone who has studied architectures for Martian colonies will recognize common elements at McMurdo. Doors are all arranged like airlocks, with outer and inner accesses. Inner doors do not open until the outer ones are closed. Door handles are the horizontal type used on freezer doors, because winds can reach hurricane force, and entries must seal completely. The difference with these freezer doors, of course, is that the cold is being kept out, not in.

Communications are of utmost importance. If anyone plans to leave McMurdo on foot or in a vehicle, they



BELOW *Mt. Erebus is part of Ross Island, which, at 2,460 square kilometers (950 square miles), is too small to be seen on this map.*

Photos by Michael Carroll unless otherwise noted

must file a report, along with a prearranged check-back time. Vehicles must drive over metal grates before entering the vast ice plains of the Ross Ice Shelf, where aircraft come and go, so that no dirt from inhabited areas is tracked into the pristine environment. Flags parade in long lines, each about ten meters apart, to serve as markers for the way back home if a whiteout occurs. Medical facilities are impressive considering the remoteness of McMurdo, but germs are of extreme concern. As a Martian settlement would be, McMurdo is a closed environment. Signs constantly remind people of the need for cleanliness and correct disposal or recycling of refuse. A hand-washing station greets all visitors on their way to the galley.

Mars settlements will serve as staging areas for extended exploration of the Martian wilderness. From a central, safe location, Mars explorers will depart for the poles, the great canyons, and the soaring volcanoes of the Red Planet. McMurdo, too, is the home base for an assortment of field camps and distant outposts. From the glacial valleys of the Transantarctic Mountains to the ice plateau surrounding the South Pole, remote camps and science stations dot the continent's landscape. Supply caches and fuel depots stand in strategic locations, lifelines between the outposts and the relative civilization of McMurdo and Scott bases.

Perhaps the most dramatic of these lifelines is the South Pole Overland Traverse, affectionately known as "SPoT." It's a 2,575-kilometer (1,600-mile) round trip from McMurdo to the Amundsen-Scott South Pole Station. Fuel used to be flown there aboard Hercules LC-130 cargo planes. But the weather often precluded full recharging of Antarctica's hungry infrastructure, as flights on the southern continent are regularly canceled. Now, SPoT's massive tractor-trailers, riding on overgrown tank treads, transport bladders containing 100,000 gallons of fuel. The LC-130s required dozens of flights to deliver the same amount of fuel, used more fuel than the Caterpillar tractors involved in the SPoTs, and left a much larger carbon footprint. As with almost every operation at the pole, the SPoTs must first go through McMurdo.

ANTARCTICA WILL TRY TO KILL YOU

Within this Mars-on-Earth settlement, Rosaly Lopes and I trained to prepare for our work on Mt. Erebus. As one instructor put it, "Antarctica is going to try to kill you in lots of ways, and I'm going to help you avoid that." Our orientation included helicopter and snowmobile travel, high altitude emergency first aid, arctic camping and survival, environmental preservation, and crevasse escape.

After nearly a week of focused training, we dutifully swallowed our high-altitude medication and helicoptered to Fang Glacier with our capable mountaineer, Evan Miller. At 2.75 kilometers (9,000 feet), the glacier is a required two-night stop for acclimatization before heading to the summit of Erebus. Travelers stay in Scott tents (polar pyramid tents) with no heat, few comforts, and an incredible view. 9,000 feet below, the ocean plays along pristine white shores. Volcanic rock rises through the ice in craggy piles of deep brown, contrasting with the shimmering frozen plain.

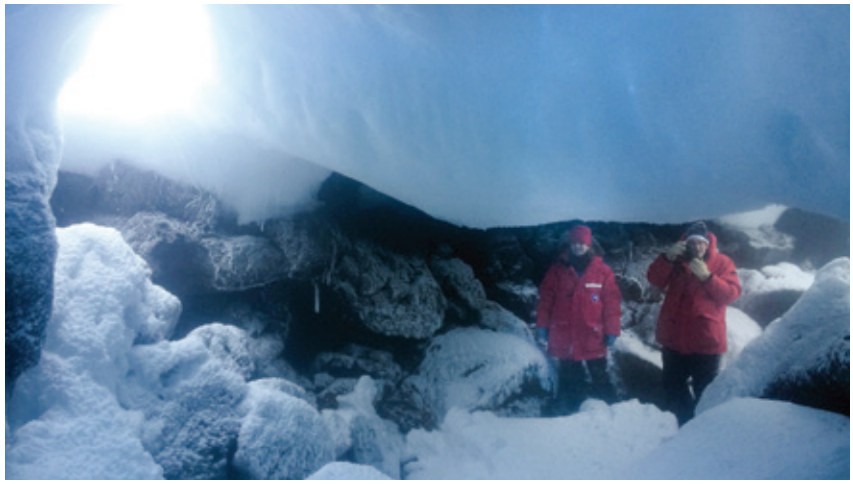
After our acclimatization process, we hitched a ride, courtesy of the United States Antarctic Program, aboard a helicopter to the relative comfort of the Lower Erebus Hut. Sitting at 3.5 kilometers (11,500 feet), the LEH is a small, heated wooden structure. No one sleeps inside; the Hut is reserved for meal time and warming up after working in the field. Researchers stay in mountain tents at the high-altitude outpost. The air is thin at the poles, so Erebus' 3.8 kilometer (12,500-foot) summit has the pressure of the Rocky Mountains at 4.4 kilometers (14,500 feet).

Once settled in, it was time to explore. The primary target of our trip was a series of ice pillars sprouting from the flanks of the peak. Building around the moist air flowing from volcanic vents, the towers take on bizarre, sometimes whimsical forms. Some are as tall as a five-story building. The towers sit atop sub-

ABOUT THE AUTHORS

Astronomical artist and science writer **MICHAEL CARROLL** *has 27 books in print, including two mystery novels set on moons in the outer solar system. His next book,* Antarctica: Finding Alien Landscapes Within Earth's Own Ice World*, will be published by Springer at the end of 2017.*

ROSALY M. C. LOPES *is a senior research scientist at the Jet Propulsion Laboratory-California Institute of Technology. She has spent most of her career at JPL, working on the* Galileo *and* Cassini *science teams and pursuing research on planetary and terrestrial geology, in particular the study of volcanoes on Earth and other worlds.*



ABOVE LEFT *The steaming entrance to Helo Cave at the base of an Erebus ice tower.*

ABOVE RIGHT *The authors pose inside one of the blue ice caves that lie below Erebus' ice towers.*

LOWER LEFT *However long it takes to become a reality, a human base on Mars will share many similarities with Antarctica's McMurdo Station.*

LOWER RIGHT *Could Saturn's hydrothermally-active moon Enceladus also sport ice towers along its water vapor-spewing vents? Michael Carroll used an Antarctic ice tower as a model for this portrait of an icy Enceladean analog.*

surface chambers, crystalline caves of lobate icicles and glowing blue ceilings. Some of these caves were accessible to us, but others contain unique biomes not found anywhere else in the world. To enter these caves, which are protected by international treaty, one must have special permits and wear what amounts to a sealed Hazmat suit. We limited ourselves to the so-called "dirty" caves that had already been explored by unprotected humans some years ago. Mountaineer Miller made sure that we did not stray into areas that might collapse into the subterranean chambers.

The ice towers provide a possible window into formations we may find in the outer solar system. Geyser activity is well known

ABOVE *Steam obscures the caldera at the summit of mighty Mount Erebus. No vegetation grows here; the greenish rocks are stained by sulfur.*

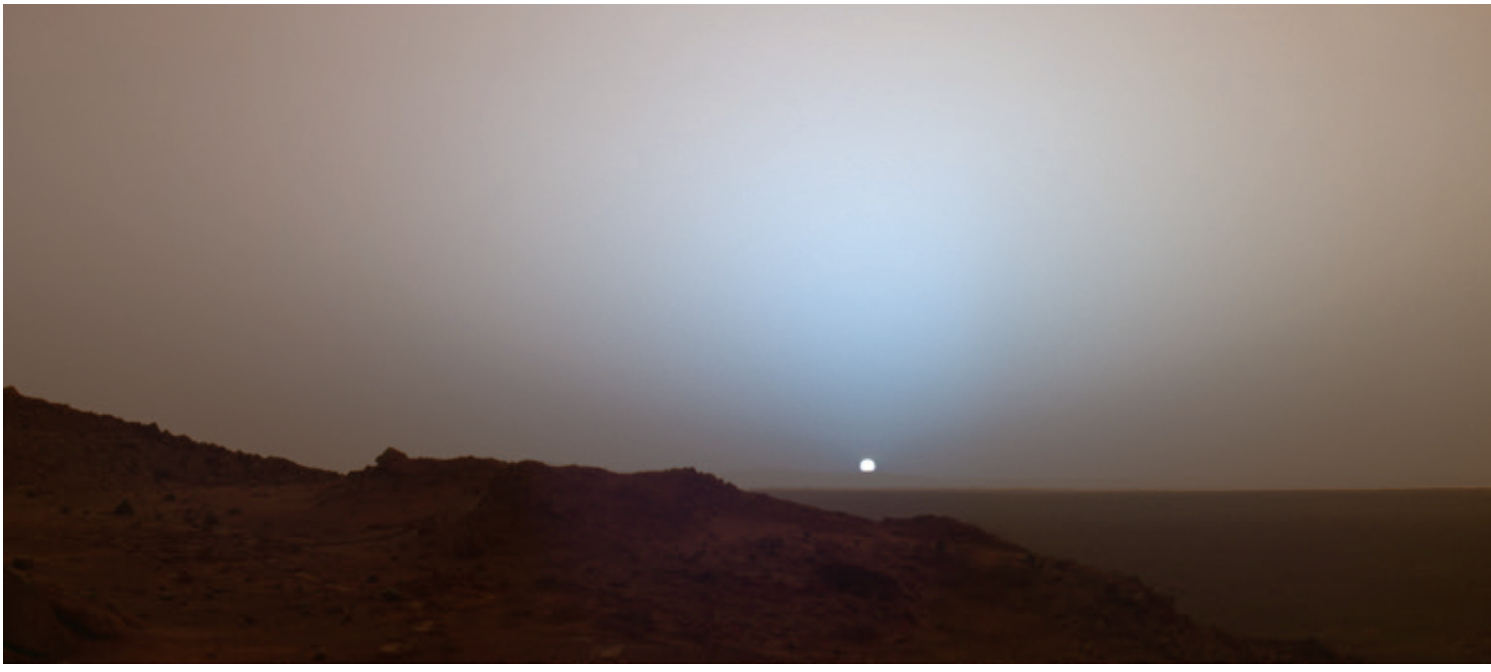
on Saturn's moon Enceladus, where fountains of water spew some 400 kilometers (250 miles) into space. Recent data suggest that Jupiter's moon Europa may periodically experience such activity as well, and cryovolcanism on Neptune's moon Triton was revealed by the *Voyager 2* flyby in 1989. Even Titan, with its dense atmosphere and methane seas, may exhibit cryovolcanism, perhaps recharging the atmospheric methane with its eruptions. Is it possible that in this bizarre environment, Erebus visitors might find similar territory?

Our last official stop, on Christmas Day 2016, was the caldera rim at Erebus' summit. Craggy, ice-slicked rock ringed the deep crater. Steam billowing up from inside betrayed the lava lake sloshing at the crater's center. The lava lake itself was obscured by steam, but the structure of the caldera's steep walls and dramatic lip echoed landscapes on ancient Mars, volcanic Io, and eruptive sites on Venus and Mercury. The site also represented a personal marker for Lopes: Antarctica was the last remaining continent on which she had to explore active volcanoes. Her global list was now complete.

YOU'VE COME A LONG WAY, BABY

The summit of Mt. Erebus was first visited by members of Ernest Shackleton's 1908 expedition. Exploration of the mountain, and of Antarctica at large, is different today. The National Science Foundation's United States Antarctica Program invests a great deal of resources toward making scientific research and travel more secure than it was in Shackleton's time. A network of experts is in place, with a range of expertise including communications, engineering, mechanics, medicine, power generation, waste management, mountaineering, and environmental safety and protection. Overseers carefully plan travel into the hostile environment, coordinating flights and surface trips. Science teams work with those who understand logistics and the hardware necessary to carry out work in the field. Future explorers will need to rely on such people as they establish base camps and remote outposts on Mars and, eventually, the moons of the outer solar system. The people who support, train, and encourage Antarctic researchers will have their counterparts at the beachheads of Syrtis Major, Elysium, Valles Marineris, and beyond. We will need them.

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



The Fading Fortunes of Mars

NASA is building a new rover that will prep samples of Mars to return to Earth. Will they ever come back?

IN THE TWILIGHT OF Bill Clinton's presidency, NASA announced that a fleet of spacecraft would explore Mars over the next decade. It was the birth of the Mars Exploration Program, an unprecedented effort to systematically explore Earth's enigmatic neighbor. The intent was to develop the critical expertise needed to design, build, and land spacecraft on Mars with shared workforce and management.

The Mars Exploration Program has been immensely successful. Of the seven missions sent so far, every one has not only met its primary science goals, but exceeded them beyond expectation. Missions designed to operate for months have lasted more than a decade. Rovers meant to drive a few kilometers have completed marathons. The rich dataset provided by these missions has led to more than two thousand peer-reviewed journal articles, providing unprecedented scientific insight into Mars' ancient past.

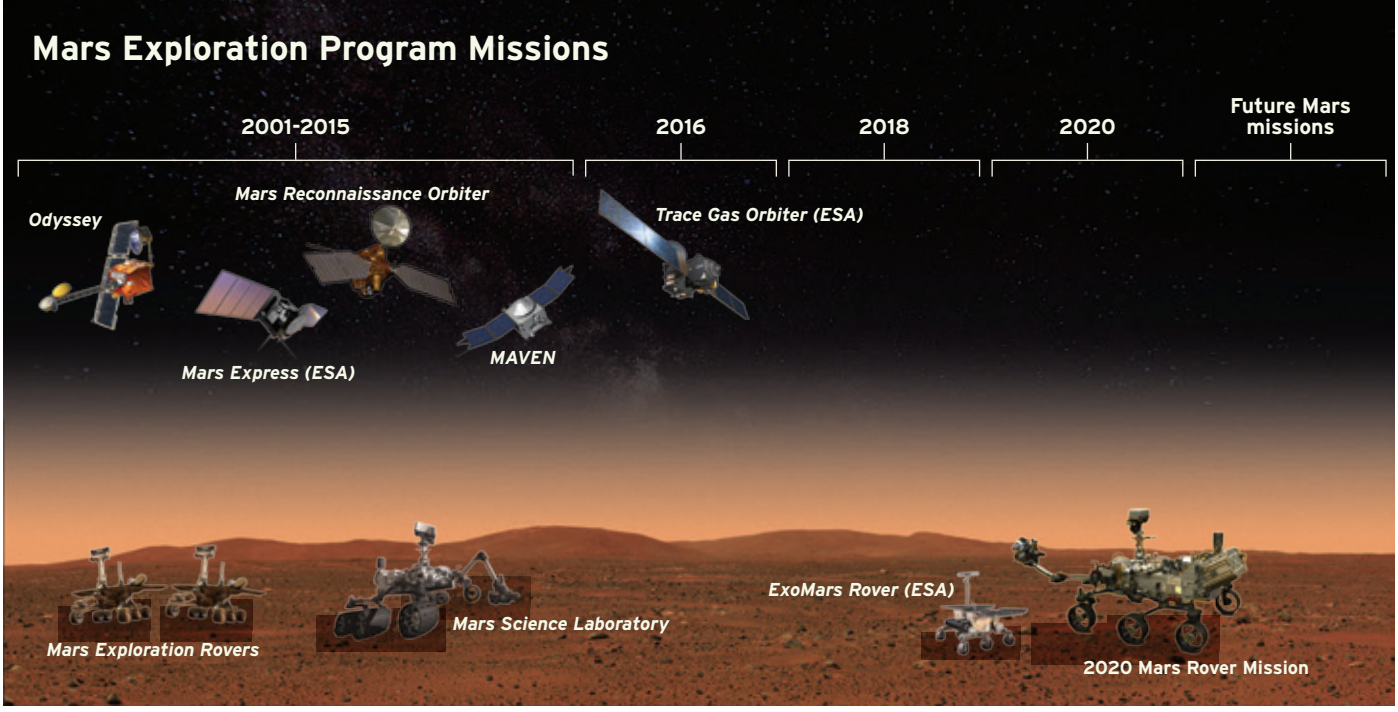
But nearly 17 years after the original announcement, and once again in the midst of a presidential transition, the people who work in NASA's Mars Exploration Program can only dream of another bold commitment. Instead of a decade of new missions on the books, there is only one: a Mars rover set to launch in 2020.

Jim Watzin, the current director of NASA's Mars Exploration Program, has not minced words about this situation. "It's important to recognize that the future is not going to be the same as the past," he said at a recent meeting of Mars scientists. "The era that we all know and love and embrace is really coming to an end."

That statement casts uncertainty on the most important goal of the Mars science com-

ABOVE Spirit *captured this view of the Sun sinking below the rim of Gusev crater on the evening of May 19, 2005. Hopefully, we have many more Martian sunsets yet to enjoy.*

Image: NASA/JPL



ABOVE *The spacecraft of NASA's Mars Exploration Program. In addition to its own missions, NASA operates scientific instruments on European Space Agency's (ESA)* Mars Express *orbiter and upcoming* ExoMars *rover, and maintains a communications system on the* Trace Gas Orbiter *spacecraft.*

munity: to return a carefully curated set of samples from Mars. Such a project requires multiple landers and orbiters to collect, launch, and return the samples, and to ensure high-speed data communication with Earth. The *Mars 2020* rover is being designed to take the first step in this effort by collecting and preparing samples. But NASA has not officially committed to returning them.

This new reality represents a marked change in fortune for the Mars science community, which has enjoyed frequent Mars missions since 1992. How did we get to this point?

BEFORE THE MARS EXPLORATION PROGRAM

NASA's first explorations of Mars occurred in the halcyon days of Apollo. This was the dawn of planetary exploration, when NASA's Mariner program attempted six missions to the Red Planet between 1964 and 1973 (four succeeded). The *Mariners* were followed up by the Viking missions, which arrived at Mars in 1976 and operated for years.

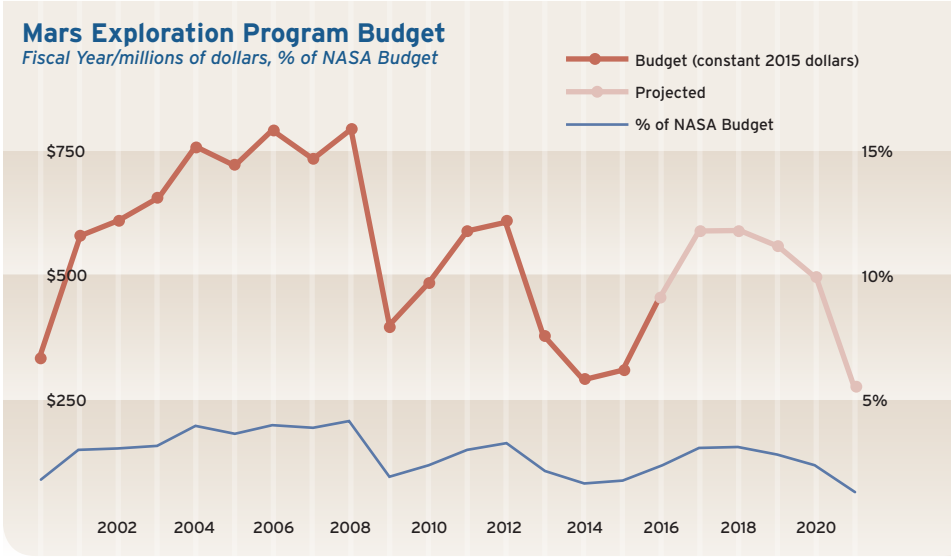
By the late 1970s, NASA's focus had shifted. Cost overruns in the space shuttle program and a shift toward space-based telescopes consumed NASA's shrinking budget. This led into the "lost decade" of planetary science—the 1980s—where no new missions launched for 11 years. Building the Galileo mission to Jupiter kept the planetary science program on life support, as did the operations of the *Voyager* spacecraft.

Fortunes began to improve by the late 1980s, which saw the launches of *Magellan*, *Galileo*, and, finally, the start of a new Mars mission. The $813 million *Mars Observer* launched in 1992, but was lost due to a design defect just days before entering Mars orbit. The failure of this expensive mission was a blow to the fledgling Mars science community and to NASA's image, and it helped push the agency toward a "faster, better, cheaper" approach to mission design. With a steady stream of small missions, the loss of any one mission would not cause a scientific and public relations disaster, or so went the thought.

In the early 1990s, NASA started Discovery, a small-class planetary mission program. *Pathfinder*, a Mars lander and micro-rover mission, was one if its first successes. In the mid-'90s, NASA began its Mars Surveyor program with the goal of launching two small missions to Mars at each launch opportunity, which occurs every 26 months. *Pathfinder* and *Mars Global Surveyor* were initial success stories of this "faster, better, cheaper approach." But in 1999 NASA suffered back-to-back failures of the *Mars Climate Orbiter* and *Mars Polar Lander*. Despite the fact that both missions were "cheap" compared to a multibillion dollar flagship mission, NASA was publicly embarrassed by the double loss. It was time to step back and reevaluate how the space agency managed its Mars program.

In early 2000, NASA released the aptly named Mars Program Independent Assess-

Chart based on a graphic provided by Fuk Li/NASA/JPL



ment Team Report. It concluded that NASA's Mars program lacked clear management responsibility and programmatic direction, and was subject to breakdowns in communication among its headquarters, field centers, and contractors. Moving forward, the report said, NASA should create a single program with centralized authority to execute a coherent Mars strategy. This program should have a director located at the agency's headquarters and management located at a single field center. It should pursue a coherent, strategic set of goals that gradually build capability and technical expertise.

Later that year, then-NASA Administrator Dan Goldin stood before reporters and announced his intention to send a fleet of spacecraft to Mars in the coming decade. Not long after, Stanford University professor Scott Hubbard was appointed the first director of the newly minted Mars Exploration Program (he now serves on The Planetary Society's board of directors).

THE MARS EXPLORATION PROGRAM'S FIRST DECADE

The Mars Exploration Program (MEP) launched five missions to Mars in its first decade—all of them operating under a single organizing principle: to follow the water. First went the *Odyssey* orbiter; then the first fully mobile Mars rovers, *Spirit* and *Opportunity*; these were followed by a new orbiter with a spy-grade camera, the *Mars Reconnaissance Orbiter (MRO)*; and finally the first competitively selected Mars Scout mission, *Phoenix*.

These missions confirmed the existence of ancient lakes, hot springs, and rivers on Mars. They discovered meteorites littering the surface and water ice hiding just below it. They silently witnessed dust devils, dust storms, and rockslides. And they persisted. Every single mission outlasted its intended design life, and all but one continue to operate to this day.

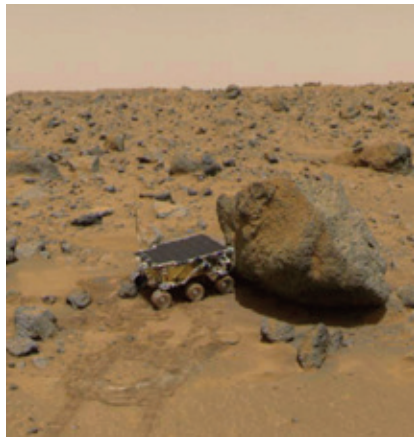
In any given year in the first decade of the twenty-first century, NASA simultaneously had a set of Mars spacecraft being designed, being built, and being operated on the Red Planet. The program received remarkably steady funding during this period, averaging $700 million per year—about four percent of NASA's total budget. This reliable funding enabled a new mission to launch at every single launch opportunity from 2001 until 2009.

But when the Mars Science Laboratory *Curiosity* mission missed its planned launch in 2009, fortunes began to change.

THE SECOND DECADE OF THE MARS EXPLORATION PROGRAM

The National Academies' Decadal Survey report represents the official scientific consensus for which science missions NASA should pursue. The current Decadal Survey recommends that NASA should commit to a flagship-class mission to begin Mars sample return.

The committee authoring the report declared that sample return "will provide the highest scientific return on investment for understanding Mars in the context of solar

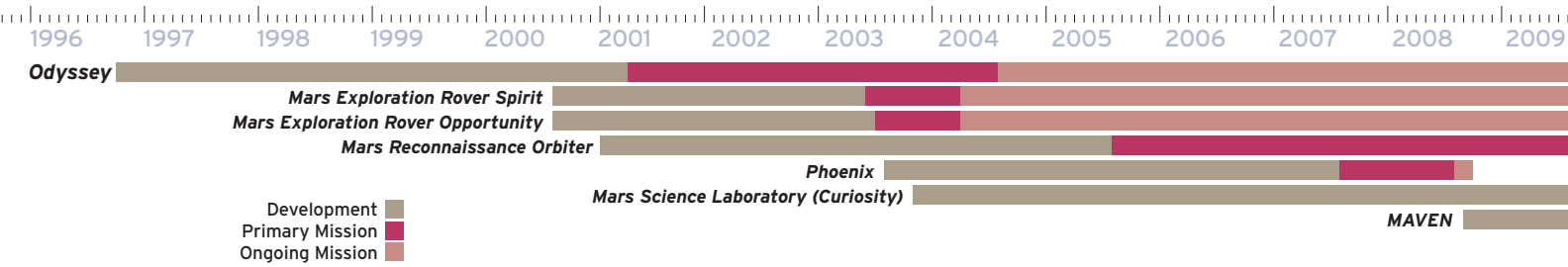


ABOVE *In July 1997, people around the world were thrilled when* Mars Pathfinder's Sojourner *rover put the first wheel tracks on Mars.* Pathfinder *was the first success of NASA's "faster, better, cheaper" approach. Here,* Sojourner *examines the rock called Yogi.*

Image: NASA/JPL

As director of space policy, **CASEY DREIER** *leads the strategic planning and implementation of The Planetary Society's policy and advocacy efforts. He works to educate and engage the public about space policy, and to empower individuals to advocate for space.*

THE FADING FORTUNES OF MARS



system evolution and addressing the question of whether Mars has ever been an abode of life." The report recommended that NASA partner with European Space Agency (ESA) to pursue this goal.

But the Mars Exploration Program had run into trouble with its largest and most ambitious mission: the Mars Science Laboratory (MSL), initially known as the Mars Smart Lander, a midsized mission designed to test new landing and mobility technology on the surface. But after the success of *Spirit* and *Opportunity*, a sense of overconfidence ran through the program, and the "smart lander" grew in scope to become a "science laboratory" with a far more ambitious set of science instruments and technology. Costs grew from less than $1 billion to $1.8 billion. Technical problems caused MSL to miss its launch date in 2009, which drove its cost to $2.5 billion. That same year, the MEP budget dropped by nearly 50 percent.

Although MSL launched in 2011 and arguably became NASA's biggest success story of 2012, the budget for the Mars Exploration Program never returned to its old levels. ExoMars, the joint ESA-NASA mission to begin a sample return campaign, was abruptly cancelled in 2011, leaving ESA to scramble for a new partner (ultimately, Russia stepped in).

In a surprise move, NASA announced the Mars 2020 rover in late 2012, despite proposing significant new budget cuts for the program in the following year. NASA struggled to pay for the operations of its existing Mars missions and ensure that development for Mars 2020 stayed on track. After the launch of its *Mars Atmosphere and Volatile Evolution (MAVEN)* mission in 2014, Mars 2020 became the Mars Exploration Program's only mission in development (*InSight*, which will land on Mars in 2018, is funded by NASA's Discovery program and is otherwise unrelated to the Mars Exploration Program). Despite clear scientific consensus on the value of Mars sample return, gone was the era in which NASA committed to long-term plans for Mars.

BELOW *Jezero crater, one of the three possible landing sites for the Mars 2020 rover, contains preserved river deltas and carbonate rocks, which can give insights into Mars' ancient atmosphere. NASA would have to retrieve samples collected by the Mars 2020 with a follow-up mission and then launch them into orbit. A third mission would then rendezvous with the orbiting samples and return them to Earth.*

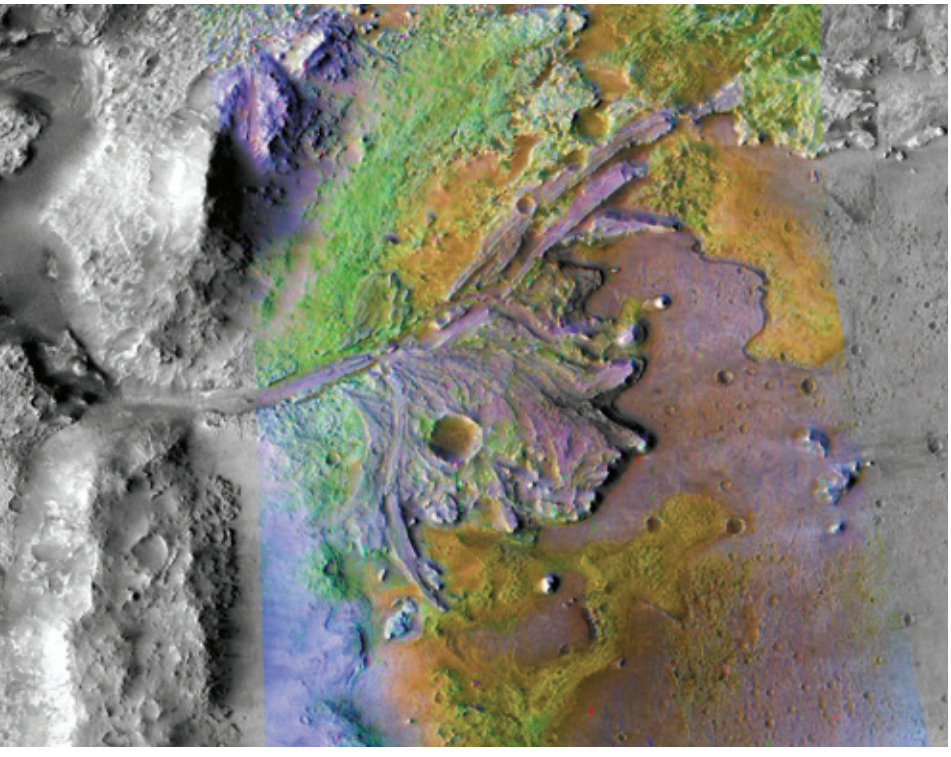
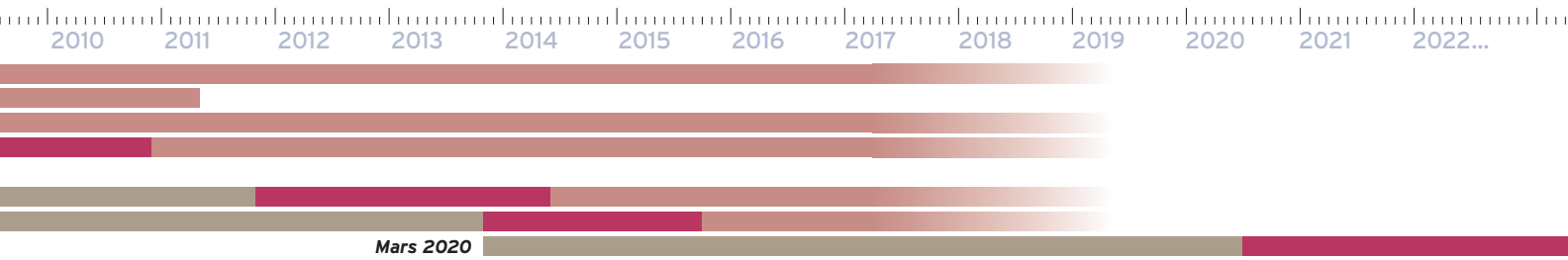


Image: NASA/JPL-CALTECH/MSSS/JHU-APL

THE FUTURE

We find ourselves now with a single, albeit very large, mission in development. No new Mars missions have been approved for development since 2012, which is the longest drought of new mission approvals in over 25 years.

Meanwhile, NASA's existing Mars fleet is aging, with no new missions in the pipeline to replenish it. NASA desperately needs a new Mars orbiter which, in addition to providing important science and imaging capabilities, will serve as a data relay for ground missions.



NASA's existing orbiters are either well past their design lifetimes or occupy inefficient planetary orbits. Without these high-speed data relays, ground missions will struggle to send back scientific data. So far, NASA has been unable to get approval for a new orbiter mission from the White House's Office of Management and Budget.

This is problematic. The Next Mars Orbiter—or NeMO—will likely take four to five years to design, build, and prepare for launch. But orbital mechanics wait for no one. If NASA does not formally include a new orbiter in its 2018 budget request, it is unlikely a new mission would be ready to launch in time for the 2022 Mars launch opportunity. A launch in 2024 would mean that a new telecommunications relay orbiter would arrive at Mars over a year after the end of Mars 2020's prime mission. By that point, *MRO* would be 20 years old and *Odyssey* would likely be gone.

And this is to say nothing of actually returning the samples collected by Mars 2020. NASA is designing the sample containers that will preserve their contents for 10 years on the Martian surface and another 10 years in space. That means NASA has only four launch opportunities after Mars 2020 to send a retrieval mission. This mission depends on new technology—a Mars Ascent Vehicle—to launch the samples into orbit, and new technology means a higher price and longer development timelines. NASA must begin work on a such a mission very soon in order to retrieve these samples.

And we haven't even discussed the third mission, which would rendezvous with the in-orbit samples and return them to Earth.

The cuts that hit the Mars Exploration Program years ago are only now beginning to manifest themselves. Instead of a healthy program with multiple missions in various stages of development, NASA has only one flagship-class Mars mission. There is a very real possibility that NASA may find itself with a cache of promising samples on Mars ready to return to Earth, but unable to bring them here in time. Should that occur, the $2.4 billion Mars 2020 rover's major effort will have been for naught.

Meanwhile, Mars is receiving unprecedented attention from international space agencies and private industry. New missions are in the works from ESA, the United Arab Emirates, Japan, and China. SpaceX has announced its intention to land uncrewed Dragon spacecraft on Mars at every launch opportunity beginning in 2020. And unless something changes very soon, NASA will slowly watch its current Mars fleet, announced with so much promise at the beginning of the twenty-first century, slowly die of old age.

BELOW *A computer-aided design illustration of the Mars 2020 rover.*

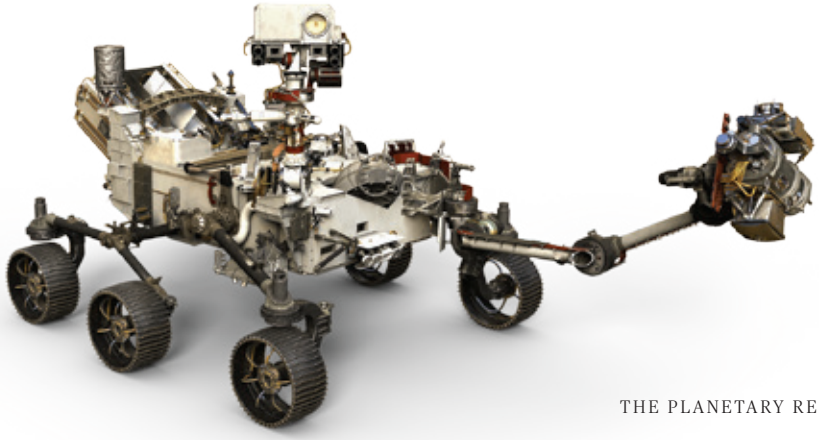


Illustration: NASA/JPL

If you want to help NASA keep its Mars exploration program going, add your voice to ours at **planet.ly/TakeAction**

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

A Planetary Defense Update

We Keep Working to Protect Earth

WE ARE IN THE MIDST of a busy time right now at The Planetary Society regarding our work in planetary defense, or protecting Earth from an asteroid impact. Here is an update on our Shoemaker Near-Earth Object (NEO) Grant program, including a new call for proposals, and the upcoming Planetary Defense Conference.

SHOEMAKER NEO GRANTS

Now in its 20th year, our Shoemaker NEO Grant program, named after pioneering planetary geologist Gene Shoemaker, supports mostly very advanced amateur astronomers—some are very advanced amateurs—around the world in their efforts to find, track, and characterize near-Earth asteroids. We are currently raising funds to support a new round of grants (to contribute, go to planetary.org/neo). Over the history of the program, we have made 49 awards to astronomers from 16 countries on 5 continents. More than $323,000 has been awarded over the history of the program. We will issue a new call for proposals in mid-May 2017 on our website.

Shoemaker NEO Grant winners have been extremely effective at using their grants, which are usually awarded for upgrading the systems they use to study near-Earth asteroids. Even in the current era in which most NEOs are found by professional surveys, Shoemaker Grant winners provide crucial follow-up observations of the discovered asteroids. These observations are required to define the orbit of an asteroid to figure out if it will hit Earth. They also characterize the asteroid by studying properties like the object's spin rate, and even determining whether what looked like one asteroid is actually a binary pair.

ABOVE *Three Shoemaker NEO winners at their shared facility, the Center for Solar System Studies, in the California desert. Left to right are: Brian Warner (2007), Robert Stephens (2013), and Dan Coley (2015).*

Photo: Center for Solar System Studies

Here is a small sampling of recent updates from some of our Shoemaker NEO Grant winners:

ALBINO CARBOGNANI, 2013 winner, Astronomical Observatory of the Autonomous Region of the Aosta Valley (OAVdA), Italy. In 2015 and 2016, the OAVdA 0.81-meter telescope made follow-up observations of 33 NEOs, captured 25 asteroidal light curves (a measurement of light intensity as a function of time), and characterized three new binary asteroids.

DANIEL COLEY, 2015 winner, Center for Solar System Studies (CS3), Landers, California. Since his new camera was put into operation in July 2015, Coley's telescope has operated a total of 343 nights, developing light curve models for 43 different asteroids, including two that had over 100-hour rotation periods.

ROBERT HOLMES, five-time winner, Astronomical Research Institute (ARI), Northern Illinois. In 2016, Holmes' observatory made more NEO observations than any other facility on Earth in the span of one year—ever. Out of 17,113 total measures, 1,093 were of (extremely faint) 22nd magnitude asteroids, and 177 were of 23rd (even fainter) magnitude asteroids.

GARY HUG, two-time winner, Sandlot Observatory, Kansas. Hug has fulfilled a personal goal of making 10,000 NEO observations from his backyard observatory.

HERMAN MIKUŽ, two-time winner, Črni Vrh Observatory, Slovenia. In 2015 and 2016, Mikuž and his colleagues used their 0.6-meter telescope to make follow-up observations of 30 near-Earth asteroids and comets, including one asteroid that missed Earth by a mere 100,000 kilometers (62,000 miles).

JULIAN OEY, 2015 winner, Blue Mountains

Thanks! Planetary Society members have helped make the Shoemaker NEO Grants—and many other projects—possible! Thank you.

Photo: Bruce Betts/The Planetary Society

ABOVE *In April 2015, the IAA's Planetary Defense Conference was held at ESRIN (European Space Research Institute), a European Space Agency facility in Frascati, Italy. This year's conference will take place in Tokyo.*

Observatory, New South Wales, Australia. In the second half of 2016, Oey obtained 70 individual light curves for different asteroids, most of which targeted suspected binary asteroids. His observations also collected the rotational periods of 30 new binary asteroids.

DONALD PRAY, three-time winner, Sugarloaf Mountain Observatory, Massachusetts. Pray, a three-time grant recipient, purchased his new CCD camera using his 2015 funding. He has since been credited with the discovery of five binary asteroids

ROBERT STEPHENS, 2013 winner, Center for Solar System Studies (CS3), Landers, California. Stephens reports CS3 was operational for about 300 nights in 2016, collectively making more than 2,000 observations that resulted in the determination of 373 asteroid rotational periods.

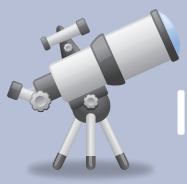
For more about the Shoemaker NEO Grants, including a blog from Jason Davis with more winner updates, see **planetary.org/defense**.

PLANETARY DEFENSE CONFERENCE

I am excited to report that, once again, The Planetary Society is a primary sponsor of the Planetary Defense Conference, which will be held in Tokyo this coming May. I serve on the organizing committee and will be presenting two papers at the conference.

The Planetary Defense Conference is unique in that it brings together international experts from all aspects of the asteroid threat issue. There will be experts on finding, tracking, characterizing, and deflecting asteroids, as well as those involved with asteroid missions. Those involved with educating the public and international leaders, like The Planetary Society, will be there, as well as members of the disaster management community. While in Tokyo, The Planetary Society will also be hosting a public event about asteroid impact.

Asteroid impact is the one large-scale natural disaster that we can prevent. There is still much to be done to make our world safe from a devastating impact, and through efforts like the Planetary Defense Conference and Shoemaker NEO Grants, we move ever closer to this goal. We don't need to end up like the dinosaurs.



IN THE SKY

Very bright Jupiter and bright, yellowish Saturn are visible high in the evening sky. Look for the Moon near Jupiter on June 3. Reddish Mars is low in the West after sunset, gradually sinking as the weeks pass. Very bright Venus is in the predawn East. Mercury is below and to the left of it for much of May.

RANDOM SPACE FACT

If Earth were the size of a racquetball, then Uranus (and the similarly sized Neptune) would be a little bigger than a basketball (about four times the diameter of Earth).

TRIVIA CONTEST

Our September Equinox contest winner is Jim DeRivera of Oxnard, California. Congratulations! **THE QUESTION WAS:** About how long does it take light to travel from the Sun to the Earth? **THE ANSWER:** About 500 seconds or about 8 minutes, 20 seconds. The time varies slightly as Earth goes around its elliptical orbit.

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 this question:

What was the first lunar rover (wheeled vehicle on the Moon)?

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 June 1, 2017. 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.*

Come on an Adventure With Us!

We invite you to join fellow Planetary Society members as we explore the world! In the 2017/2018 year, you may discover a Total Solar Eclipse at Sun Valley, a Lunar Eclipse in the Sea of Cortez, or the fascinating heritage of Cuba! You will delight in these adventures with other Planetary Society members!

SUN VALLEY IDAHO TOTAL SOLAR ECLIPSE INCLUDING THE GRAND TETONS AND YELLOWSTONE

AUGUST 15–23, 2017

See the Total Solar Eclipse August 21, 2017 from the top of Bald Mountain at Sun Valley, and discover the World Center for Birds of Prey, Hagerman Fossil Beds, the Mammoth discovery of 2014, and more! Travel from Jackson Hole and Yellowstone to Boise, Idaho!

GREAT WHALES IN BAJA CALIFORNIA – DISCOVER A WILDERNESS PARADISE AND LUNAR ECLIPSE!

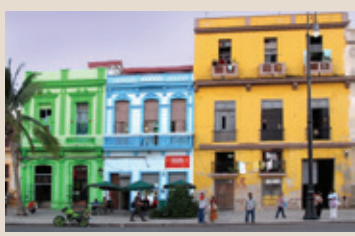
JANUARY 27–FEBRUARY 4, 2018

See the whale extravaganza of the Baja California desert wilderness on board M/V National Geographic *Sea Bird*. Travel with Dr. Tyler Nordgren and see the Lunar Eclipse on January 31, 2018 in this exciting desert wilderness with perfect 70 degree days and sparkling clear skies. Hike desert islands, snorkel with sea lions, see California gray whales in the whale nursery of Magdalena Bay.

Discover the Heritage of Cuba!

MARCH 30–APRIL 7, 2018

Come to Cuba and explore the fascination of the World Heritage cities of old Havana and historic Trinidad! Travel to the mountain station at Topes de Collantes and historic Cienfuegos! Meet Cuban astronomers and naturalists, as you relish the opportunity to visit this truly fascinating country!



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

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

Welcome to the Great Uncertainty

The New U.S. Administration Begins to Ponder NASA's Future

"I WOULD WELCOME a smaller budget," a NASA program officer once told me, "if I knew it would be stable over time." This is a common lament in a world where long-term projects are funded annually by politicians who can be replaced every two to four years.

We are in the midst of such a transition now. The 115th Congress is just gearing up, and though many of the same faces will return to their roles in overseeing NASA, we have a new president and a brand new director for the Office of Management and Budget, Mick Mulvaney.

While the details of Trump's agenda are still hazy, the big picture elements are there, and the overall math doesn't look good. We can expect proposals for large tax cuts, increases in military spending, and an infrastructure bill in the hundreds of billions of dollars. Sequestration, the across-the-board cuts to government spending that began in 2013, has been on pause but will once again come back into force in 2018. At the same time, Mulvaney, who voted against nearly every spending bill that came across his desk during his time in the U.S. Congress, will lead the agency that prepares NASA's budget requests and controls the flow of money to its major projects.

Discretionary spending is what Congress approves of the total annual U.S. budget, and it amounts to roughly $1.2 trillion out of the $4 trillion total spent every year. The Department of Defense receives a little more than half of that discretionary amount. Pretty much every other part of government that is not a social service program splits the rest. If the overall nondefense discretionary pot shrinks—which appears likely—NASA will have a hard time maintaining its current budget, much less growing it.

Not all is lost for NASA, but things are mighty uncertain. Fortunately, the agency enjoys broad bipartisan support in Congress (its Earth Science Division being the unfortunate exception). Trump mentioned space in his inaugural address and Jeff Sessions, his new attorney general, represented Alabama (and NASA's Marshall Space Flight Center) in the Senate. And Mulvaney may temper his budget-cutting zeal now that he works for an administration that has big ambitions for spending.

This is the essence of uncertainty. The Trump administration could very well propose a good space policy for the country, but if NASA succumbs to broader fights over spending, no amount of good words on paper will replace the actual currency that enables the exploration of space.

The Planetary Society intends to fight hard to maintain NASA's funding and to help provide clear direction for its major programs—both for human spaceflight and for science. There are so many promising missions ahead of us that need certainty and continued support. You can help. Stay connected at **planetary.org/spaceadvocate** to help fund our work and to engage with your representatives (or, if you live outside the United States, write the president). It's the only way we can provide the stability we need.

As this issue was going to press, the Trump Administration released an outline of its 2018 budget proposal for NASA. Read a detailed analysis at **planet.ly/BudgetOutline**

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SNAPSHOTS FROM SPACE

EMILY STEWART LAKDAWALLA
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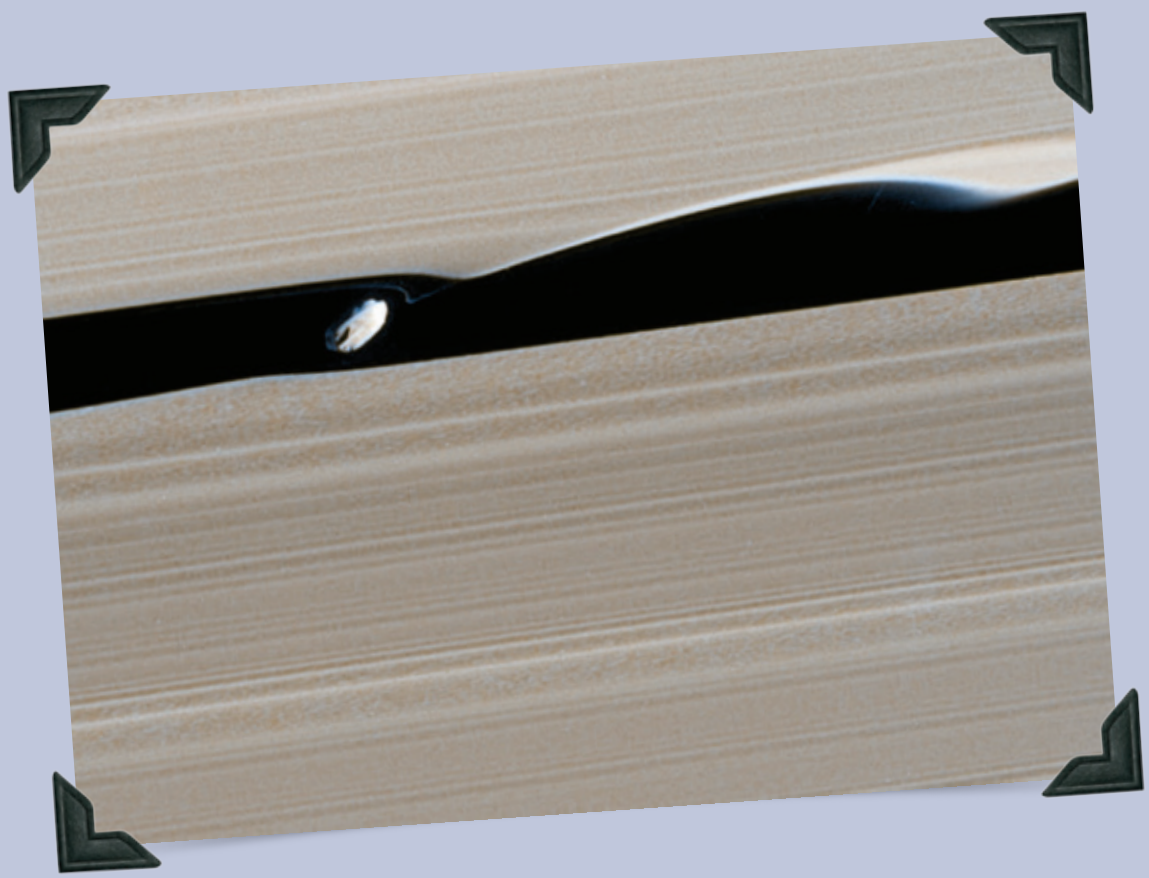

***CASSINI* IS IN** the thick of its "F-ring orbits" now, so named because the spacecraft's orbit takes it just outside Saturn's F ring (and inside the G and E rings) every time it crosses Saturn's ring plane. Because its orbit is passing closer to the main rings, it is also passing closer to the moons embedded in the rings: Pan and Daphnis near the outer edge of the A ring, Prometheus and Pandora on either side of the F ring, Janus and Epimetheus outside the A ring. In this *Cassini* image taken January 16, 2017, Daphnis, the tiny, 8-kilometer (5-mile) moon that orbits within the Keeler gap, gently tugs on the edges of the gap to create delicate scallops.

–Emily Stewart Lakdawalla

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