THE PLANETARY SOCIETY

THE PLANETARY REPORT

JUNE SOLSTICE 2017

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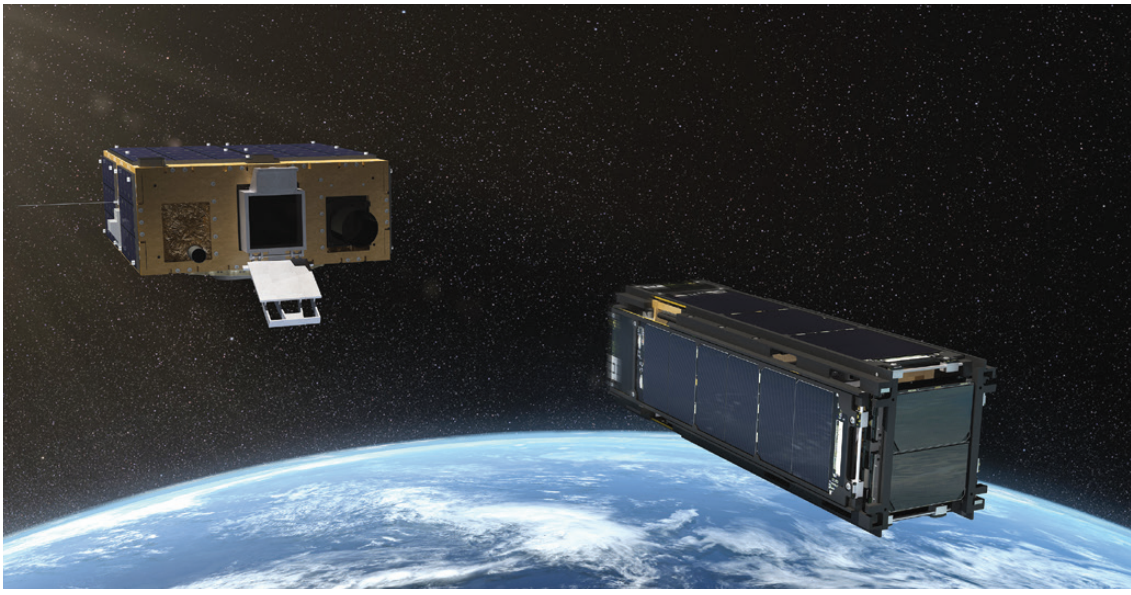
SPECTACULAR JUPITER

***JUNO* REVEALS A SURPRISING AND COMPLEX WORLD**

CHINA'S *CHANG'E-5* ✵ A NEW SMOKING GUN? ✵ A PLANETARY DEFENSE PLAN

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



Help Us Fuel Up for Launch!

Watch As We Get Ready for *LightSail 2*...

We could employ solar sails, vast but very thin films that catch sunlight...plying the void between the worlds. Especially for trips to Mars and beyond, such methods are far better than rockets.

– Carl Sagan, *Pale Blue Dot*

THE PLANETARY SOCIETY'S *LightSail® 2* spacecraft is one step closer to the launch pad and ready to make space exploration history! In the two years since our test launch of *LightSail 1*, our spacecraft has undergone an extensive review followed by a series of critical upgrades and tests.

Our new and improved *LightSail 2* is now being prepared for delivery to the Air Force Research Laboratory in Albuquerque, New Mexico, where it will be integrated with its "mother ship," *Prox-1*. Once there, we will wait for confirmation of our final launch date from SpaceX, and prepare for the trip to Kennedy Space Center.

With these key steps completed, we are now focusing on final preparations for mission operations and the challenges of demonstrating controlled solar sailing in orbit. And to get there, we need one more boost from our vitally important mission team: the members of The Planetary Society.

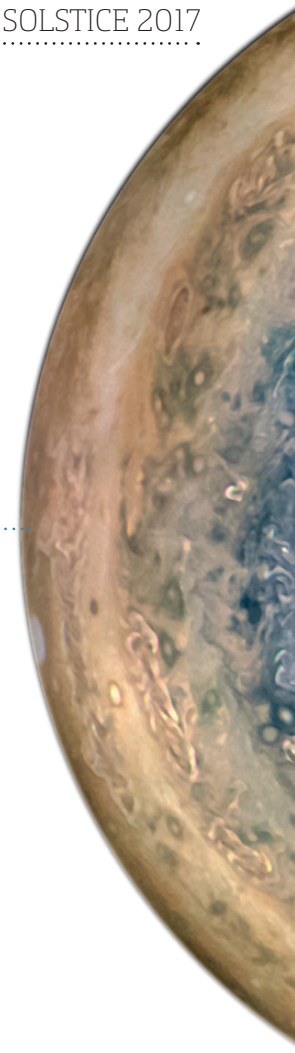
In the coming weeks, we'll be launching a special member appeal to help us store the financial fuel we need to complete the work ahead of us. Watch for our special mailing and the opportunity to make a gift that will help us secure our place in history. Soon we'll be announcing how your gift will stretch farther, thanks to a generous match from one of our visionary members, someone who is deeply committed to our efforts to advance space science and exploration.

But wait! In the early fall, look for an exciting online opportunity for members and donors to win a special VIP trip to watch *LightSail 2*'s historic launch from Cape Canaveral! More details are coming soon.

ABOVE LEFT *A remote camera placed near the launch pad captured this photo of* LightSail 1 *blasting off on May 20, 2015.*

ABOVE RIGHT LightSail 2 *will ride to space onboard a SpaceX Falcon Heavy. Once released from* Prox-1, *its carrier satellite,* LightSail 2 *will embark on its mission to demonstrate controlled solar sailing in Earth orbit.*

Launch photo: Navid Baraty; illustration: Josh Spradling/The Planetary Society



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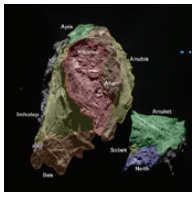

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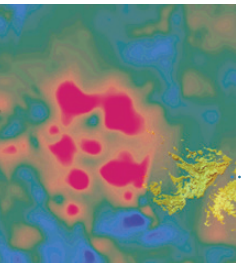

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THE PLANETARY SOCIETY

ON THE COVER: The *Juno* spacecraft is revealing a new Jupiter to us—with roiling north and south polar storms, a "fuzzy" planetary core, a "lumpy" magnetic field, and more. As this magazine goes to press, *Juno* will fly over the Great Red Spot, surely changing our ideas about this iconic Jovian feature. Jupiter's unexpectedly storm-congested south pole is highlighted in this JunoCam image captured on May 19, 2017, from a height of 49,900 kilometers (about 29,000 miles). *Image: NASA/SWRI/MSSS/Gerald Eichstädt/Seán Doran*

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

Thinking Carefully About the Future

Sufficient and Steady Investment in Space

RECENTLY, I MADE what I hope is only my first appearance on *The Late Show* with Stephen Colbert. And what did he want to talk about? *LightSail*! It was a marvelous moment. I brought out a model of our spacecraft (created by the Jet Propulsion Laboratory's Dave Doody, a longtime Society member) and spoke briefly about the big ideas behind solar sailing and our decades of support for solar sailing missions. It meant a great deal to me. I was, after all, following in Carl Sagan's footsteps. In 1976, Carl showed a model of JPL's proposed Comet Halley solar sail to TV talk-show host Johnny Carson. That mission never flew, and The Society's first solar sail, *Cosmos 1*, wound up in the sea. But I showed the world a model of a solar sail that actually has flown. I shared our mission and our vision with the audience of America's most popular late-night TV show. It was really something for me and, especially, for The Society.

I'm also happy to report that *LightSail 2*'s partner spacecraft, Georgia Tech's *Prox-1*, has shipped safely to the Air Force Research Laboratory in Albuquerque, New Mexico. Once *Prox-1* reaches orbit, it will open up and deploy *LightSail 2* onto its mission to perform controlled solar sail flight in Earth orbit. This is yet another important milestone in *LightSail 2*'s exciting journey to launch.

THE MARCH FOR SCIENCE

Also this spring, I participated in the international March for Science in Washington, D.C. I was an honorary cochair and The Planetary Society was a partner. There were at least fifty-thousand people out there in the pouring rain

along with four or five times that many at the four-hundred-plus "sister" marches around the world. That's a lot of people sharing and expressing the same sentiment: that science, basic research, and many of the scientific discoveries made in recent years be valued and protected by important elected representatives and government officials around the world. It is in absolutely no one's best interest when science—and for us at The Planetary Society, space science—is undervalued by the powers that be. Investment in basic research, especially space science research, leads to innovations. New materials and alloys, new fabrication techniques, new computer processors, and new software all keep a country competitive on the world stage. Without innovation, countries and their economies fall behind and get out-competed by other

Sagan/Carson video still: Johnny Carson Estate; Nye/Colbert video still: CBS TV

LEFT *On April 22, 2017, people around the world joined the March for Science to show their support for all aspects of science, and to urge their governments' lawmakers to make it a top priority. The Planetary Society was a sponsor, with Bill Nye as an honorary cochair, of the main march in Washington, D.C.*

OPPOSITE PAGE *In 1976, Carl Sagan appeared on* The Tonight Show with Johnny Carson *where he discussed the concept of solar sailing. He displayed a model of an early sail design, captivating Johnny and* The Tonight Show*'s millions of viewers. This past May, forty-one years later, Bill Nye was a guest on* The Late Show with Stephen Colbert. *Bill displayed a model of our own* LightSail*, honoring his former professor and showing off our groundbreaking spacecraft.*

nations where investment is steady and for the long term.

When considered from an Earthling's point of view, the planets of our solar system are quite far apart. So, travel between them is a serious and inherently long-term undertaking. We will not make discoveries on other worlds without well-planned, steady investment. If one asks any member of any parliament or congress, he or she will agree at once that space requires careful thought about the future. He or she will further accept that, in order to make discoveries on other worlds or garner national prestige, a country has to ensure that investment in space is sufficient and steady.

Almost any citizen of any government, along with their politicians, would generally agree that planetary science and planetary exploration bring out the best in all of us. I'm proud to say that The Planetary Society has been promoting the connection between space, innovation, progress, and the world's citizens since our founding more than 37 years ago. And you are a part of it. You support us and enable us to influence policymakers. You can count on The Society's policy analysts and our entire staff to make sure your concerns and desires are known in the halls of power. We will advocate and recommend what we feel are the best and logical courses for space exploration agencies around the world.

SOMETHING ASTONISHING OUT THERE

As I often remark, we citizens of Earth are on the verge of something wonderful. We are going to make a discovery; we will soon find something astonishing out there. I'm confident in my prediction because we can look back on the steady progress humankind has made in space. We explored the heavens with telescopes. We developed rockets. We explored the Moon, then Mars, and our spacecraft toured the solar system. At summer's end, the *Cassini* spacecraft will take its final dive into the gaseous "surface" of Saturn and deliver a wealth of data on the way down into the planet. Every day, we are learning more about our place in space.

At The Planetary Society, our view of the planets in our solar system and beyond is optimistic, no matter what may be going on politically. Here on Earth, our scientists and engineers, supported by citizens like you, are ensuring that the best is yet ahead. Our investment in planetary exploration is very small compared with investments some governments make in their militaries, or what some average citizens invest in their sports teams. So with just a little encouragement, we will help lawmakers do the right things to carry our instruments and our astronaut envoys farther and deeper into space, where they will find planetary features and phenomena that will astonish us all.

Bill Nye

Navid Baraty

Marco Parigi • February 27, 2017
planet.ly/rosettachanges

Citizen Scientist Spots Changes On *Rosetta*'s Comet

BACK IN 2015, as *Rosetta*'s comet, 67P, was approaching perihelion, scientists noticed the surface changing before their eyes. These "very significant alterations," according to the European Space Agency, were located in Imhotep, the smooth region on the comet's large lobe.

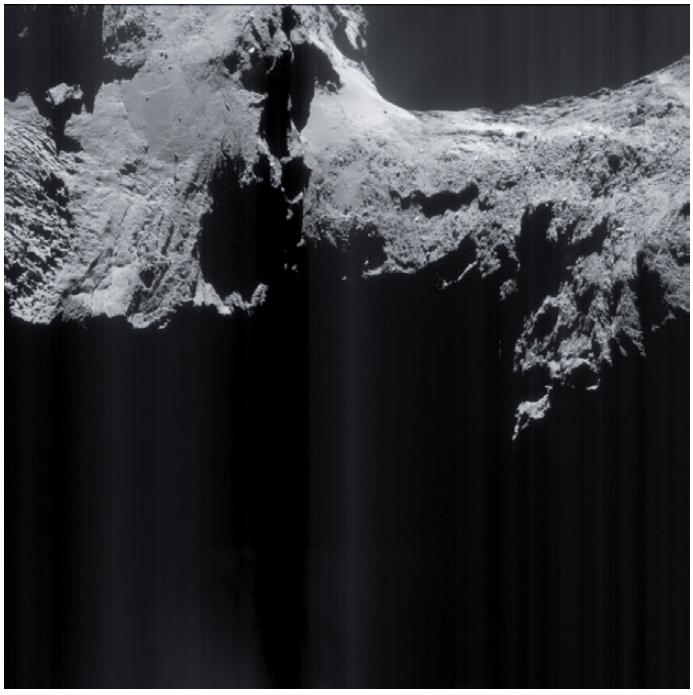
One exciting aspect of the *Rosetta* mission was that on a comet there was a high expectation that visible changes would occur during perihelion, which is the point in the orbit where the comet makes its closest approach to the Sun. How these changes relate to the processes theorised to happen on comets is still a work in progress. Many new papers are proposing various mechanisms, and data from the mission will be informing scientific results for years to come.

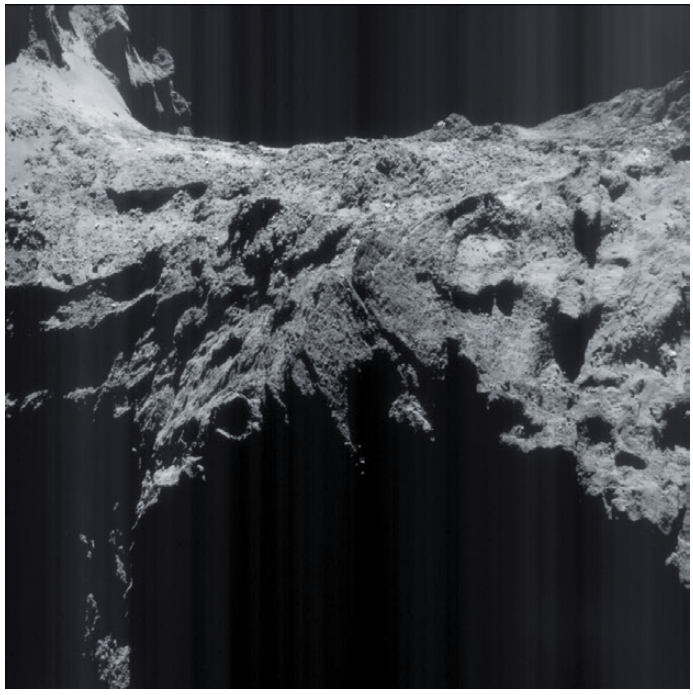
Thousands of *Rosetta* images are available from the European Space Agency (ESA). In March 2016, ESA put out a call for citizen scientists to help spot changes on the comet's surface.

I like looking through comet images for changes, so I decided to contribute. It's a wonderful way for non-scientists to get involved. The process has been very rewarding–as one becomes more and more familiar with features, changes start to jump out, and there are usually multiple images of the same area to help validate differences.

Here's a change I discovered last year. Take

BELOW *European Space Agency citizen scientist (and Planetary Society guest blogger) Marco Parigi spotted an easy-to-miss change in the surface of comet 67P as it neared the Sun in 2016. A small feature in these* Rosetta *NAVCAM images became the focus of Marco's attention. The images are angled and lit slightly differently. Can you see what changed?*

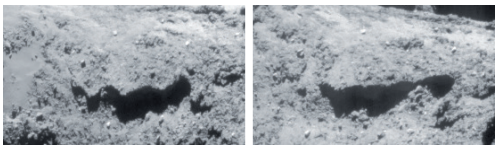




Images: ESA/Rosetta/NAVCAM

a look at these two raw images below. Can you spot the difference?

It's tricky! The lighting and camera angles are slightly different. But if you look closely, you'll notice this:



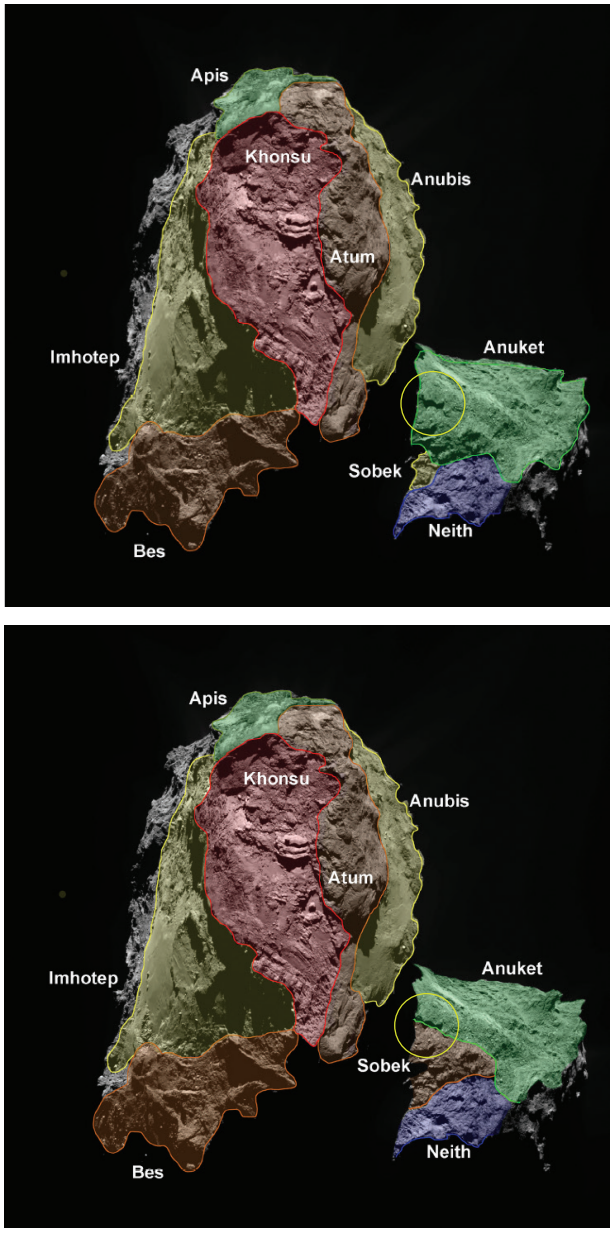
Do you see it now? Part of the cliff has apparently collapsed during the interval between the two images.

With the help of fellow comet enthusiast Andrew Cooper, I concluded the time window for the cliff collapse can likely be narrowed to between February 18 and March 1, 2016. That means it happened after perihelion, with comet 67P outside the orbit of Mars—which is interesting, considering the most dramatic outbursts of activity occurred closer to the August 2015 perihelion.

What's also interesting about this discovery is where it happened. The "top" of the cliff is located in a region called Anuket, and the "bottom" is in a region called Sobek. The cliff collapsed from Anuket into Sobek.

I became very familiar with this part of the comet due to my work on narrowing down the time of the collapse. In the September 2016 issue of the journal *Astronomy and Astrophysics*, a paper was released describing the different regions of the comet. Reading through the paper, I noticed a discrepancy: the border between Anuket and Sobek was wrong. Here's what the paper showed [top figure at right]; can you see the cliff from above, contained entirely within the Anuket region?

I described the mapping discrepancy in the comments section of ESA's original article asking for citizen scientist contributions. The paper's lead author, Ramy El-Maarry, replied to say I was correct, and an erratum was issued correcting the boundaries.



LEFT *Marco became very familiar with the Anuket region of 67P, analyzing the timing of the cliff's collapse (shown in the circled area). As a result, he was able to alert the authors of a paper in* Astronomy and Astrophysics *to a discrepancy in the border area of the image (top). The authors published an erratum, and a corrected image (bottom), based on Marco's evidence.*

The bottom figure at right is the upgraded diagram from the paper's erratum, which was published in February 2017. Notice how the boundary between Anuket and Sobek now runs along the bottom of the region where the cliff collapsed.

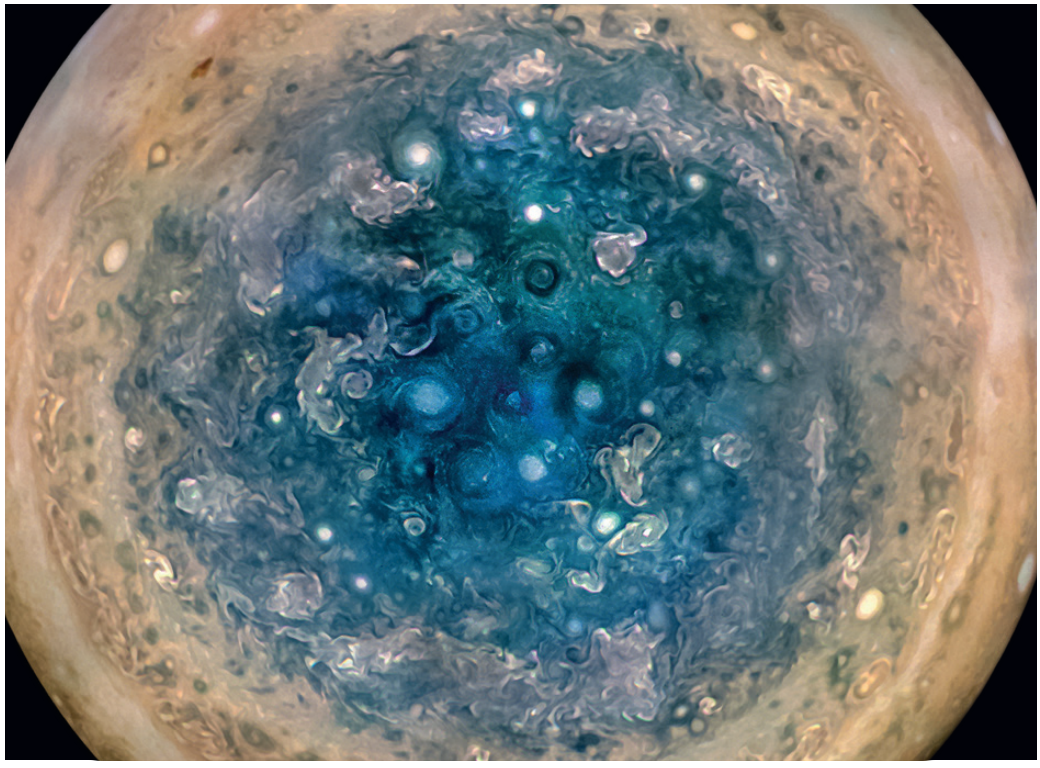
The front page of the erratum paper acknowledges me and Andrew Cooper for having spotted the inconsistencies. Not bad for a couple citizen scientists! I believe it is a wonderful idea for ESA to make spacecraft data available to the public, and allow everyone to contribute to the mission.

Images: M.R. El-Maarry et al. (2016)

MAT KAPLAN *is producer and host of* Planetary Radio.

Spectacular Jupiter

A conversation with *Juno* principal investigator Scott Bolton



RIGHT *This view of Jupiter's south pole, captured from an altitude of 52,000 kilometers (32,000 miles), reveals a chaotic mass of rotating storms that can span up to 100 kilometers (62 miles) across. Multiple JunoCam images taken over several orbits were combined to show the enhanced-color detail visible here.*

On July 4, 2016, Juno *arrived at Jupiter. In the short time since then, the spacecraft has upended our notions about how the giant planet looks and works. On May 25, 2017, mission scientists gathered at the Jet Propulsion Laboratory to share their findings from* Juno*'s first few orbits.* Planetary Radio *host Mat Kaplan caught up with Scott Bolton, the mission's principal investigator, for a chat about the Jovian marvels that* Juno *is serving up. This interview is excerpted and adapted from the full broadcast at* planet.ly/scottbolton.

MK Holy cow, that is some world you are revealing to us.

SB I'm awed at the beauty of this planet.

MK And you're not alone. I think that image of the south pole, albeit with a little bit of false color there, is destined to become one of the great, iconic images of our solar system.

SB I agree. The amazing thing is that these images are all made by the public. We post the raw data from the imager onto our *Juno* website and we depend on them to create the pictures. It's incredible. I think if somebody had showed anyone that picture five years ago, nobody would have guessed that it was Jupiter.

MK Even after *Juno*'s first pass, we talked at a conference and there were surprises from the start about the storms you saw.

Image: NASA/JPL-Caltech/SwRI/MSSS/Betsy Asher Hall/Gervasio Robles

SB I think there's a lesson here. When you get to a new vantage point, and you use new kinds of instruments that you haven't flown before, the discoveries abound. Of course, this is why we explore. We've never been this close to a giant planet before. When you get really close with sensitive instruments, you see things that you didn't expect, that you couldn't even imagine.

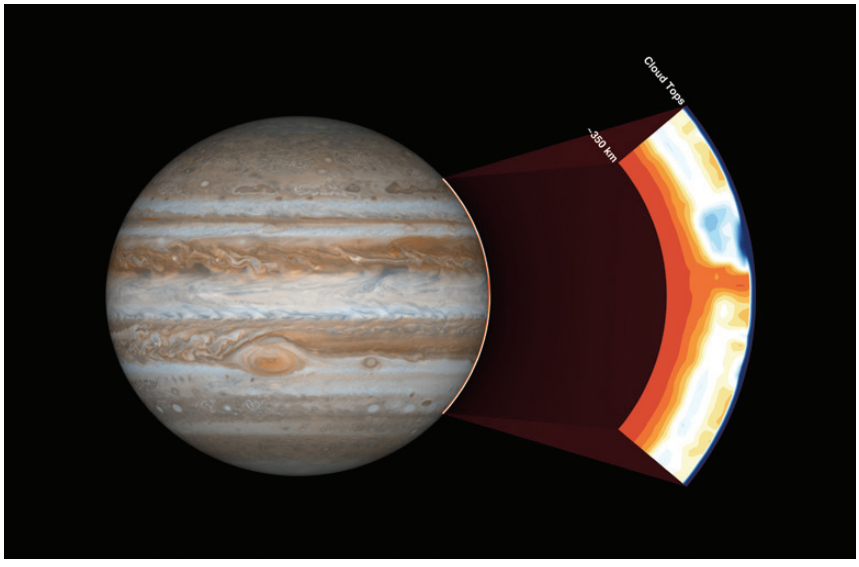
MK It is the great truth of all planetary science missions; there will be surprises. Let's talk about some of what you're already learning. Begin with those famous belts, or bands, that I can see even with my little telescope from Earth.

SB They're gorgeous in the visible light images. We have this special instrument onboard, the microwave radiometer (MWR), looking through the clouds for the first time. It can see a few hundred kilometers down. Looking underneath the belts, I think most scientists thought we would see hints of the zones and belts at every latitude, but we don't. The structure at the top of the atmosphere seems to be replaced with something new in the deep atmosphere. Nobody expected that.

There's also a big equatorial band that seems to go as deep as we can see. We observe a narrow strip right near the equator, and it's warmer and has a concentration of ammonia compared to its surroundings. That was a real surprise—that instead of the zones and belts like you would have thought, you see this completely different structure that goes really deep down before the ammonia content really peaks out. It keeps increasing all the way down as far as we can see. For all we know, it may even go deeper.

MK When you say very deep, how far below the tops of those clouds is *Juno* letting us look?

SB We measure it in pressure, so it's about a thousand bars' pressure. One bar of pressure is what we feel on Earth at sea level. That's our atmosphere pushing down at sea level.



So, our thousand-bar measurement is a few hundred kilometers down into Jupiter, which is well below the cloud tops. The naive assumption that people have made for decades is that once you drop below the cloud tops and the sunlight is shaded out, Jupiter would be uniform, kind of boring. That isn't true. Not only are there features down there, but they vary as a function of latitude, and the variability appears to be independent of the zone and belt structure.

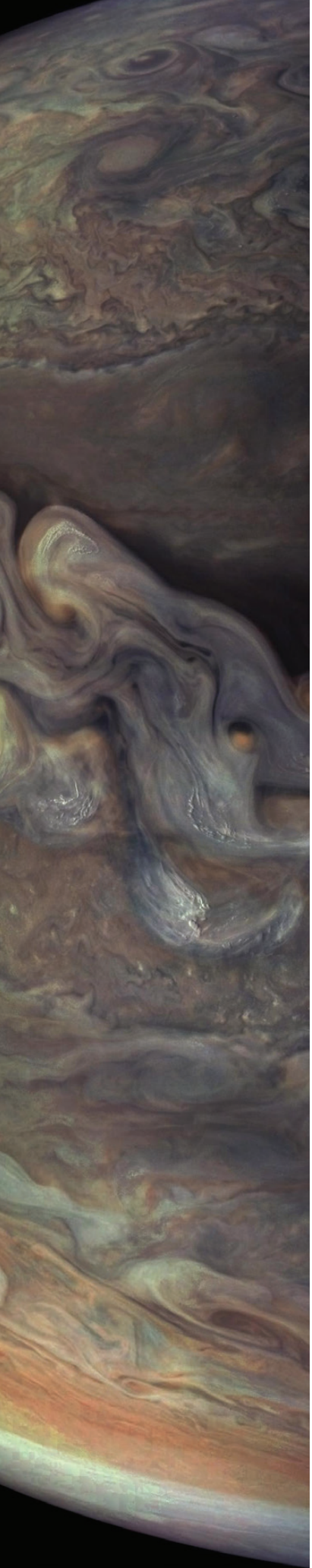
MK This is an incredibly complex world.

SB I think it might be representative of all giant planets. We just haven't gotten this close to one of them before, and this is our first example of looking in deep. Maybe they're all like this and we just have to rethink the way these giant planets work. In hindsight, I wonder, "Why did we think it would be all uniform?"

TOP *The coils decorating Jupiter's north pole were a Jovian surprise. These cyclones and anticyclones at each of the planet's poles had never been seen, much less imaged, so closely. This view was captured on May 19, 2017.*

BOTTOM Juno*'s microwave radiometer examines the atmosphere below Jupiter's familiar, banded cloud tops. In the magnified image at right, orange represents high ammonia levels, while blue represents low. Scientists were stunned to find the orange band in the middle, which suggests that an equatorial swath with high ammonia content wraps around the planet.*

Images: NASA/JPL-Caltech/SwRI/MSSS/ Gerald Eichstädt/Alexis Tranchandon/Solaris; NASA/JPL-Caltech/SwRI/MSSS



MK Most of the planets we've found elsewhere in the galaxy are more like Jupiter than they are like Earth. We're learning about stuff all over, aren't we?

SB Jupiter is our example of what giant planets are like, and giant planets are all over the place. Some of them are a lot bigger than Jupiter. We need to understand planets in general, and giant planets are their own beasts. There are similarities between Earth and Jupiter that people wouldn't have expected. I can't say we understand it, but this deep equatorial band around Jupiter looks a little bit like our own tropical band. We have an explanation for Earth's tropical band that doesn't really work for Jupiter. On Earth we think the circulation comes down and hits a surface, whether it be ground, land, or sea, and this sets up a circulation with a return flow so you get this equatorial tropical band. We wouldn't have thought Jupiter would have that because there is no sea or land underneath. It's fluid all the way down, but there it is. So maybe that's the general nature of atmospheres and we thought it was just Earth.

MK If we go down below where *Juno* can see, one of the great mysteries you were hoping to discover more about is what's down at the center—at the core—of this planet. Is *Juno* beginning to give us clues about what's down at the center of Jupiter?

SB Absolutely. *Juno* sees in different ways, and not in the ways our eyes work. The microwave instrument (MWR) looks into the deep atmosphere, but we also measure the gravity field, looking all the way down. We were thinking there are two different possibilities for Jupiter's center. One was that Jupiter has a compact core of heavy elements, sort of a rocky core of maybe one to ten Earth masses in the middle, and the other was that there is just gas all the way down. It turns out neither is true.

Our data are not consistent with a compact core. It doesn't mean one doesn't exist, but it looks like there's some sort of fuzzy core instead, something that's distributed, and much larger than a compact thing—maybe half the size of the planet. That was totally unexpected. And there are motions. The gravity field seems to be consistent with very deep motions or zonal winds going around.

Juno looks deep into Jupiter three ways: sensing the gravity field, microwave emissions, and magnetic field. Sensing the gravity field, we can see all the way to the core, or the center of Jupiter, which might be 40 megabars down. Microwave radiometry (MWR) lets us see down to about 1000 bars. Our magnetometer (MAG) might see down to the metallic hydrogen layer, generally, believed to be about 2 megabars (2 million bars). That's where we think the magnetic field is created—or just above that layer. We saw very, very narrow features in the magnetic field on a couple of *Juno*'s close passes. Some passes don't show it, which means this field may be created very close to the surface, closer than what we had thought. It looks like there are winds, motions, and convection at all levels. Things are moving and churning around inside of Jupiter. It's not as simple as we thought.

MK We don't think Jupiter is actually a living thing, but when you look at all these dynamic processes on this big world, do you ever start to think of it as a living thing?

SB I think it is sort of like that. I look at Earth that way, too. I don't know if it's alive the way we define something as alive and reproducing, et cetera, but it is like a living organism in the sense that it's naturally evolving, and very complex. Jupiter is certainly that way. And inside it must be that way, too.

MK Back to the magnetic field. As you said, you're getting surprises there, too.

SB We still want to map out the magnetic field and understand how that's being created. We don't have all the answers yet, but we've confirmed that *Juno* is the right tool to figure this out. We have the right kind of instruments and the right kind of orbit. If we finish the mapping, the key will be in seeing how variable it is as a

Image: NASA/SWRI/MSSS/Gerald Eichstädt/Seán Doran

function of longitude. Every time we do a close pass we go by a different longitude in order to slowly map out the whole planet. That's what will reveal to us how the magnetic field is really working.

MK With a longer orbital period than originally planned, are you at all concerned about getting all the science that you want from this mission?

SB I'm not concerned about the longer orbit because the science still works. I think the discoveries we've made already show that the measurements can be made with this long orbit just as well as with a short orbit and, it turns out, the radiation will be a little bit less with the longer orbit. There's always a concern that as we go around—and this is true with any planetary orbit—eventually the radiation is going to get us. It gets a little bit worse with each orbit. It's always very tense every time we get close to the planet. We go by for two hours every 53 days. You can't get close to this planet for very long without dying. We go in over the poles and we scream past the planet and try to get whatever measurements we can at that location, and then we get out of there as fast as we can. That technique works, but we all know that eventually, even with that dive-bomber mentality, we're going to get burned. There's a fuse lit, and we ask, "How many of these flybys can we get through before something fails?" All of our shielding is holding up. It's a little bit like *Star Trek*; shields are still holding.

MK Shields at 60 percent, sir.

SB I'd say we're at 90 to 95 percent still, but we know they'll go down quickly at the end, especially in the second half of the mission. We're going to approach Jupiter on July 11, the seventh pass. What's special about that one is we're going to go right over the Great Red Spot for the first time. I imagine the images that we'll get close up from the Great Red Spot will blow us all away, and by the time we get through the 16th pass we'll start going through much more severe places. Sometime next year it'll get even tenser.

MK I've got to think that nobody is watching this mission or the health of your spacecraft more carefully than the people who are planning the *Europa Clipper* mission. Have you had any contact from them?

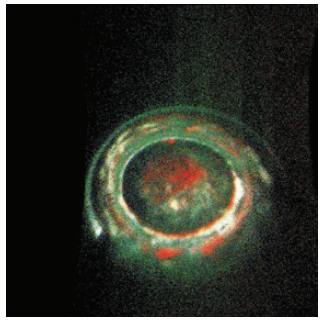
SB We're working very closely with them. I worked with them when we were first conceiving the *Europa Clipper* and the European Juice missions. These missions have their own challenges. They go through a different kind and amount of radiation, but the spacecraft designs are very similar to *Juno*'s, so they're watching us closely. We're promising to feed them information on how we're doing. Two of their big questions will be: "How did the solar panels hold up?" and "How did the instruments hold up as the radiation accumulated?" We won't get that information for a while, but so far it looks really promising for them.

MK What other science from *Juno* do you want to bring up before we close?

SB Because we go over the poles, we have instruments that are designed to look at Jupiter's auroras—its northern and southern lights—and to study the magnetosphere and compare it to those on Earth and Saturn. Some of our science from that is just as puzzling and surprising as Jupiter's interior and deep atmosphere. We flew over the poles a couple of times. The auroras are incredibly beautiful, but we don't see what we expected. In fact, we see a bunch of electrons coming out of the planet, and they're not necessarily the ones we see going in. It may work very differently from the way Earth's auroras work. I think a lot of scientists assume that, at least in part, the process would sort of mirror Earth's.

MK What are the remaining mysteries that you hope *Juno* will shed light on before it succumbs to the tough conditions near that planet?

SB As I've said, Jupiter doesn't work the way



ABOVE *In this single frame from an animation of Jupiter's south polar aurora, red represents electrons emitted from deeper within the atmosphere, while green and white show upper atmosphere emissions. Watch the full animation at* planet.ly/southjupiter.

OPPOSITE *In this image taken on May 19, 2017, from an altitude of 8,900 kilometers (5,500 miles), details as small 6 kilometers (4 miles) can be identified. The small, bright-white clouds at center formed high in Jupiter's atmosphere and are almost certainly composed of water and/or ammonia ice.*

Image: NASA/JPL-Caltech/SwRI

TOP *A massive rotating storm is highlighted in white in this JunoCam image processed by citizen scientist Björn Jonsson. The* Juno *mission team welcomes the public's participation in processing JunoCam images.*

BOTTOM *This detail from a JunoCam image taken March 27, 2017, highlights a swirling Jovian storm. Citizen scientist Jason Major enhanced the color and contrast of the original data to showcase Jupiter's beauty. The end result is a blend of science and art.*

we thought. We see the interior and the core are different from what we expected, but we don't have the answers to the way the planet actually is. So, for the rest of the mission we really want to get to those answers—to definitively say something about the core and the structure and how the motions are working inside the planet. How has it evolved? How did it form? And we're still waiting to make the key measurements and analyses that tie to the water abundance. A very important question is how much water is there in Jupiter? And we've been puzzled about why the *Galileo* probe results looked the way they did.

We have to rethink how we're going to explore these giant planets. Sending in probes may not be the best way to try to understand them, because they're so variable. I feel particularly humble about this because, more than 10 years ago, I wrote a paper that sort of outlined the way to explore Saturn with a probe, and the assumption was that when it dropped below the atmospheric clouds, everything would be well mixed. I have to admit I might be wrong.

MK To finish, let's go back to the citizen science angle in this show—JunoCam, primarily. Candy Hansen, who developed and operates JunoCam, told me it took you awhile to convince her to come in and be in charge of that camera. Then she added how thrilled she is now with what that camera is delivering and the participation that you're getting.

SB Candy and I go way back. We both worked on *Cassini* and other missions together. So when we were putting *Juno* together I said, "I want to put a camera onboard. I don't know how to run those. You do. We'll make great pictures." She said, "I'm really busy." But I was relentless. One day we were discussing the camera and had this idea where all the pictures could just go to the public to process. I asked, "Can you make that happen?" and she said, "That sounds like a great idea. Let's see how we would do that." Of course, she's done a fantastic job, so now we are all excited about sharing *Juno*'s discoveries.

MK There is still plenty of opportunity for people to get involved with JunoCam, right?

SB Oh yes, we hope more people will get involved. Classrooms, anybody, can get in. They can do something that just takes a little bit of time. They can vote on where we point the camera, or they can go in and make their own images. People can invest whatever time they wish and be involved with the project. We're so happy with the public's involvement that we're including some of their work in publications. They're becoming scientists in their own right. A lot of people are just expressing themselves by making images that are more art than science. We welcome it all.

MK There is so much to be thankful for about this mission. You are the principal investigator (PI), so most of the gratitude goes to you, although I know you have a terrific team backing you up.

SB I thank you very much. It is important to realize that, while I'm the PI, it's a big team that made this happen. A large team of people helped think of the ideas and put together how it would work. It wasn't a one-man show in any way. I'm very thankful for everybody who got involved.

Images: NASA/SWRI/MSSS/Björn Jonsson; NASA/JPL-Caltech/SwRI/MSSS/Jason Major

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

Science Is Universal!

Did you get your March for Science shirt?

We partnered with Omaze, a crowdfunding site, to produce a limited-edition t-shirt to spread our message that Science Is Universal. The effort expanded to a viral #ScienceIsUniversal campaign generating thousands of hashtags! Bottom line? By selling over 7,500 tees we raised more than $70,000 for The Society, and shared our positive message with millions of citizens around the globe.

We may reopen sales later this year, so if you didn't get your shirt, watch for upcoming opportunities to purchase one. In the meantime, remember: Science Is Universal!

Photo: Omaze/The Planetary Society

Our Official Store Is Now Open

Wear and share space exploration in style! Visit The Planetary Society's exclusive ChopShop page at planet.ly/store372. For one month only—July 21, 2017 through August 21, 2017—get a 15 percent discount on any item in The Planetary Society collection. Enter the code: PLANREP15.

Volunteers Marching for Science

THIS PAST SPRING'S March for Science movement began in the United States, but it quickly became a global phenomenon. People organized rallies, gave speeches, and filled city streets, showing that support for science is something that Earth's citizens have in common. Regardless of political leaning, nationality, or language, people around the world value the role of science in society, and this message was made loud and clear during the March for Science.

Our volunteers worked with community organizers to bring The Planetary Society into their local marches, helping spread our message of optimism, exploration, and the crucial importance of science.

Plus, they convened local members to make signs and march together. They set up Planetary Society booths to teach science supporters about space exploration and advocacy. They gave speeches and wrote news articles about the importance of exploration. Wherever they live, Planetary Society volunteers made the most of this international event, encouraging the public to stand up for science—and for space.

TOP *A Planetary Society member shows his support at the March for Science in Amsterdam, The Netherlands.*

MIDDLE *Society members and volunteers ready to march in Kagoshima, Japan.*

BOTTOM *Volunteers join Robert Picardo to make signs for the March for Science in Washington, D.C.*

Andrew Jones • April 6, 2017
planet.ly/change5future

A Lunar Sample Return Mission

China's Plans Pave Way for Future Ambitions

Photo: VCG/Getty Images

LATER THIS YEAR, China will launch one of its most complex and exciting missions so far, when its *Chang'e-5* spacecraft attempts to land on and collect samples from the Moon and then deliver them to Earth. This will be the first such mission by any country for more than four decades. The mission will be an engineering feat and result in some significant science, but it also has some interesting subplots.

Chang'e-5 marks the third and final stage of the original China Lunar Exploration Program (CLEP), approved in the early 2000s, which set out to first orbit and map the Moon (*Chang'e-1* and *2*), then land and rove on the lunar surface (*Chang'e-3* and *Yutu*), and, finally, collect samples and bring them to Earth for analysis.

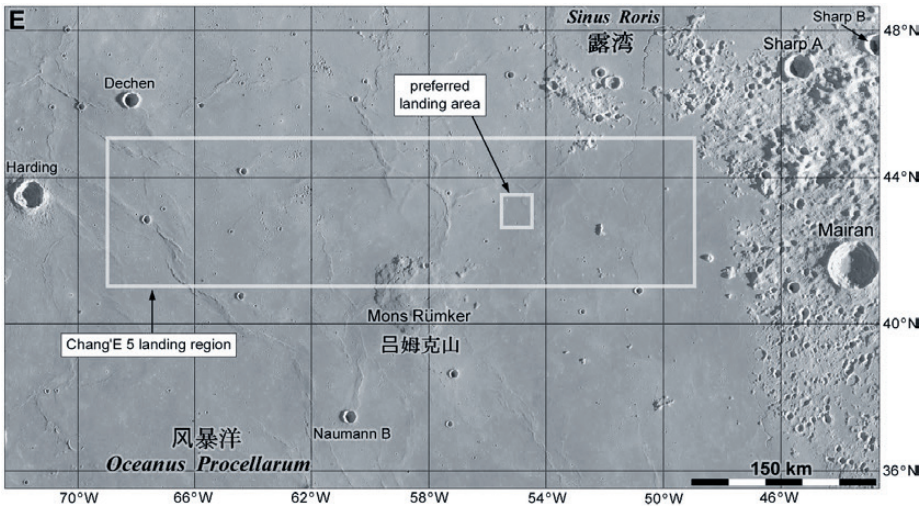
Following earlier successes and technological breakthroughs, *Chang'e-5* is now scheduled to launch in late November from Wenchang on a new Long March 5 heavy-lift rocket.

The last lunar sample return was the Soviet Union's *Luna 24* in 1976, so China is clearly still catching up. But rather than merely copying Cold War-era missions, as has often been suggested, China's plans will also provide lessons and experience for more ambitious missions in the future.

The *Luna 24* ascent stage returned directly to Earth, but China has decided that the *Chang'e-5* mission will rely on a lunar orbit rendezvous similar to that used for the Apollo landings. The 8.2 metric ton (9 ton U.S.) *Chang'e-5* spacecraft thus consists of a service module, lander, ascent unit, and a return vehicle.

After collecting samples, the ascent module will lift off and dock with the service module in orbit around the Moon, nearly 400,000 kilometers (about 250,000 miles) away from Earth. The samples will be transferred to the reentry capsule, which itself will separate from the service module a few thousand kilometers from Earth before reentry and landing.

The lunar orbit rendezvous approach is a very interesting choice we'll look at later, but note for now that this will be the first robotic rendezvous and docking around a planetary body other than Earth.



Map: Phil Stooke; *Chang'e-5* image: CCTV

LANDING SITES AND SCIENCE GOALS

Six *Apollo* and three Soviet robotic *Luna* missions brought lunar rocks and regolith back to Earth, but the Moon is a large and diverse body and there is much to be learned. According to a paper recently presented at the 48th Lunar and Planetary Science Conference, a number of target sites near Mons Rümker in the northern Oceanus Procellarum are being considered.

Spectral analysis of craters using imaging data from the *Chandrayaan-1* Moon Mineralogy Mapper suggests that material at one candidate area is just 1.33 billion years old, meaning *Chang'e-5* could return by far the youngest lunar basaltic samples yet (*Apollo* basalt samples were 3 to 4 billion years old).

Planetary Scientist Phil Stooke, using information from another paper presented at the European Geoscience meeting in April, mapped out the region containing seven candidate sites identified by scientists with the Chinese Academy of Sciences. In the map on the top of this page the "preferred landing area" box marks the candidate site discussed above.

The *Chang'e-5* lander will also be carrying three scientific payloads. The Lunar Regolith Penetrating Radar (LRPR) will investigate the subselenean structure and guide the drilling process, which will penetrate to a depth of around two meters and retrieve around about two kilograms (4 pounds) of samples. This system is similar to the ground-penetrating radar the *Yutu* rover employed to uncover the previously unknown complexity beneath the surface of Mare Imbrium.

The Lunar Mineralogical Spectrometer (LMS) will collect in-situ measurements and analyze the mineralogical composition of the sample site, look for water absorption features, and provide comparisons with returned samples.

Last but far from least, a panoramic camera (PCAM) with stereo capability will be along for the ride and hopefully return spectacular images like those from the panoramic camera on *Yutu*. Emily Lakdawalla's blog post on the *Chang'e-3* data set is essential reading [see it at **planet.ly/change3**].

To reduce risk, Chinese mission planners expect to attempt all of this within a single lunar day (14 Earth days). The reentry capsule is scheduled to touch down in the grasslands of Siziwang Banner in Inner Mongolia–the same landing area used for Shenzhou human spaceflight missions–before the end of December.

Once on Earth, the samples will then be immediately sent for analysis at a specially built, but unspecified, laboratory headed by Chinese cosmochemist and CLEP chief scientist Ouyang Ziyuan. Scientists hope the mission will reveal new information about the Moon's interior, its thermal evolution, and late-stage volcanism.

LONG MARCH TO THE MOON AND BACK

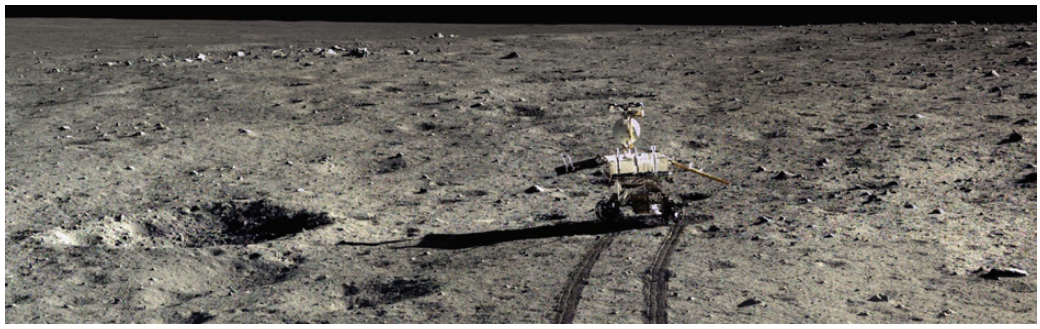
To make a mission of this complexity possible, China has taken a number of incremental and necessary steps to ensure they are ready for the challenge.

The lander and service module are based on successful earlier *Chang'e* missions, while

ABOVE LEFT Chang'e-5 *mission planners are considering several candidate landing sites within a region in Oceanus Procellarum. Spectral analysis of craters from India's* Chandrayaan-1 *Moon Mineralogy Mapper indicated that surface materials at the preferred landing site are only 1.3 billion years old.*

ABOVE RIGHT *Once* Chang'e-5 *lands and collects samples, its ascent module will lift off and dock with its orbiting service module. There the samples will be transferred to a reentry capsule for the trip back to Earth.*

OPPOSITE PAGE *This November, China will embark on the final stage of its China Lunar Exploration Program with the launch of* Chang'e-5. *The spacecraft, which will collect samples from the Moon and return them to Earth for analysis, will hitch a ride to space onboard China's first heavy-lift launch vehicle, the Long March 5. Here, the Long March 5 moves to the launching tower at China's Wenchang Space Launch Center on October 28, 2016.*



ABOVE Chang'e-3*'s lander captured the four images comprising this mosaic of the* Yutu *rover on December 23, 2013. As the camera on* Yutu *did,* Chang'e-5*'s panoramic camera will return fabulous, wide-field images of the Moon.*

rendezvous and docking have been proven by *Shenzhou* missions visiting the *Tiangong-1* and *2* space labs.

In 2014, China launched the *Chang'e-5* T1 test mission, including a reentry capsule nicknamed *xiao fei*, which returned from lunar orbit and successfully demonstrated a "skip reentry," a maneuver used to help get rid of the extra energy that comes with a high-velocity return from the Moon (about 11 kilometers /7 miles per second from the Moon, compared to 7 kilometers/4 miles per second from low Earth orbit).

China has also needed to develop a heavy-lift launch vehicle and new launch site to get to this point. The Long March 5 will also be sending an orbiter, lander, and rover to Mars in 2020. A Long March variant, the 5B, will allow the country to begin constructing its *Mir*-class space station around late 2018.

Space missions are also almost always an international effort. Though plans are not yet confirmed, China may once again receive tracking, telemetry, and command (TT&C) support from ESA's European Space Operations Center, as with *Chang'e-3*. In this case, tracking stations in Kourou and Maspalomas would provide crucial assistance for the probe's trip to the Moon.

HUMAN AND MARTIAN SUBPLOTS

The fact that the *Chang'e-5* will be carrying out a difficult lunar orbit rendezvous rather than a simpler direct return is an indication that the mission is also a small step towards putting astronauts on the Moon.

China has not officially announced a program for human lunar landings, but the *Chang'e-5* mission, together with the development of a successor to the Shenzhou crewed spacecraft and preliminary work on a Saturn V-class super-heavy launch vehicle (Long March 9), leaves little doubt that China is targeting the Moon around the 2030s.

Another monumental mission that the *Chang'e-5* rendezvous approach could prove useful for is a Mars sample return, which the country is planning for around 2030 using the requisite Long March 9. Returning samples from the Red Planet, a mission now being studied, could yield clues or direct evidence for past or even present extraterrestrial life, a finding that would be a clear marker in human history (and "change the world" in the words of Bill Nye). NASA also has plans for such a project, but its future is unclear. While there is no "space race" between China and the United States, this could be one small arena in which they might compete for a potentially seismic "first." There's a long way to go before sampling Mars, but, hopefully, *Chang'e-5* will be a step along this road.

The other good news is that *Chang'e-5* is far from the end of China's robotic plans for lunar exploration, which are now being expanded. *Chang'e-4*, the backup to the successful *Chang'e-3*, is being repurposed for an unprecedented 2018 far side lander and rover mission, involving a relay satellite at Earth-Moon Lagrange Point 2.

Should both *Chang'e-5* and the (slightly confusingly) later *Chang'e-4* mission succeed, the backup sample return probe Chang'e-6 is expected to be used to collect material from the lunar far side or south pole. Afterward, the early 2020s will see robotic visits separately to both poles.

Image: Chinese Academy of Sciences/China National Space Administration/The Science and Application Center for Moon and Deepspace Exploration/Emily Lakdawalla

Jason Davis • June 12, 2017
planet.ly/falklands

A Massive Find

Did a Planetary Society-Funded Citizen Scientist Help Find One of Earth's Biggest Impact Craters?

ABOUT 66 MILLION YEARS ago, a 10-kilometer-wide hunk of rock smashed into Earth near what is now Mexico's Yucatán Peninsula.

The impact created a global dust cloud that snuffed out the sunlight, leading to the demise of 80 percent of Earth's plants and animals—including most of the dinosaurs. A 200-kilometer-wide crater buried near the city of Chicxulub is all that's left of this impact. It's ground zero for one of the world's most notable extinction events.

Throughout Earth's history, there have been five major extinction events. The largest of these occurred about 250 million years ago, when a whopping 96 percent of life on Earth died. Scientists aren't sure what caused the event, known as the Great Dying. If it was a Chicxulub-sized impact, no one has ever found the crater.

Until possibly now.

A trio of scientists—one of whom is funded by The Planetary Society—thinks they may have found it. Off the coast of South America, near the Falkland Islands, there appears to be a 250-kilometer-wide crater buried under ocean sediment. An upcoming paper in the August edition of the peer-reviewed journal *Terra Nova* suggests it was formed by a massive asteroid or comet bigger than the one that hit Chicxulub.

Has the mystery of the Great Dying been solved?

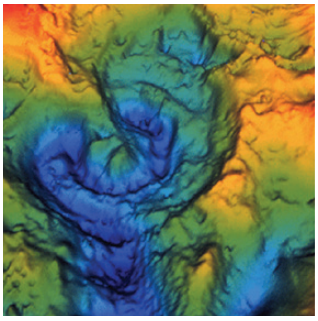
THE DISCOVERY

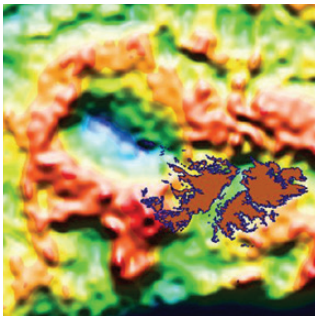
The story of the Falklands crater begins in 1991, shortly after evidence began piling up showing Chicxulub was probably the notorious dinosaur-killing impact site. Maps of Earth's gravity field there showed a circular distortion, indicating less-bulky sediment had settled in the crater since its formation.

Michael Rampino, a geologist at New York University who now also works for NASA's Goddard Space Institute in New York, started looking for similar gravity anomalies elsewhere on Earth. He reasoned that a crater associated with the Great Dying would be even larger than that at Chicxulub, and he soon found one.

"I was struck by this gravity anomaly on the Falkland plateau just to the west of the Falkland Islands," Rampino told me during a recent phone call. "It was a very nice circular well of gravity about 250 kilometers in diameter."

Rampino published his discovery in a brief abstract for the American Geophysical Union in 1992. It received modest press attention, but





ABOVE RIGHT *In 2015, cosmonaut Oleg Artemyev took this photo of the Falkland Islands from the International Space Station, 400 kilometers (about 250 miles) above Earth.*

ABOVE *These maps show similar wells of gravity, or anomalies, at Mexico's Chicxulub crater (top) and at the recently detected site just west of the Falkland Islands. A gravity anomaly is one of five types of data used to support an impact hypothesis.*

ISS Image: Oleg Artemyev/Roscosmos; Chicxulub: Lunar and Planetary Institute/Virgil L. Sharpton, University of Alaska, Fairbanks/NASA Solar System website. Falkland Islands: British Geological Survey/Courtesy of Maximiliano Rocca

was soon forgotten—mainly because there was no additional evidence available to back up the finding. "That's all the information I had," Rampino said. "I suggested that this should be looked at, with respect to the possibility that it might be a buried impact crater."

It would be more than two decades before anyone was able to follow his suggestion.

THE CRATER HUNTER

Maximiliano Rocca is not your typical crater hunter. Though he studied geology at the University of Buenos Aires, he never became a geologist, and instead works as a systems analyst in Buenos Aires, Argentina.

When he's not working at his day job, Rocca hunts for hidden Earth-impact craters. He pores through scientific data, including gravity maps, and alerts the scientific community when he finds something interesting. Over the years, Rocca has published and co-published dozens of abstracts and papers, and presented at academic conferences.

Since 2002, The Planetary Society has funded Rocca's research through our Planetary Defense program. Rocca's unique research has paid off, most notably in 2004, when he discovered a 50-kilometer-wide feature in Colombia now confirmed to be the largest impact crater in South America.

Rocca, who prefers to communicate via e-mail because of spotty Internet service that makes Skype calls difficult, often sends multiple exclamation-point-laden e-mails to convey his excitement. In one such e-mail, he told me the Colombia crater was "one of the best things I have ever done in my life."

The Falklands impact crater, if confirmed, could dwarf his Colombia find.

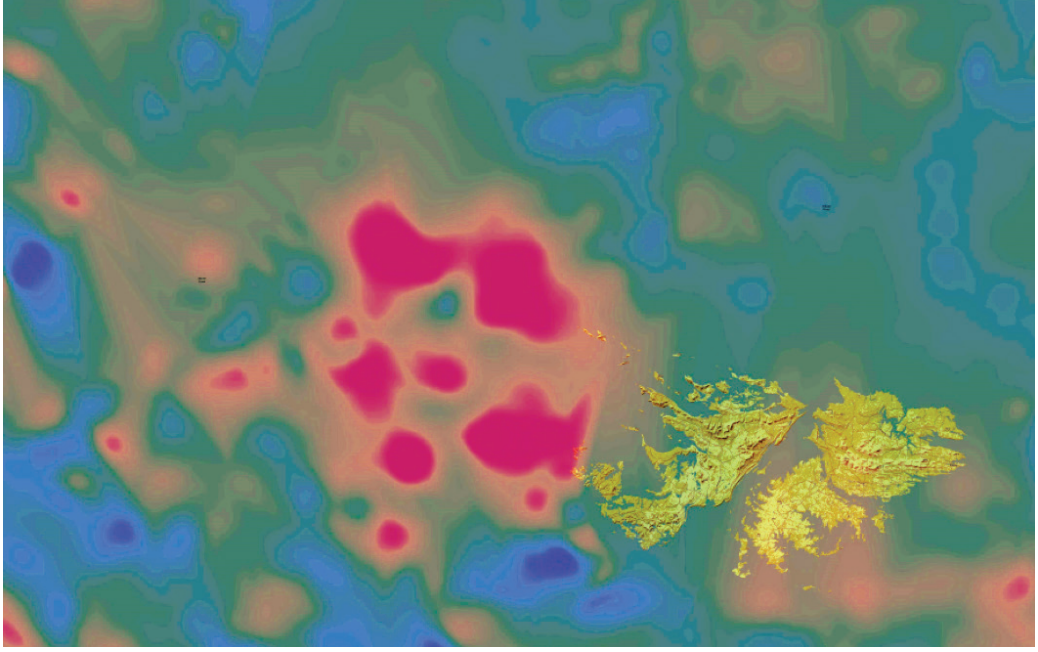
THE REDISCOVERY

Rocca first read Rampino's abstract in 2002, 10 years after its publication. He looked at updated gravity maps and, sure enough, the crater was visible—but he still needed additional evidence.

At Chicxulub, there are five pieces of data to support the impact hypothesis. First, there's the gravity anomaly. Second, the magnetic field of the area has a positive anomaly, indicating the presence of molten rock that remagnetized after the impact. Third, the crater shape can be readily seen in seismic data—basically, a boat shoots out and records the reflections of sound waves, which penetrate beyond the loose sediment burying the crater. Fourth, drilling samples show rock layers that correlate to those created by a massive impact. Fifth and finally, a thin layer of iridium, which is rare on Earth but common in asteroids, can be found embedded in rocks all around the world corresponding to the time of the crater formation.

Rocca searched in vain for Falklands magnetic data until 2015, when he finally got the necessary information from Jaime Báez Presser, a geophysicist in Paraguay. The magnetic maps showed a positive anomaly at the site and, furthermore, it was rose-shaped—exactly like the one seen at Chicxulub.

Next, Rocca obtained seismic data of the area from the petroleum company



Schlumberger, which further confirmed the crater's presence.

By then, Rocca had contacted Rampino.

"He got in touch with me, and told me what he was doing," Rampino said, and together Rocca, Rampino, and Presser submitted their findings to *Terra Nova* in 2016. The paper was accepted for publication.

HOW OLD IS IT?

The age of the area around the impact crater isn't precisely known. Rocca told me a 1990s survey calculated the Falklands plateau to be about 250 million years old. Later studies came up with a slightly older estimate.

"If the early age is correct, then we could be on the track of an impact structure of the same age as that of the worst life mass extinction event in the history of Earth, which would match the time period of the Great Dying," Rocca said.

There's only one way to know for sure: collect a drilling sample.

"The actual smoking gun would be if you could drill down into that crater and find stuff at the bottom showing there had been a hypervelocity shock event," Rampino said. "But that's a very expensive operation."

Rampino also noted thatthis difference in the evidence for the Chicxulub impact: there there is no iridium layer spread around the world corresponding to the time of the Great Dying.

"So it's a situation where we have a crater, but we don't know the age of the crater," he said.

The hope, said Rocca and Rampino, is that the *Terra Nova* paper will attract enough attention to warrant funding for a drilling expedition.

THE SIMPLEST EXPLANATION

I asked Erwan Mazarico, a geophysicist at NASA's Goddard Space Flight Center, to read the paper and weigh in.

"The paper is quite intriguing, and the gravity and magnetic data seem suggestive," he said.

Mazarico cautioned that the seismic mapping data from Schlumberger only slices through one side of the suspected impact crater. There is clearly a cavity filled with sediments on the ocean floor. But is it definitely a crater?

"The seismic line is not aligned toward the center, so it's hard to assess what the entire planform shape of the interface actually is," said Mazarico.

Mazarico and another independent geologist said the paper's hypothesis could be bolstered by providing a more detailed comparison between the Falklands data and Chicxulub, or even other known impact sites.

For his part, Rocca is hopeful he has helped make what could amount to a major scientific discovery. Pointing to Occam's razor, he told me that, among competing hypotheses, the one with the fewest assumptions should be selected.

"Well, concerning our giant structure at West Falkland, the impact hypothesis is the most simple of all," he wrote. "It explains all the geophysical data with only one assumption."

ABOVE *Is there a new "smoking gun" in the geological record? That's the term often used to describe the Chicxulub crater as evidence of the Cretaceous/Tertiary (K/T) impact that wiped out the dinosaurs 65 million years ago. The rose-shaped magnetic anomaly shown here could well be evidence of the most deadly impact event in Earth's history, 250 million years ago.*

Image: M. Rocca, M. Rampino, and J.B. Presser, 2017

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

Defending Our World

Five Steps to Preventing Asteroid Impact, and More

ABOVE *More than once in Earth's ancient past, asteroid impacts may have caused massive, planet-wide extinctions. But now that we have a space program, it doesn't have to happen again. Since its beginning, The Planetary Society has worked to support and advance the field of planetary defense.*

AT THE INTERNATIONAL ACADEMY of Astronautics' Planetary Defense Conference (PDC) in Tokyo in May of this year, I presented our paper, "The Planetary Society's Five-Step Plan to Prevent Asteroid Impact." The gist of the plan is not unique, but what is significant is how its five simple organizational elements add up to a coherent plan for defending Earth from an asteroid impact. Here is a summary of the plan:

STEP 1: FIND

If we don't know an asteroid is there, we can't prevent its impact. The sooner we find a threatening asteroid, the more options exist to change its orbit so that it won't hit Earth.

STEP 2: TRACK

Even if we find an asteroid, how do we know if it will hit Earth? We need to track it—acquire telescopic observations over days, months, and years to help pinpoint the asteroid's predicted orbit.

STEP 3: CHARACTERIZE

To understand asteroids and be prepared to deflect them, we need to characterize them, using telescopes and spacecraft to learn things like their spin rates, compositions, and physical properties, and whether what seems like one asteroid is actually a binary system.

STEP 4: DEFLECT

When an asteroid is found to be on a collision course with Earth, we need to move its orbit so that it won't hit Earth. There are various possible techniques in differing states of readiness for deflecting an asteroid, but all need more development and testing.

STEP 5: COORDINATE AND EDUCATE

Asteroid impact is an international issue that requires international coordination. In addition, international education about the asteroid threat is required at all levels, including policy makers, disaster management agencies, and the general public.

You can find more information on the plan, as well as background on planetary defense, on our website at **planetary.org/defense**. Recently added to that site is a special Planetary Defense edition of our short, educational, and humorous Random Space Fact videos. These six episodes, most under two minutes, will give you information about why we should care about planetary defense, and more information on each step of the plan. You'll also get the graphics and jokes that come along with Random Space Fact videos. Also available are printable infographics about the asteroid threat and the five-step plan.

THE PLANETARY DEFENSE CONFERENCE

After serving on the organizing committee, with The Planetary Society as a primary sponsor, I was excited to attend the Planetary Defense Conference in Tokyo. The five-day PDC, held every two years, is the one conference that brings together international experts from all aspects of the asteroid threat issue. There were experts on finding, tracking, characterizing, and deflecting asteroids, as well as those involved with asteroid missions and those who, like The Planetary Society, are involved with educating the public and international leaders.

Presentations included updates on two sample return missions currently headed to near-Earth asteroids: NASA's *OSIRIS-REx* and the Japanese *Hayabusa 2* mission, both

of which are scheduled to reach their target asteroids next year. There were also reports of future missions, including NASA's DART mission, which will test the ability of a kinetic impactor spacecraft to slam into an asteroid to alter its orbit and protect us from a dangerous asteroid.

Also part of the conference was a simulation of an asteroid on an impact trajectory with Earth. Conference attendees filled various technical and nontechnical roles in attempts to better understand the threat, then deflected the simulated asteroid.

Together with the Japanese space agency JAXA and the Space Guard Association of Japan, we also cohosted a public event in Tokyo about asteroid impact. For more on the conference, see my blog, which is linked from **planet.ly/defenseconference**. You'll find more information about the conference, including a link to videos of all the talks given at the conference, at **pdc.iaaweb.org**.

CALL FOR PROPOSALS: SHOEMAKER NEO GRANTS

To support Steps 1 to 3 in the plan outlined above, The Planetary Society conducts the Shoemaker NEO Grant program, named after pioneering planetary geologist Gene Shoemaker. It mostly supports very advanced amateur astronomers around the world in their efforts to find, track, and characterize near-Earth asteroids. 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 program's history.

In conjunction with the Planetary Defense Conference, we issued a new call for proposals for the program. You can find out more about our Shoemaker NEO grant program at **planetary.org/neogrants**.

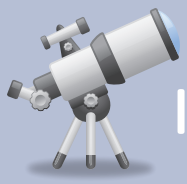
CONCLUSIONS

First, don't miss the article in this issue by Jason Davis about an ongoing Planetary Society-funded effort by Max Rocca that may have pulled together evidence of a huge impact some 250 million years ago off what is now the Falkland Islands.

Asteroid impacts don't happen often, but they do happen, and the results can be disastrous. Asteroid impact is the one large-scale natural disaster we can prevent, if we work at it. With your help, that is exactly what The Planetary Society is doing.

ABOVE *Doctor B. meets with the cast of our special six-part Random Space Fact series "Defending the Earth." Have some fun at* **planetary.org/defense**.

The Planetary Society



IN THE SKY

On August 21, the "Great American Eclipse," a total solar eclipse, will cross the United States from Oregon to South Carolina. A partial eclipse will be visible from North America, northern South America, and western Europe. Learn more at planetary.org/eclipse. The Perseid meteor shower peaks August 12/13, with increased activity several days before and after. Viewing will be somewhat hampered by a gibbous Moon. Bright Jupiter and somewhat bright Saturn are up in the early evening. Venus dominates the pre-dawn East. In September, Mars and Mercury join it even lower to the horizon. Mars and Mercury appear very close on September 16.

RANDOM SPACE FACT

The August 21, 2017 solar eclipse will be the first solar eclipse to cross both the U.S. Pacific coast and Atlantic coast since 1918.

TRIVIA CONTEST

Our December Solstice contest winner is Dan Court, of Poole, Dorset, United Kingdom. Congratulations! **THE QUESTION WAS:** What are the names of all of Pluto's known moons? **THE ANSWER:** Charon, Styx, Nix, Kerberos, and Hydra.

Try to win a copy of *Earth in Human Hands* by David Grinspoon, and a *Planetary Radio* t-shirt by answering this question:

In what year was a solar eclipse first used to test Einstein's theory of general relativity, showing that light from background stars was indeed bent by the gravity of the Sun?

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 September 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 take a Lunar Eclipse Voyage with us to Baja California's Sea of Cortez in January 2018. And in March, we will explore the fascinating heritage of Cuba! Please join us and share the delights of these adventures with other Planetary Society members!

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

JANUARY 27–FEBRUARY 3, 2018

See the whale extravaganza off the Baja California coast on board the *National Geographic Sea Bird*. Travel with astronomer Tyler Nordgren and witness the January 31, 2018 lunar eclipse from this exciting wilderness with perfect 70-degree days and sparkling, clear night skies. Hike desert islands, snorkel with sea lions, and watch 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 the World Heritage cities of old Havana and historic Trinidad! Travel to the mountain station at Topes de Collantes in historic Cienfuegos province! Meet Cuban astronomers and naturalists as you relish the opportunity to visit this truly beautiful Caribbean island nation!

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

Eclipse photo: Tyler Nordgren; Whale watch photo: Lindblad Expeditions

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

Planetary Science Resurgence

Budget Reaches Near-Historic Heights for Robotic Program

ON MAY 5TH, the president signed legislation that funds NASA at $19.65 billion in 2017, an increase of $368 million from the year before. The Planetary Science Division received a boost to $1.85 billion–its best budget in a decade.

What a difference five years makes.

Five years ago, NASA's Planetary Science Division was in decline, facing a $308 million cut down to $1.1 billion. These cuts had a severe impact on the program and forced NASA to abruptly pull out of a joint Mars mission with the European Space Agency. Many missions were delayed. Research funding stagnated. A mission to Europa was a laughable fantasy.

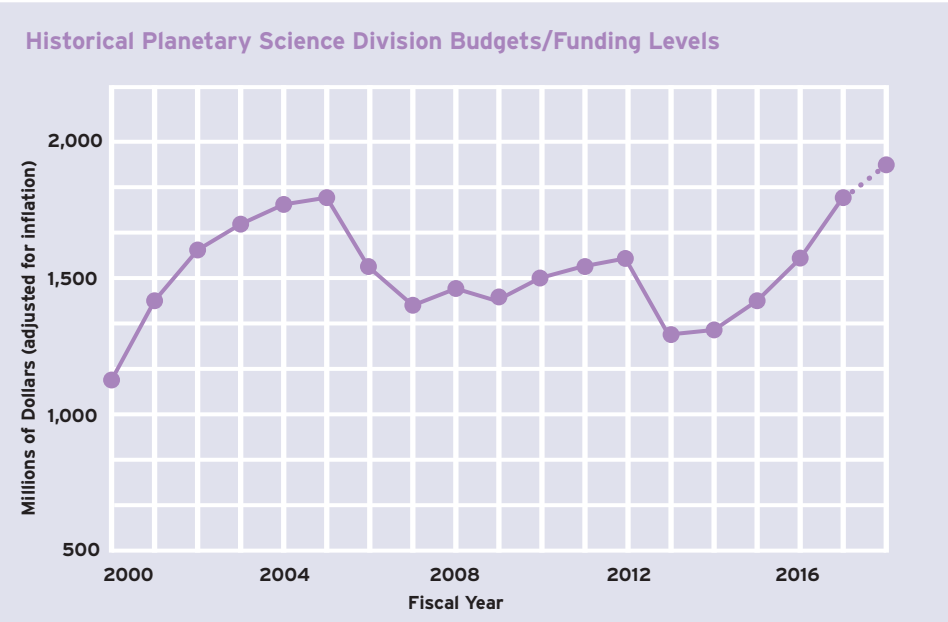
So we asked you to fight back, and fight back you did.

In the intervening years, you sent over 400,000 petitions to Congress and the White House, and made thousands of phone calls and hundreds of in-person visits during our annual "congressional blitzes" supporting NASA.

And in every year since 2013, NASA's planetary science budget went up. Our original goal–$1.5 billion–was surpassed last year. The final 2017 budget supports a program we couldn't even dream of a few years ago: a mission to Europa in the early 2020s, a robust sample-caching Mars rover (with a bonus helicopter!) in 2020, and two new small-class Discovery missions to launch in 2021 and 2023. We are now seeing alignment between the White House and Congress, with the president's budget request for 2018 proposing an excellent $1.93 billion for planetary science at NASA. It's a bright spot in an otherwise miserable budget for science in the United States.

Our advocacy and policy program also grew. When I first joined The Planetary Society in the summer of 2012, it was just me working on advocacy, and part time at that. Now I am the director of the space policy program, where I work closely with two full-time colleagues based in Washington, D.C. Thanks to the generosity of our members, we have a deeper policy bench at the Society than at any other point in our history. The complementary expertise of our staff means we can run parallel efforts in policy development, analysis, education, and government relations. And because we depend primarily on small donors like you, we ensure our independence from corporate and government interests as we promote space science and exploration.

We have accomplished so much in the past five years, and there are so many exciting missions and discoveries that now lie ahead of us. But it is imperative that we keep applying political pressure. We must keep a focus on our goal: to know the cosmos and our place within it. Extraordinary claims require extraordinary evidence. So we'd better make sure we gather that evidence.



ABOVE *The final 2017 budget signed by the president provided the best budget for NASA's Planetary Science Division since 2005. 2018 may be even better. Note all values adjusted for inflation and for programmatic consistency. Source:* planet.ly/planetarybudgets

We just released our latest paper, *Mars in Retrograde: A Pathway to Restoring NASA's Mars Exploration Program*, which provides a unique analysis and new proposals to help the search for life at the Red Planet. Read it at planet.ly/retrogrademars

THE PLANETARY SOCIETY
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Join Us for the 2017 North American Eclipse!

On August 21, 2017, a solar eclipse will be visible throughout Earth's Western Hemisphere, and the eclipse's path of totality will cut a swath across the continental United States. The Planetary Society has teamed up with the United States National Park Service (NPS) to celebrate this spectacular celestial event.

If you can watch the eclipse from a national park near you, go for it! Otherwise, simply get outside, wherever you are. Just be sure to wear your eclipse glasses before looking directly at the Sun. And check in often at planetary.org/eclipse. There you'll find special Planetary Society eclipse videos, articles and photos, and eclipse event postings. Plus, you can download the NPS's Junior Ranger Eclipse Explorer Activity Book, a National Park Service educational project (in partnership with The Planetary Society) dedicated to creating young "eclipse experts."

We'll see you at planetary.org/eclipse!

Clear skies,
The Planetary Society

Image: Tyler Nordgren