THE PLANETARY SOCIETY

THE PLANETARY REPORT

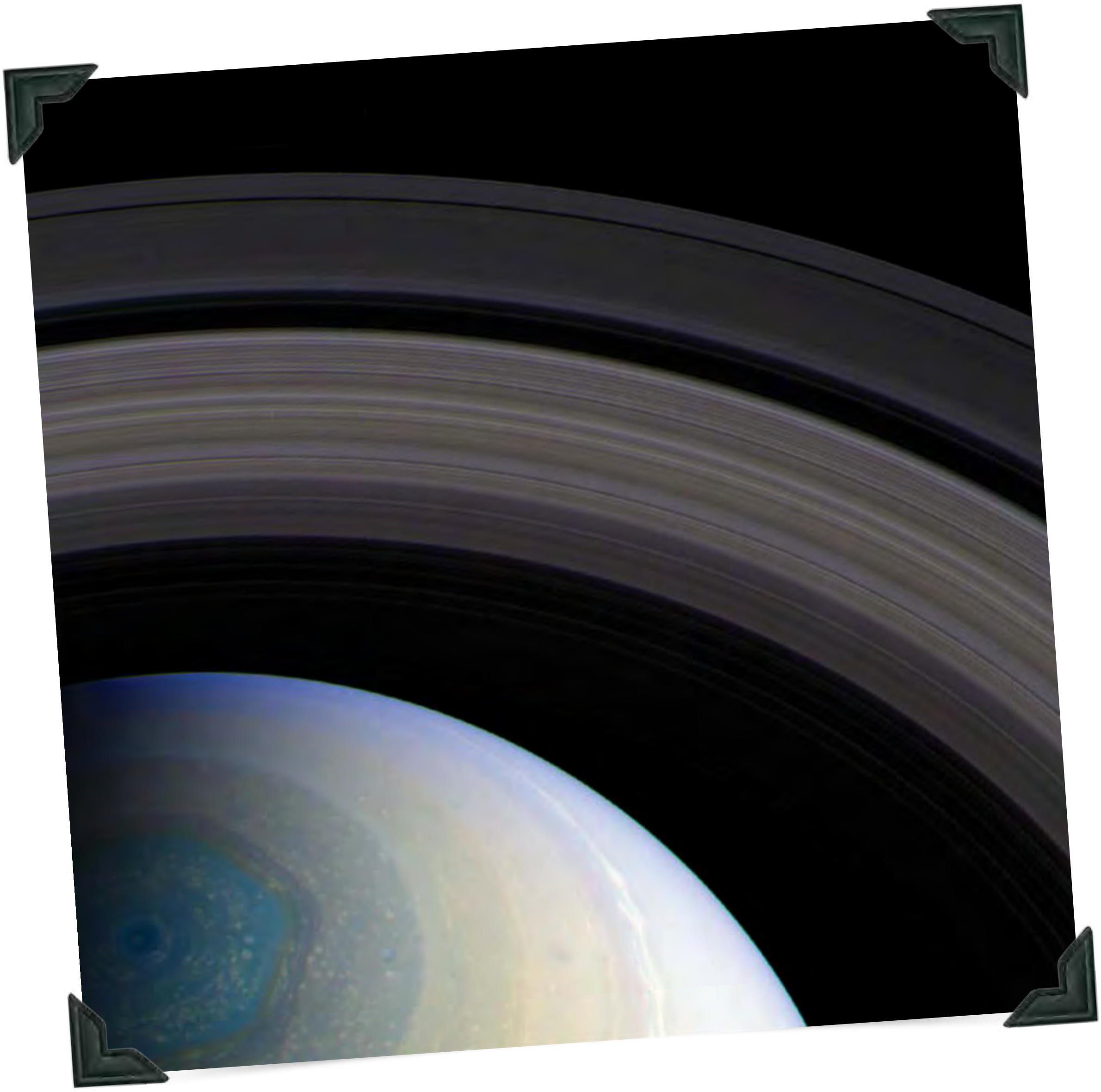
MARCH EQUINOX 2015
VOLUME 35, NUMBER 1
planetary.org

MAIDEN VOYAGE

LIGHTSAIL'S TEST MISSION IS READY TO LAUNCH!

TELLING TIME WITH ROCKS ✲ A NEW EUROPA MISSION ✲ PROTECTING OUR WORLD

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.



North Pole Viewing

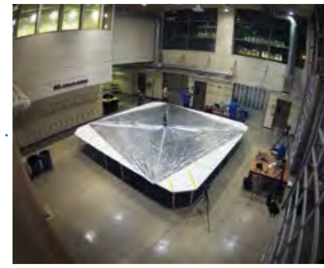
AS SUMMER ARRIVES at Saturn's north pole, sunlight dawns on the planet's strange north polar hexagon—a wavelike, atmospheric feature visible even to Earth-based telescopes. To obtain this view, *Cassini*'s navigators flew the spacecraft into a highly inclined orbit that swung it far above Saturn's ring plane. From that vantage point, *Cassini* can see something we never can see from Earth: Saturn's globe unobscured by its rings.

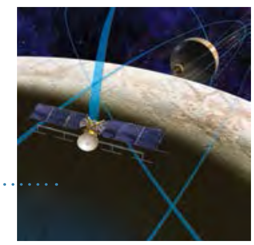
—Emily Stewart Lakdawalla

Image: NASA/JPL/SSI/Bill Dunford

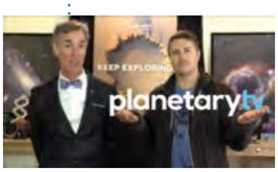
SEE MORE AMATEUR-PROCESSED SPACE IMAGES PLANETARY.ORG/AMATEUR

SEE MORE EVERY DAY! PLANETARY.ORG/BLOGS





DEPARTMENTS



ON THE COVER: We're at the Cape! The design changes, the do-overs, the tests and retests are all done and *LightSail* has arrived at Cape Canaveral, Florida, ready for its launch to orbit on an *Atlas V* rocket. This will be *LightSail*'s shakedown cruise; we're checking all its systems in preparation for our primary mission in 2016. This moment has been years in the making and a sometimes wild ride. Thank you for riding with us. *Illustration: Josh Spradling*

CONTACT US
The Planetary Society
85 South Grand Avenue
Pasadena, CA 91105-1602
General Calls: 626-793-5100
E-mail: *tps@planetary.org*
Internet: *planetary.org*

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

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

True to Our Roots

The Society's Original Vision Still Stands

EVERY TIME I notice that it's 2015, I involuntarily raise my eyebrows. This spring, the Society will celebrate its 35th year. It amazes me in a few ways. First of all, it means that I am somehow, inexplicably, over 35 years old. Next, it means that we have been at this business of advancing space science and exploration for a substantial fraction of a human lifetime.

The staff and I have been looking over some remarkable early video footage (centimeter-age?) of Carl Sagan and others discussing the work of this (then new) organization. While we have expanded our methods of communication, we have remained true to our original optimistic and future-oriented vision. We still work to empower citizens everywhere to know the cosmos and our place within it. Since our beginning, we have advocated for the search for life elsewhere, and for understanding our world and others from a planetary perspective. Just look at a few examples of our legacy:

LIGHTSAIL TEST LAUNCHES IN MAY

Since the Society was founded, we have supported solar sailing. Professor Sagan talked about the concept when I was in his class. Even before this organization was formed, our cofounder Lou Friedman worked on the Jet Propulsion Laboratory's proposed Comet Halley mission, and his book on solar sailing was published back in 1988. As I write, our test *LightSail* spacecraft has just been loaded onto its ULTRAsat platform. In early May, the assembly will be launched atop a venerable Atlas 5 rocket. In this issue, our own Jason Davis has a feature story on *LightSail*'s progress. At last, we are going to fly our very own, citizen-funded solar sail spacecraft. We have learned a lot since our first attempt with *Cosmos 1* in 2005. I send my sincere thanks to all of you. It is your support that makes this mission possible. This is quite a milestone (or, kilometer marker).

UNDERSTANDING THREATS TO EARTH

The Society has long been in the vanguard working to understand and assess the threat near-Earth objects (NEOs) can pose to Earth. Our first NEO project was undertaken back in 1981. Today, our work in the field of detecting, tracking, and characterizing NEOs is more robust than ever. In April, several members of our staff will be at the Planetary Defense Conference in Frascati, Italy, where we will award our eighth round of Shoemaker NEO grants. Astrogeologist Gene Shoemaker was an inspiration, and his work in this field was of extraordinary significance. Put bluntly, if an errant NEO were to get too near, I mean crash into Earth, well, that could be the end of all of us. This work is another part of our legacy. It couldn't be more important, and we've been at it from the start. On page 20, Bruce Betts describes the work we all make possible with our Shoemaker Grants.

NEW HORIZONS NEARING PLUTO

Ask school kids, "What's your favorite planet?" and a great many will still respond, "Pluto!" This distant world has held great mystery from the time of its discovery in 1930. Since the 1990s The Planetary Society has been advocating for a mission to explore Pluto. In October 2000, I delivered to Congress a wheelbarrow carrying 10,000 of your postcards supporting a Pluto mission. This summer, at last, the mission we worked hard to support, *New Horizons*, will fly past Pluto (currently called a dwarf planet) and then on to another destination, even farther into the Kuiper Belt. I'd bet that each of us has imagined what Pluto looks like up close. Well, we will soon see. Wow, a dream more than 85 years in the making will come true. And, the Society has been a part of this vision since before the spacecraft and its mission became possible.

A MISSION TO EUROPA

Just as we advocated for the *New Horizons* mission to Pluto, we are now fighting for the Europa Clipper mission to Jupiter's fascinating moon–and we are winning. For the first time in history, NASA's budget includes a mission to Europa, where there is twice as much seawater as there is here on Earth. In his Advocacy column on page 22, Casey Dreier provides more detail on the budget and the mission. It is hard to exaggerate the potential of this undertaking. If we can enable the next step in the search for life, or stranger still, find evidence of life from orbit there, it will utterly change this world. Everyone on Earth will think differently about what it means to be a living thing in our corner of the cosmos.

MORE WAYS TO UPDATE YOU

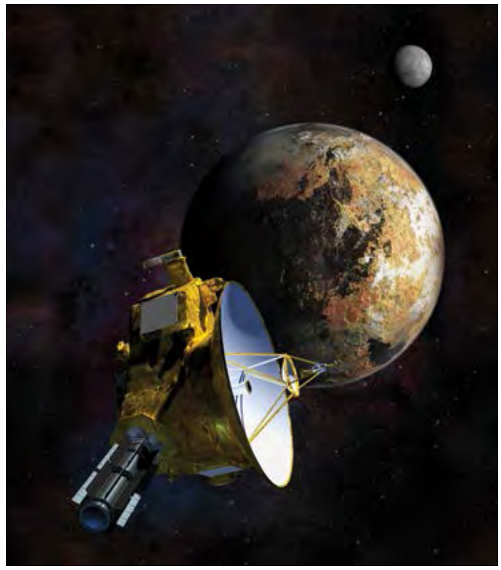
The Planetary Report has been our way of communicating with every single member. We remain committed to *The Planetary Report* and, looking forward, we have many new, wonderful ways to be in touch and keep you up-to-date. We have **planetary.org**, *Planetary Radio*, our excellent bloggers, and social media communities. And now, we also have **planetary.tv**. It's informative and, as I like to say, big fun. In the coming months, we will make the move to our biggest, most modern office space yet. It will enable us to be even more effective in communicating about our work to educate, advocate, and create programs and technical projects to advance space science and exploration.

THANK YOU

None of this good work would be possible without you, our members and supporters. Our 35-year history reflects your steady support of big ideas that have brought out the best in humankind: exploration of our neighboring worlds, defending our own planet from a devastating impactor, searching for a signal that tells us we are not alone, and educating people everywhere of the significance of our place in space. It is a proud heritage, and I hope you are as proud as I am to have been a part of it. But with all this, I like to keep in mind that space exploration is inherently optimistic. The best is yet to come. The discovery of life on another world such as Mars or Europa is just around the interplanetary corner. New and less expensive ways to travel in space are at hand. The ability to deflect a dangerous object out there is becoming more attainable with each passing week. And you all have made it happen. Thank you.

We're in this business for knowledge of the cosmos and for the betterment of humankind. Together, we are changing the world.

Bill Nye



LEFT *The Planetary Society fought long and hard for a mission to Pluto; this summer,* New Horizons *will reach the Pluto system.*

New Horizons illustration: JHU/APL/SwRI

JASON DAVIS *is a digital editor for The Planetary Society. He reports on* LightSail *at* planetary.org.

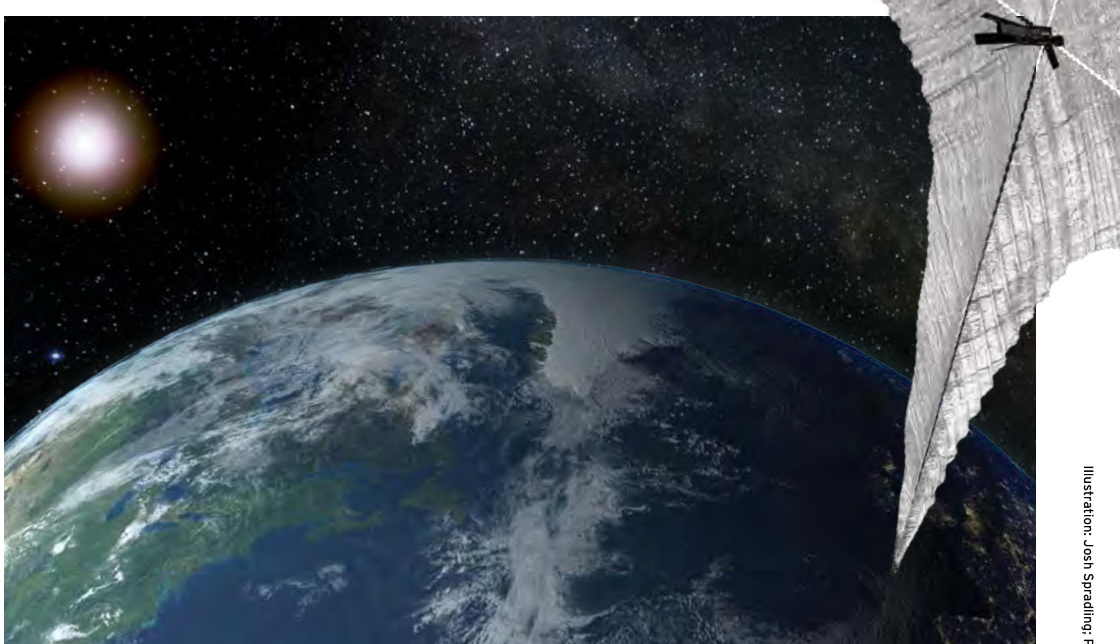
Countdown

The Long Road to *LightSail*'s Biggest Test Yet

THIS YEAR MARKS the tenth anniversary of one of The Planetary Society's most famous—or perhaps, infamous—moments. On June 21, 2005, the Russian submarine *Borisoglebsk* sat silently off that country's northwest coast in the chilly waters of the Barents Sea. The *Borisoglebsk* carried a rocket that was originally built as a weapon of mass destruction—a ballistic missile designed to strike the enemies of the Soviet Union.

In the ultimate act of turning swords into plowshares, the missile had been converted into an instrument of peace. It bore the name *Volna*—Russian for "wave." Nestled in its payload fairing was *Cosmos 1*, The Planetary Society's solar sail spacecraft. *Cosmos 1*, a mission funded entirely by private donors, was set to become the world's first solar sail.

At 12:46 p.m. Pacific daylight time, *Volna*'s engines roared to life, sending the rocket hurtling toward space. For the first 83 seconds of flight, everything went well. But then, a rotor inside the rocket's first-stage turbopump began vibrating out of control. The turbopump shut down, starving the engine of fuel. The engine flamed out. The rocket coasted for another 50 seconds, its steering engines dutifully firing to stay upright. Finally, at a height of 75 kilometers (47 miles), the *Volna* and *Cosmos 1* succumbed to gravity and tumbled back to Earth. Six minutes later, they smashed into the sea. No wreckage was ever found.



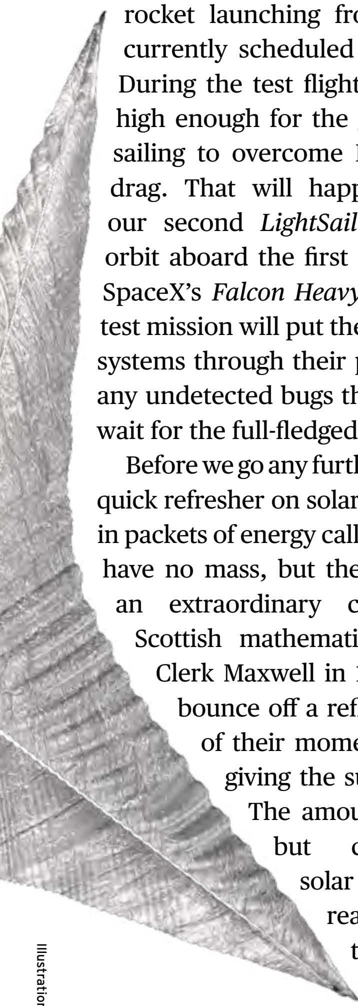
RIGHT *Once* LightSail *has been in Earth orbit for four weeks, its software timer will command the sail deployment sequence to begin. One minute after the solar panels swing open, the deployment motor will begin extending the metallic booms that will pull out the four sails, a process that will take two to four minutes.*

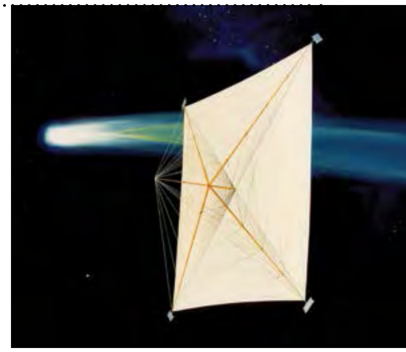
BELOW *In June 2005,* LightSail*'s predecessor* Cosmos 1 *roared toward space atop* Volna, *a converted ballistic missile launched from the submarine* Borisoglebsk. *The rocket failed and* Cosmos 1 *was lost in the Barents Sea.*

Illustration: Josh Spradling; Photo: The Planetary Society

SPACECRAFT POWERED BY SUNLIGHT

Instead of marking the ten-year anniversary with a groan, The Planetary Society is hoping to celebrate with a new solar sailing triumph: a test flight for the first of our two *LightSail* spacecraft. This long-awaited mission comes courtesy of a free ride to orbit aboard an Atlas V





ABOVE *Before cofounding The Planetary Society, Louis Friedman and Bruce Murray worked with a team at the Jet Propulsion Laboratory to develop a solar sail mission to Halley's comet. One of two proposed designs, this huge sail measured a half-mile per side. Ultimately, the mission was cancelled.*

rocket launching from Cape Canaveral, currently scheduled for early May 2015. During the test flight, *LightSail* won't fly high enough for the gentle push of solar sailing to overcome Earth's atmospheric drag. That will happen in 2016, when our second *LightSail* hitches a ride to orbit aboard the first operational flight of SpaceX's *Falcon Heavy* rocket. This year's test mission will put the spacecraft's critical systems through their paces and shake out any undetected bugs that might be lying in wait for the full-fledged solar sail flight.

Before we go any further, let's back up for a quick refresher on solar sailing. Light travels in packets of energy called photons. Photons have no mass, but they have momentum–an extraordinary concept shown by Scottish mathematical physicist James Clerk Maxwell in 1865. When photons bounce off a reflective surface, most of their momentum is transferred, giving the surface a gentle push. The amount of force is small, but continuous–meaning solar sails can eventually reach speeds higher than those gained by "one-and-done" chemical rockets.

The romantic notion of a spacecraft powered by sunlight alone has existed in science fiction for more than a century. In the 1970s, Planetary Society cofounders Bruce Murray and Louis Friedman were part of a group at NASA's Jet Propulsion Laboratory that tried to build a huge solar sail spacecraft to send to Halley's comet. The idea never made it off the drawing board (you can read the entire story at our new LightSail website, **sail.planetary.org**), but the dream lived on, eventually coming to fruition as *Cosmos 1*.

Cosmos 1, of course, never made it to space. In the following years, NASA began experimenting with solar sails on a smaller scale, using a new breed of miniature spacecraft called CubeSats. CubeSats have standardized sizes of 1,000 cubic centimeters and you can stack them together to make bigger spacecraft. *LightSail*, for instance, is housed in a three-unit CubeSat measuring 10 by 10 by 30 centimeters–about the size of a loaf of bread.

NASA's first CubeSat solar sail spacecraft, *NanoSail-D*, launched in 2010 and deployed a small sail in low-Earth orbit. The spacecraft had no means of orienting itself, and simply tumbled around Earth until it reentered the atmosphere. While this showed solar sails might be useful for de-orbiting defunct spacecraft, The Planetary Society decided to take the technology a step further. With the ability to turn its 32-square-meter sail toward the Sun and tack like a sailboat on the open

"Sailing" Using the Sun's Energy

LightSail *accelerates when the sun's photons bounce off the spacecraft's solar sails. To do this, it must "tack" like a sailboat, turning its sails into and away from the Sun during each orbit.*

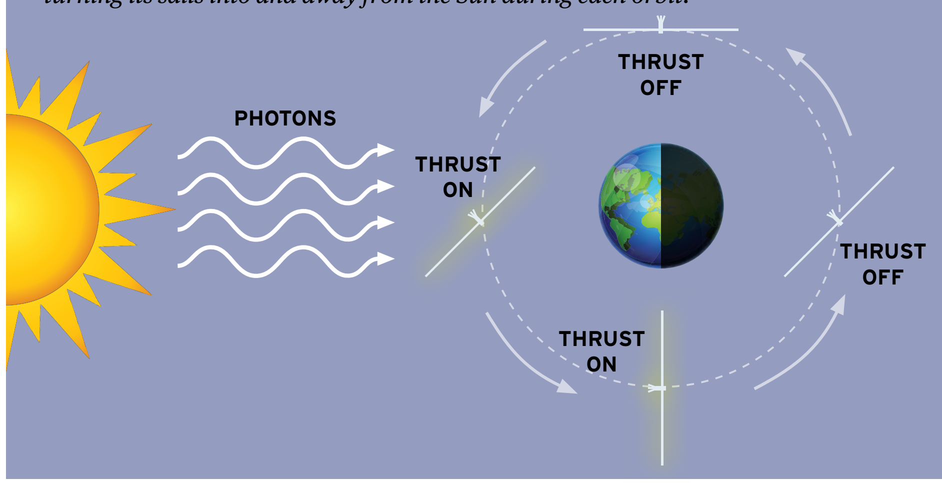


Illustration: Ken Hodges for NASA/JPL; infographic: Loren A. Roberts/Jason Davis

Photo: Jason Davis

ABOVE *At Cal Poly San Luis Obispo,* LightSail *teammates Alex Diaz and Riki Munakata set up the spacecraft on the deployment table custom-made for* LightSail*'s October 23, 2014 Day-in-the-Life tests.*

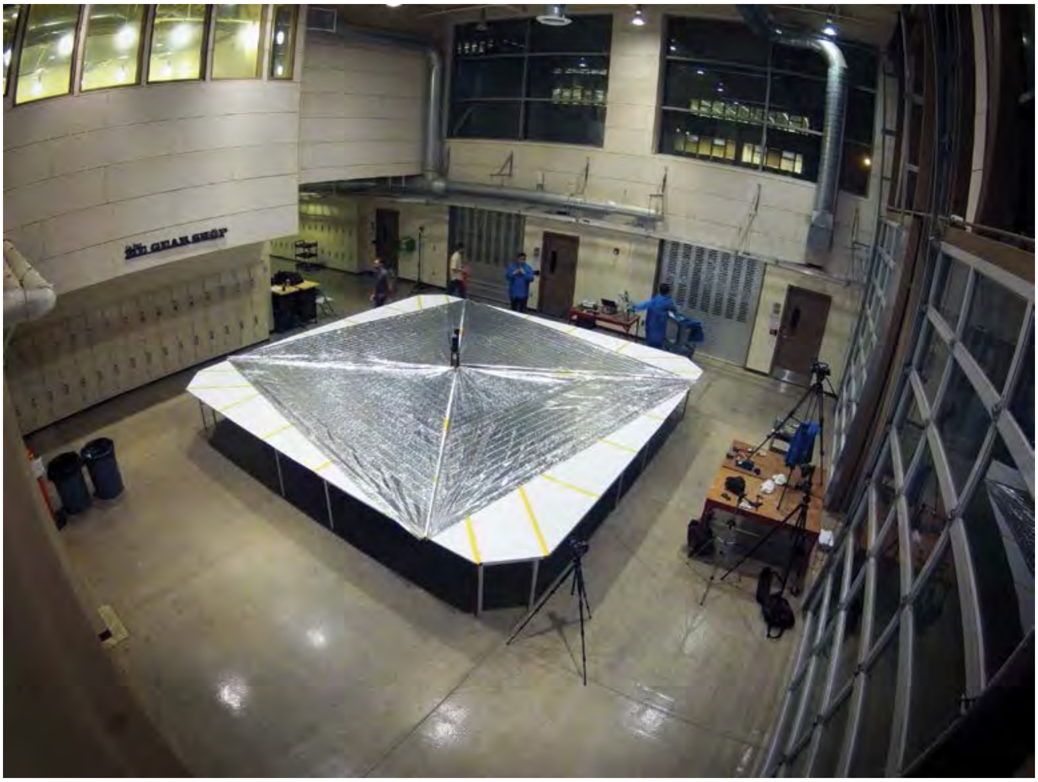
sea, *LightSail* will be the first controlled-light Earth-orbit spacecraft to use the Sun's energy as its sole method of propulsion.

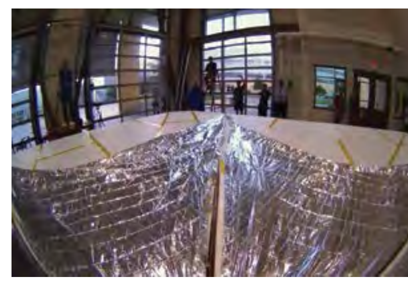
THE BUMPY ROAD TO 2015

We announced the *LightSail* project in 2009, and the first spacecraft was built shortly thereafter. So why are we just now getting around to flying it? Part of the problem was finding an orbit high enough to overcome Earth's atmospheric drag, where we could measure the effect of sunlight on the spacecraft. While we were waiting, *LightSail*'s manufacturer, Stellar Exploration Technologies, suggested we build a second, nearly identical spacecraft that could either be used for ground testing or flown in a lower-than-desired orbit.

It also turned out that *LightSail*'s avionics system—the circuitry responsible for communications and attitude control, among other things—was more complex to integrate and test than originally envisioned. Timelines slipped. Funding ran dry. And when combined with the need to find a modestly high orbit, these problems sent the project into hiatus.

In 2013, backed by an additional, generous donation, we brought in a new project team, led by Doug Stetson, the founder and principal partner of the Space Science and Exploration Consulting Group (see Doug's article, "Preparing to Sail" in the June Solstice 2014 issue of *The Planetary Report*). Integration and testing were shifted to Ecliptic Enterprises Corporation, best known for its family of RocketCam systems that provided spectacular real-time views of the space shuttle's belly during launches. In just one year, Ecliptic's team, led by CEO Rex Ridenoure and integration lead Riki Munakata, completely overhauled the spacecraft's electronics systems. Barbara Plante of Boreal Space and Alex Diaz of Half-Band Technologies helped Ecliptic with the effort. At California Polytechnic State University (Cal Poly) San





ABOVE LEFT *The fully deployed sail rests on its table in the lab at Cal Poly after a test on September 23, 2014.*

TOP RIGHT *Two Planetary Society Cameras (PSCAMS) sit at the ends of LightSail's X-axis solar arrays.*

BOTTOM RIGHT *The PSCAMS' 2-megapixel fisheye lenses will record the sails unfurling in space. To watch a video of this deployment test captured by one of these cameras, go to* **planet.ly/unfurl**.

Photos: Justin Foley, Jason Davis, and PSCAM

Luis Obispo, where the first *LightSail* spacecraft was integrated for launch, a team led by team head Justin Foley went above and beyond the call of duty to provide assistance during system testing. And at the Georgia Institute of Technology (Georgia Tech), Professor Dave Spencer has worked closely with the team to help out with orbital modeling.

In the end, we found launches for both spacecraft. The May 2015 test flight is sponsored by NASA's Educational Launch of Nanosatellites (ELaNa) program, which helps CubeSat operators find free rides to orbit. The Atlas V rocket's primary payload is a classified U.S. Air Force mission called AFSPC-5, an acronym for Air Force Space Command. *LightSail* is part of a secondary payload called ULTRASat, which consists of a small cadre of ride-along CubeSats. Per the Air Force's request, we've agreed not to disclose further details about the rocket, including orbital parameters, until we get closer to launch.

The 2016 flight will be different. We'll be riding on a high-profile launch vehicle: SpaceX's new *Falcon Heavy* rocket. Our orbit is 720 kilometers (447 miles) high. And we're teaming up with another small spacecraft called *Prox-1*, built by students at Georgia Tech, to autonomously approach and inspect other spacecraft. *LightSail* will be enclosed within *Prox-1*, which will

JASON DAVIS *holds a master's degree in journalism from the University of Arizona, where he specialized in science writing and digital publications. He received a NASA Space Grant graduate fellowship and used it to produce* Desert Moon*, a 35-minute documentary narrated by former astronaut Mark Kelly.* Desert Moon *screened at the 2015 San Luis Obispo International Film Festival. When Jason isn't working to advance space exploration, he's enjoying time with his wife and daughter at home in Tucscon, Arizona.*

RIGHT *As part of the spacecraft's October 24, 2014 Day-in-the-Life tests,* LightSail *was subjected to vibrations similar to what it will endure during its* Atlas V *launch. Watch a brief clip of that test at* **planet.ly/vibe**.

ABOVE LightSail *and its fellow ULTRASat CubeSats sit, loaded and locked into their P-PODs, waiting to be shipped to Cape Canaveral.* LightSail *was integrated into ULTRASat on January 22, 2015.*

ABOVE RIGHT *A team of engineers at the Naval Postgraduate School in Monterey, California prepares ULTRASat for its trip to Cape Canaveral, where it will be integrated into the* Atlas V *for launch.*

deploy *LightSail* into space, track it, and eventually watch as it unfurls its solar sails.

THE TEST MISSION PLAN

For the May 2015 test flight, *LightSail* will be encapsulated within a Poly-Picosatellite Orbital Deployer (P-POD). P-PODs are standardized, spring-loaded CubeSat containers built by Cal Poly. While *LightSail* is in its P-POD, its power-on switch is mechanically inhibited–imagine pressing and holding the power button on a computer without releasing it. When our P-POD is opened, a spring will gently push *LightSail* out into space. This releases the power button, booting the spacecraft's flight software.

LightSail runs on Linux and boots like a normal computer. Everything that happens aboard the spacecraft will be preprogrammed according to a timed sequence. The solar arrays and antenna bay door are held closed with burn wires, thin strands of fishing line-like material that loop through coils of wire. When these coils are commanded to heat up, the burn wires sever.

The antenna bay's burn wire will be released shortly after *LightSail* is released from its P-POD, allowing a coiled antenna to pop loose (you can watch a video of this at **sail.planetary.org**). Once its antenna is deployed, *LightSail* will begin sending out radio chirps containing telemetry data. We will have two ground stations listening: one at Cal Poly and another at Georgia Tech.

At Cal Poly, the chirps will be received and processed by a computer into plain text files. These text files have lines like "SP1_Temp=21.500000" (the temperature of a solar panel in degrees Celsius), and "Camera_0_Remaining_Pics= 0" (the number of slots available on one of the camera's memory cards). We are building a web dashboard to display this information in real-time, along with the spacecraft's ground track and current position.

For four weeks after *LightSail* reaches orbit, this is all the spacecraft will do. The sails will remain stowed as it zips around Earth. There's an important reason for this waiting period. Initially, all of the CubeSats deployed from the Atlas V will be relatively close together. Anyone trying to tune into our little spacecraft's chirps might hear garbled transmissions from other, nearby CubeSats. We want to make sure we have predictable, clean communications with *LightSail* before the sails deploy. Waiting four weeks will ensure all the CubeSats have time to drift apart.

After the waiting period, *LightSail*'s software timer will command the sail deployment sequence to begin. First, the burn wires holding the solar panels closed will heat and snap, allowing the panels to swing

Video still: Riki Munakata; photos: Naval Postgraduate School open. Just a minute later, the sail deployment motor on the bottom of the spacecraft will crank to life, extending four 4-meter metallic booms. The booms are made of a tape measure-like material and wind around a single spindle. As the booms extend, they gently pull the four triangular sails out of storage. This deployment sequence takes two to four minutes.

While all this is happening, two cameras at the end of the solar panels will be capturing images. The result will be a wild sight—a sequence of pictures showing a silver sail unfurling against the backdrop of space. We hope to catch a shot with Earth in the background, depending on the spacecraft's position and orientation.

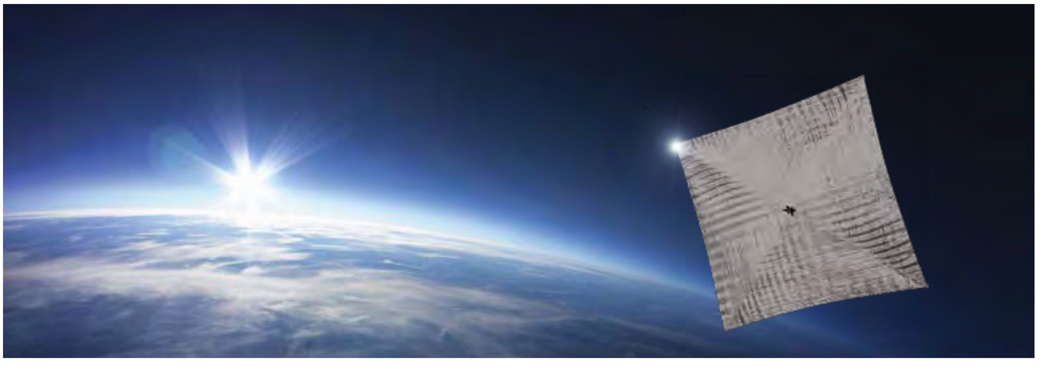
BUYING DOWN RISK

As exciting as this moment will be, it will also mark the beginning of the end for the spacecraft. During the first four weeks of flight, while *LightSail* remains folded in its miniature CubeSat form, Earth's atmosphere will drag it downward by only a kilometer or two. But once the large sails are out, they will trawl through the edges of the atmosphere, slowing the spacecraft dramatically. Georgia Tech's orbital models predict a sails-out spacecraft lifetime of just two to ten days. We'll quickly try to pull the images off the cameras, and tell the world where to look to catch a glimpse of *LightSail* shimmering in the sky via our dashboard at **sail.planetary.org**. It will then reenter the atmosphere in a brief, fiery flash.

It's important to keep in mind the purpose of the test flight. There are bound to be hiccups, and that's the point—we're trying to "buy down risk," as NASA would say. The data collected during the mission will be invaluable for the second flight.

Additionally, we're trying to advance the concept and technology of solar sailing for other groups, including NASA. In 2018, the Space Launch System's inaugural flight will send the *Orion* spacecraft on an uncrewed lap around the Moon. Hitching a ride to lunar orbit will be two NASA-built solar sail CubeSats: *Lunar Flashlight* and *NEA Scout*. *Lunar Flashlight* will circle the Moon, adjusting its position via solar sailing, and using its sails as a mirror to reflect sunlight into the Moon's permanently shadowed craters for scientific observations. *NEA Scout* (the NEA stands for Near Earth Asteroid) will use its solar sails to spiral out of lunar orbit entirely, heading for a rendezvous with an asteroid.

The *LightSail* team is already meeting regularly with NASA to compare technical notes, and the space agency will be watching with the rest of the world when *LightSail*'s first images from orbit are downloaded. Our spacecraft will demonstrate a viable method of propulsion for CubeSats, opening the burgeoning technology to destinations beyond our planet. Could we one day see CubeSats propelled solely by sunlight leaving Earth orbit for interplanetary destinations? It's possible. And if it happens, The Planetary Society—with the backing of its members—will have helped make it possible.



Composite illustration: Josh Spradling/Loren A. Roberts

HAPPENING ON
PLANETARY RADIO
planetary.org/radio

WHERE DID THE AIR GO?
And where is the water that was plentiful on the Red Planet billions of years ago? *MAVEN* may help answer these questions. Principal Investigator Bruce Jakosky reports on the early, exciting science data. planet.ly/pr1223

DR. J AND THE WORLD'S BIGGEST TELESCOPE
Joe Liske is the top scientist on the European Southern Observatory's European Extremely Large Telescope (E-ELT). He tells us what this telescope, now under construction, will help us discover. planet.ly/pr0113

YEAR OF THE ICY WORLDS
Learn more about spacecraft that are exploring Ceres, Enceladus, and Europa, with special guests from the Jet Propulsion Laboratory: Bob Pappalardo, Marc Rayman, and Linda Spilker. planet.ly/pr0210

LET'S REDIRECT AN ASTEROID!
Jonathan Goff of Altius Space Machines wants the ARM (Asteroid Redirect Mission) to succeed. planet.ly/pr0224

JIM BELL WELCOMES "THE INTERSTELLAR AGE"
Planetary scientist and author Jim Bell has just written *The Interstellar Age—Inside the Forty-Year Voyager Mission*. He talks with Mat Kaplan about the magnificent grand tour of the outer solar system that is now headed toward the stars. planet.ly/pr0303

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

ON *PLANETARY.ORG*

NEW PORTAL!

PLANETARY.TV has launched with a special intro video from Bill Nye and producer Merc Boyan. Check it out! planetary.org/tv

DOLLARS VS. SCIENCE

ITS TIME HAS PASSED? Can *Opportunity* truly be finished? We take a look. planet.ly/oppy15

PROJECTS

INTERVIEW WITH A SPACE LAUNCH SYSTEM ENGINEER
Jason Davis speaks with solid rocket booster designer Tim Lawrence in anticipation of the SLS booster test. planet.ly/slstim

SAIL COVERAGE
CBS Evening News ran a story on *LightSail* on March 16. planet.ly/lscbs15

THE (CLOUDY) RED PLANET

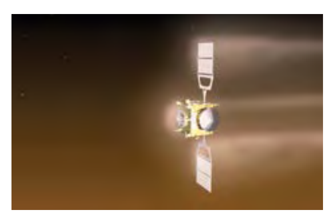
CLOUDS AND CHASMATA Bill Dunford takes a look at the newest European Space Agency images of Mars. planet.ly/meximg

EMILY LAKDAWALLA

MINI MISSION UPDATES Emily delivers a stunning amount of information in a small space every time she takes a look at all current missions. planet.ly/miniup

PLANETARY RINGS

CENTAURS WITH RINGS Intriguing new research on ring systems around small, icy worlds. planet.ly/rngcnt



A GHOST MISSION 238 MILLION KILOMETERS AWAY
Daniel Scuka looks at the weakening signal from ESA's *Venus Express*. planet.ly/ghost

BARBARA COHEN *is a planetary scientist at NASA's Marshall Space Flight Center.*

Stories in Stone

Reading a Planet's History in Its Rocks

THE STORY OF A PLANET is told through its rocks. Every rock that forms captures its environment—the grain size of a sediment tells us how far the particles were transported, the trace elements in igneous rock tell us what the magma source was, the mineralogy of a metamorphic rock tells us how much pressure it endured. A rock tells us whether an area was wet or dry, whether the fluids percolating through it were warm or cool, whether the surface was disturbed by impact breakup or tectonic folding. Every rock is a page in the book of a planet's history.

Geochronology is what puts the pages in order. It is the study of how old rocks are and when they were affected by geologic events. We know the conditions under which rocks form by using instruments on our rovers, such as *Opportunity* and *Curiosity*, and on our orbiters like the *Lunar Reconnaissance Orbiter*, *MESSENGER*, and *Cassini*. Geochronology is an additional measurement that puts those conditions into a time context. It allows us to put planetary events in order and also ties them to other events in the solar system. For example, what was happening on Earth when Mars changed from a warm, wet climate to its current inhospitable state? When did impacts pummel the asteroids, Mars, and the Moon? Geochronology can also tell us how long events lasted—how long did different planets have interior heat sufficient to drive magmatic systems? How much time did organisms have to thrive in a warm, wet Martian environment? How long have surfaces been exposed to (and possibly changed by) the space environment?

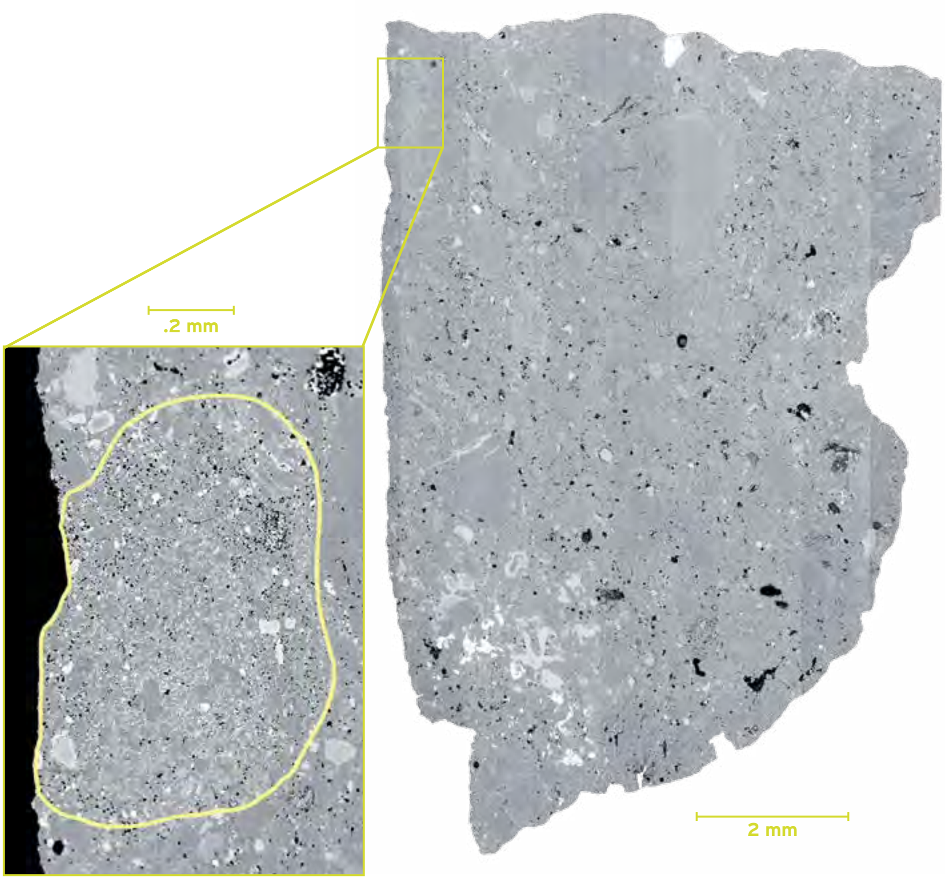
SAMPLES IN THE LAB

I describe myself as a sample person. I love getting my hands on rocks from other

The Persistence of Geology by Tyler Nordgren

BELOW *The image below is a thin section of Dhofar 025, one of the lunar meteorites with impact melt blebs that I've studied. It was taken using backscattered electrons in a scanning electron microscope. Here, dark and medium grays mean lighter elements that make up typical rocks and minerals, while bright white means heavier elements, such as metals, and black areas are holes or void space. The inset is a close-up of an impact-melt clast in this meteorite—a single rock bit made up of many crystals of minerals that are intergrown, having melted and recrystallized in an impact on the Moon.*

planets—*Apollo* lunar samples, meteorites from around the world—opening them up, and analyzing them to find out how and when they formed. I started learning different laboratory techniques while I was an undergraduate geology major at the State University of New York at Stony Brook, one of the first places to analyze the *Apollo* samples back in the 1970s. When I attended graduate school at the University of Arizona to focus on planetary science, I developed a project using geochronology to date tiny blebs of impact melt that were preserved in lunar meteorites. The *Apollo* samples that formed in large impacts on the Moon all mysteriously have similar ages of about four billion years, which some workers have taken to mean there was an increase in bombardment of the Moon at that time—a bombardment that Earth could not have escaped. When I was doing my dissertation, I thought for sure I would find older impact melt rocks, and I would solve this mystery. In fact, I found nothing older than four billion years in any of my samples. It's harder than I thought.



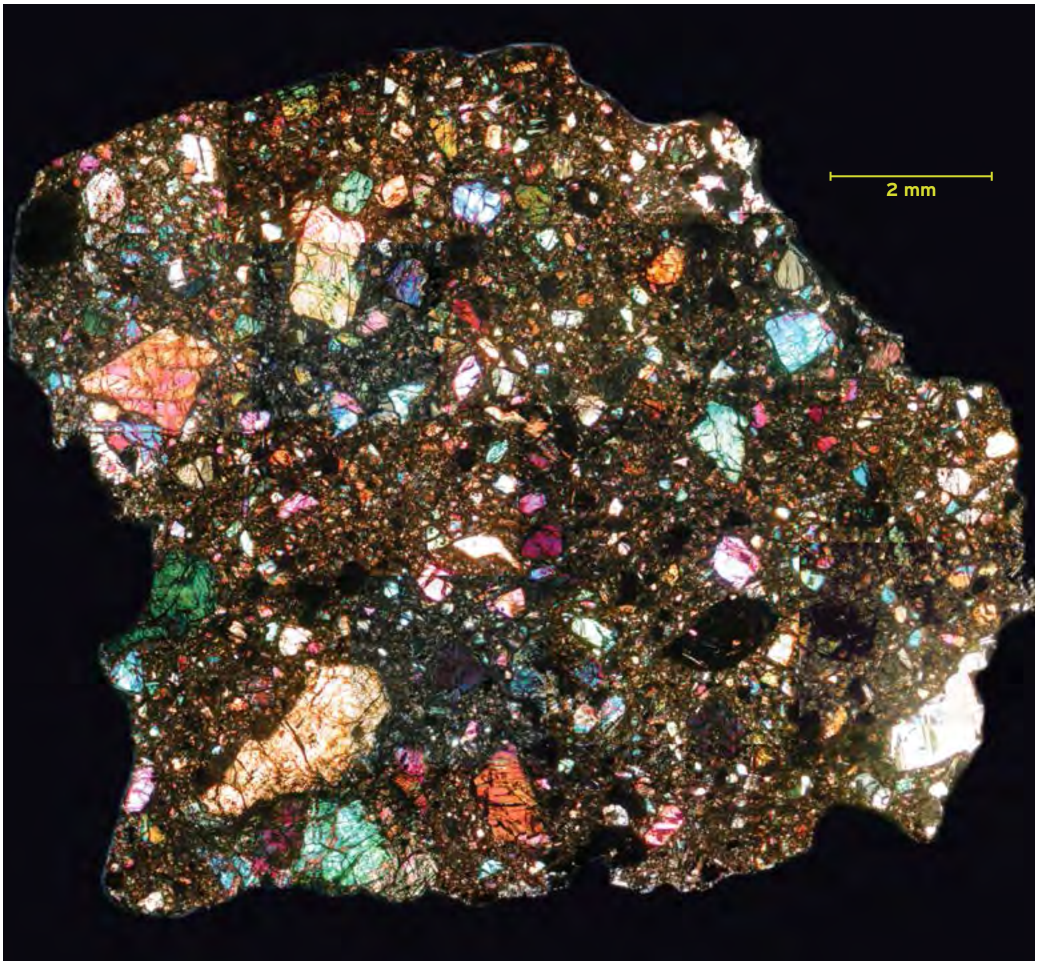
When we don't have samples to pick apart in the lab, how can we tell how old a planet is? We use relative ages. Older rock units underlie younger ones—this is the principle of stratigraphy, which you can see in places like the Grand Canyon. When we have only orbital images, it's harder to see layers stacked on top of each other, but we can use features such as lava flows and impact craters to distinguish younger areas from older ones. In fact, impact craters are quite useful because, since that time of heavy bombardment four billion years ago, they seem to form at a constant rate. This means the number of craters on a surface can be tied to its age, like leaving a piece of paper outside as it begins to rain.

But how do we tell how many craters correspond to what age? We need a tie-point, or an absolute age. On the Moon, the *Apollo* astronauts returned samples from the nearside lava flows. We dated them in the laboratory to get an age, then counted the craters on the surface of the lava flow, and created a calibrated time scale for the Moon. Now, we could count craters on parts of the Moon where we didn't visit, and use their relationship determined using the *Apollo* samples to infer the surface age. Even further, we can use this calibration to extend crater counts on other planets like Mars to estimate planetary surface ages, although it has a lot of uncertainties when used this way.

IN SITU SAMPLING

In 2004, I was part of a committee that advised NASA on what lunar science will be important to do when humans return to the Moon. "The Scientific Context for Exploration of the Moon" was our report, and the committee agreed that the early bombardment of the Moon, the period when

Images: Courtesy of the author



ABOVE *This row of impact craters, imaged by* Dawn, *is one of the most striking features on the large asteroid Vesta. These and other impacts on Vesta have churned up its surface, creating a regolith.*

LEFT *This magnified thin section (QUE 94200) is a howardite, a sample of Vesta's regolith. It's from a group of meteorites linked to Vesta, called HEDs (howardite, eucrite, diogenite). This sample contains small pieces of impact-melted material from Vesta's craters. However, since we don't know exactly where on the asteroid these meteorites originated, we can't yet link the absolute ages of samples to crater counting on its surface.*

Craters image: NASA/JPL-Caltech/ UCLA/MPS/DLR/IDA; Howardite image: Courtesy of the author

the huge nearside basins like Imbrium and Orientale were formed, was a huge outstanding question with important implications for the entire solar system. We advocated for more samples—samples from different places on the Moon, not just the nearside *Apollo* sites. In fact, we need samples from many places. For example, Mars sample return is a longstanding goal of the planetary science community. Our meteorites tell us when their parent bodies formed and evolved, but where are their parent bodies? A lot of asteroids need sample return, too. And the smooth, lightly cratered surface of Venus, the iron-poor crust of Mercury—when did they form?

Get sample returns from all these places? Clearly, that's not practical. But I learned of another approach to sampling when my lunar science colleague and fellow Committee member Paul Lucey asked me about in situ geochronology, which basically means taking our lab out into space instead of bringing the samples back. I pshawed at the idea. I told him how we need clean room sample preparation and handling, eking out sensitivity from instruments that took up half a room, to obtain ages precise within millions of years on tiny specks of billion-years-old samples.

Paul shook his head disappointedly at me and said, "Really? You can't think of a single question in all of planetary science that could be addressed with a slightly less precise age?" I stopped in my mental tracks. Well, we don't know the age of the Martian highlands within about a half billion years.

BELOW *Most scientists agree that ALH84001 is the oldest Mars meteorite ever found. This piece of the Red Planet crystallized 4.51 billion years ago. Half a billion years later, while residing on the Martian surface, it was affected by an impact shock event. We don't know where on Mars this meteorite originated, so we can't tie its age to a Martian crater count.*

That's a wide range. If we could narrow that transition to even within 100 million years, it would be enough to tie it to lunar history. Young lunar basalts; key craters on the Moon, Mars, Vesta; magmatic age of differentiated asteroids—all these could be addressed to a first cut with an idea like this.

TIME AND DECAY

Our methods of absolute dating rely on radiometric decay. Each element in the periodic table has a set number of protons and electrons, which give the element an identity. For example, carbon has six protons and six electrons. All atoms also have neutrons in their nucleus, and these can vary in number. Atoms that have the same number of protons but different numbers of neutrons are called isotopes of each other. So, a carbon atom with six neutrons is 12C and one with seven neutrons is 13C. Many elements have naturally radioactive isotopes, where the parent atoms decay over time to more stable daughter atoms. Radioactive elements decay at a known rate, so if we can measure the parent and the daughter, we know how long the system has been decaying; or for rocks, the time the rock formed.

I use a radioactive system based on potassium (K) decaying to argon (Ar). Potassium is a naturally occurring element in our everyday life, found in bananas and granite countertops, but a very small number of potassium atoms have extra neutrons and are radioactive. When potassium is in a mineral or rock, it forms part of a lattice. When it decays to argon, a noble gas, the argon is trapped inside the lattice. So, we can take a rock and measure its parent potassium and its daughter argon, and know how long argon has been building up—or the age of the rock. With a half-life of 1.29 billion years, the potassium-argon system is a nice one for solar system rocks and has been used on Moon rocks and meteorites, as well as terrestrial rocks.

THE POTASSIUM-ARGON LASER EXPERIMENT

It was my former graduate advisor Tim Swindle who first tried to develop the potassium-argon system for use in a flight instrument. Tim called his approach the Argon Geochronology Experiment (AGE), and he meant to fly it on a Mars mission. AGE used a laser (like Chemcam on

ABOVE *Scientists use stratigraphy to learn the relative age of rocks. As shown by the differently colored strata in the Grand Canyon, younger rocks overlie older rocks. To know their absolute age, the rocks need to be analyzed in a laboratory.*

BARBARA COHEN *Barbara Cohen is interested in the geochronology and geochemistry of planetary samples from the Moon, Mars, and asteroids. She is a principal investigator on multiple NASA research projects, a member of the Mars Exploration Rover mission team still operating* Opportunity*, and the principal investigator for* Lunar Flashlight*, a lunar CubeSat mission that will be launched in 2018 as a Space Launch System secondary payload. Asteroid 6186 Barbcohen is named for her.*

ALH84001 photo: NASA

Curiosity) to measure potassium in small samples, then melted it in a 1,500-degree Celsius (2,730 Fahrenheit) oven to liberate the trapped argon.

I was a collaborator on Tim's proposals. In a conversation with him at a meeting at NASA Ames in 2008, I mused that the high-energy laser would break up the crystal lattice and set the argon free without needing an oven. I asked Tim if he'd like to try this approach but, explaining that he was coming to the end of his development grant and taking on other responsibilities, he suggested that I try it myself. We switched roles, and I began developing the Potassium-Argon Laser Experiment (KArLE) with Tim as my collaborator.

Since I'm a scientist, not a technologist, I designed KArLE with the principle of taking instruments that already exist for planetary surface missions and using them to make a new measurement: the rocks' age. KArLE uses a Chemcam-like instrument to both ablate a rock sample and measure the K in the plasma state using laser-induced breakdown spectroscopy (LIBS). As the rock breaks down, we measure the liberated Ar using mass spectrometry, like the kinds that are used in such missions as *Curiosity*, *LADEE*, and *Cassini*. We've had about three years to develop a KArLE laboratory breadboard and test it on planetary analog samples with encouraging results, giving accurate ages with about 10 percent to 15 percent uncertainties. This level of precision is great for answering lots of planetary science questions.

We can make the potassium and argon measurements well, but an age is the interpretation of a geologic event, so each KArLE component helps make context measurements to interpret the sample's age. For example, the surface textures of a rock are characterized with the imager, LIBS provides a complete elemental analysis of the rock, and all the liberated gases can be measured. I thought I was being quite clever by repurposing these components and using them for geochronology. But a good idea is sometimes just waiting to be had and, quite independently, two other groups in Japan and France were developing this technique nearly simultaneously with us. Fortunately, over the last several years, we have come to think of each other as collaborators working toward a common goal.

BELOW LEFT *Mare Serenitatis is one of the lunar maria, vast lava plains on the Moon's surface. This is a* Lunar Reconnaissance Orbiter *Camera (LROC) view of Station 6, where* Apollo 17 *astronauts explored a collection of boulders and regolith. Five large boulder fragments lie at the base of a long boulder trail. All are from a single boulder that rolled down the hill and broke apart.*

ABOVE RIGHT *Pieces of the Mare Serenitatis lava flow were returned to Earth and dated in laboratories, where an absolute age for the flow's formation was found to be between 3.7 and 3.8 billion years. This is a piece of the* Apollo 17 *basalt that yielded this age, linking crater counting from the image at left.*

LROC image: NASA/GSFC/ASU; Lunar basalt: NASA

OPPORTUNITIES FOR IN SITU DATING

The capability of flight instruments to conduct in situ geochronology is called out in the NASA Planetary Science Decadal Survey and the NASA Technology Roadmap as needing development to serve the community's needs. *Beagle 2*, the exobiological lander for ESA's *Mars Express* orbiter, is the only Mars mission launched to date with the explicit aim to perform in situ K-Ar isotopic dating of rocks. Unfortunately, the *Beagle 2* lander failed to communicate during its first expected radio contact, and this science objective was not fulfilled. The first in situ K-Ar date on Mars was recently published, using SAM and APXS measurements on the Cumberland mudstone. The age of 4.21, plus or minus 0.35, billion years ago for Cumberland suggests that it records a very old formation age and validates the idea of potassium-argon dating on other planets, though the *Curiosity* method is very imprecise. To get more precise and meaningful ages, several groups are developing dedicated in situ dating instruments. The latest opportunity for an in situ dating instrument came last year when the Mars 2020 payload was being competed. Four in situ dating instruments using potassium-argon and other radioactive dating schemes were proposed, including KArLE. Though none won a place on the Mars 2020 rover, in situ dating may soon become a reality.

There are lots of questions in planetary science that still will require the precision of laboratory measurements and need samples back on Earth to address. In situ dating doesn't replace sample return, but rather extends our ability to use it as a tool, along with our imaging and compositional tools. I want it to be a common tool that we can use on the Moon, Mars, asteroids, and beyond. Wouldn't it be romantic to have a date in all those places?

ABOVE *Barbara is holding a shatter cone (a piece of a terrestrial impact crater) in her laboratory at NASA's Marshall Space Flight Center.*

To read an in-depth paper on KArLE and geochronology by Barbara Cohen and team, go to **planet.ly/karle**.

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

Volunteers!

THE PLANETARY SOCIETY'S volunteers around the world have been doing some great community outreach over the past few months. Here is a stellar example:

Members of a student group called the Space Exploration Society-Berkeley (SESB), represent The Planetary Society at the University of California at Berkeley. The club organizes activities and events aimed at promoting space science and exploration in the student community, in collaboration with both The Planetary Society and Students for the Exploration and Development of Space.

SESB students organize star parties, field trips, movie nights, lectures by local professors, and other events. This year the club also started hosting a series of space forums—student-facilitated talks on topics related to space exploration. Topics so far have included "The Past, Present, and Future of Space Propulsion;" "Mars Exploration;" "SETI: The Search for Extra Terrestrial Intelligence;" and "Man Versus Machine: The Future of Space Exploration." SESB students are also developing their own research projects, including a weather balloon to be launched as part of Berkeley's campus-wide Science, Technology, Engineering, and Math (STEM) Day.

The Planetary Society is proud to have members and volunteers around the world who are this committed to the future of space exploration. Check out **planetary.org/volunteer** to read more stories about our volunteers at work, and to find out how to get involved.

Photo: Courtesy of the author

Tanzania Wildlife and Annular Eclipse Safari

AUGUST 19–SEPTEMBER 3, 2016

Join us on safari in Tanzania to see the Annular Solar Eclipse as it passes over Africa on September 1, 2016! Enjoy splendid days looking for lions, leopards, and other wildlife in superb wildlife reserves, including Ngorongoro Crater and remote Ruaha National Park. This once-in-a-lifetime opportunity will be led by David Bygott, who led the Planetary Society Uganda Eclipse Safari in 2013. This safari is limited to 24 attendees.

$6,995 + AIRFARE

Madagascar and the Annular Eclipse

AUGUST 20–SEPTEMBER 4, 2016

Madagascar is a zoological and botanical wonderland of unique species. On September 1, 2016, it will become an astronomical wonderland as well when the Annular Solar Eclipse crosses over this island nation. Delight in watching fuzzy lemurs scamper down the trails (or perch on your shoulder) along with many birds unique to Madagascar and countless fascinating plants! Our outstanding guide will share the enchantment of the eclipse and this exotic island with you.

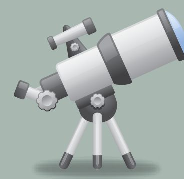
$4,995 + AIRFARE

To get started on your adventure, go to **planetary.org/expedition** to download more information.

You can also contact Taunya at Betchart Expeditions to learn more:
Taunya@betchartexpeditions.com
408-252-4910 (International)
800-252-4910 (USA only)
408-252-1444 (Fax)

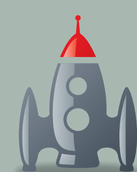
Betchart Expeditions
17050 Montebello Rd., Cupertino, CA 95014 USA
info@betchartexpeditions.com
betchartexpeditions.com

WHAT'S UP? *by Bruce Betts*



IN THE SKY

The two brightest planets in the sky, Jupiter and the even brighter Venus, will put on a show in the coming months. Venus will remain in the West in the evening. In April, Jupiter will be high in the South in the evening, but will gradually move toward Venus. On July 1 they will be at their closest, a mere 0.3 degrees apart. Far below Venus, Mercury will join much dimmer Mars low in the West in late April and early May. They will be closest to each other around April 21. Saturn rises in the East at midevening in April, and rises earlier as the weeks progress.



RANDOM SPACE FACT

On March 6, 2015, the *Dawn* spacecraft went into orbit around the dwarf planet Ceres, making *Dawn* the first spacecraft to go into orbit around two extraterrestrial bodies. Previously, it orbited the asteroid Vesta.

TRIVIA CONTEST

Our September Equinox contest winner is John M. Myers of Imperial, California. Congratulations! **THE QUESTION WAS:** What was the first successful Mars orbiter? **THE ANSWER:** *Mariner 9*, which went into Mars orbit on November 14, 1971.

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

What type of propulsion does the* Dawn *spacecraft use?

E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 85 South Grand Avenue, Pasadena, CA 91105. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by June 1, 2015. 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.*

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

Protecting Our Planet

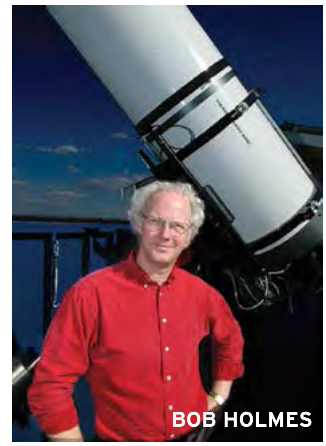
Shoemaker NEO Grant Winners Are Making Strides

ON ANY GIVEN DAY, or even any given year, a large asteroid is not likely to hit Earth. However, it is certain that one will hit Earth in the future, unless we work to prevent it. And we are, through the Planetary Society Gene Shoemaker NEO (Near Earth Object) Grants, thanks to generous support from Society members.

The Shoemaker NEO Grants, named after planetary impact pioneer Gene Shoemaker, are designed to assist amateur observers and underfunded professional observers in contributing to vital NEO research. The grants are particularly instrumental in enabling talented observers to make follow-up tracking observations critical to determining asteroid orbits (if we don't know an asteroid's orbit, we don't know whether it will hit Earth). Also, Shoemaker NEO Grants enable observations to characterize asteroids by determining things such as their rotation rates, and even whether what looks like one asteroid is actually two: a binary pair.

These types of observations not only help us understand the NEO population, but also will be critical for planning any needed asteroid deflection in the future. Increasingly, professional surveys are discovering NEOs, and as a result the known NEO population has grown. This has made the work of Shoemaker NEO Grant winners all the more critical to determining the asteroids' orbits and characterizing them, something the professional surveys do not have the telescope time to do for all the discoveries.

Here are some updates on the work made possible by your contributions to past winners of Shoemaker Grants:



BOB HOLMES

BOB HOLMES at the Astronomical Research Institute (ARI) in Illinois, the only four-time Shoemaker NEO Grant winner, has recently installed a 1.3-meter telescope at the observatory and fitted it with a sensitive camera he had purchased with a 2009 Shoemaker NEO Grant for a 0.6-meter telescope. This has enabled follow-up and tracking observations of the extremely faint objects being discovered by the professional surveys. Some of these observations are as faint as astronomical magnitude 24.2, which in nontechnical terms is amazingly, ridiculously faint. In 2014, ARI made over 14,000 astrometric position measurements of NEOs, which is number one in the world!

BOB STEPHENS, a 2013 Shoemaker NEO Grant winner at the Center for Solar System Studies (CS3) in Landers, California, focuses on characterizing the physical properties of asteroids by using lightcurves, i.e., carefully measuring the brightness of the asteroid and how it varies with time. These data aid in determining an asteroids' properties, such as spin rate, and whether one asteroid is actually a binary pair. The Shoemaker NEO

Thanks!

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

Photos courtesy of NEO grant winners


HERMAN MIKUŽ


BOB STEPHENS


BRIAN WARNER

Grant enabled the purchase of a new Finger Lakes CCD camera for a 0.4-meter telescope. The new camera enables precise measurements and greatly extends the night use of the telescope. Since the camera was installed in April 2013, the telescope has observed on 83 percent of nights.

BRIAN WARNER from Colorado robotically operates another telescope located at the CS3 in California. His 2007 Shoemaker Grant enabled purchase of that telescope, which is still going strong. Brian has compared lightcurves and analysis of rotation rates of NEOs with a main asteroid belt group of asteroids called the Hungarias. Brian reports that his work "helped confirm that YORP, (a thermal effect that causes asteroids to spin faster or slower) is the primary mechanism in the formation of small binary systems among the NEOs."

HERMAN MIKUŽ at the Črni Vrh Observatory in Slovenia had a 2000 Shoemaker grant that helped complete the construction of a new 0.6-meter telescope, and a 2010 grant that helped overcome the telescope's sensitivity limitations by using a new cooled camera. Now his team's fully robotic, web-based program has recorded hundreds of asteroid and comet discoveries made through the telescope, and performs NEO follow-up observations. They also have done numerous detailed comet observation campaigns, and have set up a comet observation database online as a resource for comet observers to submit their observations and review those made by others.

You can find more complete updates from these and other Shoemaker NEO Grant winners at **planet.ly/neogrants**.

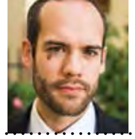
The Planetary Society is a primary sponsor of the Planetary Defense Conference that will be held this April in Frascati, Italy. The conference brings together experts in all areas of asteroid threat defense. At that conference, I will be announcing the latest winners of Shoemaker NEO Grants; grants that we couldn't give without your support. Information about the winners will be on our website, and in a future issue of *The Planetary Report*.

Free Online College Introductory Astronomy Class

Come explore the solar system and the universe with Planetary Society Director of Science and Technology Bruce Betts. His online college level class, Introduction to Planetary Science and Astronomy, runs through May 6, 2015 on Wednesdays at 15:00 Pacific time through California State University Dominguez Hills (CSUDH). The classes are broadcast live as well as archived on YouTube.

The CSUDH online system allows Dr. Betts to point out topics of interest directly on images of planets, moons, galaxies, and so much more. The course, while light on math, is designed to provide both a solid introduction to the solar system and increased understanding/enjoyment of future discoveries. The class focuses on our solar system, but also covers exoplanets, stars, galaxies, and the universe. Dr. Betts will also provide tips for personal sky observation.

Because this is a CSUDH Young Scholars Program class, only California high school and community college students can take the class for credit, but everyone can participate in the class and ask questions during the live classes. Everyone who watches the classes can also earn a certificate of achievement. Learn more on the class page at **planetary.org/bettsclass**.



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

We're on Our Way to Europa

A New Start for a Long-Delayed Mission

ABOVE *Our determination to explore Europa is paying off; NASA has now funded the Europa Clipper misson.*

Image: NASA/JPL/Ted Stryk

IT'S ALMOST TOO GOOD to be a coincidence. The very year that *New Horizons* arrives at Pluto—a mission for which the Society and its members fought hard—the White House officially calls for a new mission to Jupiter's moon Europa, another hard-fought objective of the Society and its members.

President Obama's 2016 budget request for NASA included, for the first time, a coveted "new start" for a major mission to explore Europa. This provides the final piece to the Europa puzzle; the mission has long been a high priority of the scientific community and the recipient of unusually strong congressional support. What was missing was the White House's official blessing to proceed. The new start (entering the mission's formulation phase) allows NASA to build a team, make contracts, and, ultimately design the blueprints for an actual spacecraft. None of this has happened before.

A Europa mission has been a goal of The Planetary Society's advocacy program for nearly 15 years, and a primary focus since 2013. Just last year, Society members rallied support, sending over 50,000 pro-Europa messages to Congress and the White House. We also held two major events in Washington, D.C. to promote the mission—one in the Senate and one in the House of Representatives—with Bill Nye and preeminent Europa scientists. Our efforts helped tip the scales of support within a skeptical Office of Management and Budget, which had to sign off on any new mission.

Long-time Society members may find this story familiar. Back in the early 2000s, NASA faced a similar situation with a mission to Pluto. As with Europa, The Planetary Society was an aggressive force in lobbying for a Pluto mission, making numerous visits to Capitol Hill and triggering over 25,000 letters of support from its members (then-board member Bill Nye has vivid memories of carting those letters around Congress). The industry magazine *Aviation Week & Space Technology* even presented us with a "Laurel" award for our Pluto advocacy efforts in 2002. After a series of political near-death encounters, a mission to Pluto was firmly established by 2003 and launched in 2006, just in time to utilize a crucial gravity assist trajectory past Jupiter that shaved years off the travel time.

That we are just now about to savor the fruits of those Pluto efforts 13 years later is a reminder of the long game that we play here at the Society. There's a lot of space in space, as our CEO likes to say. It takes time to see the results. But when we get them, they're worth it. Later this year, when you see those first stark pictures of Pluto's surface, take a moment and tell yourself, "I helped make this happen," because you did. We all did.

Europa will likely be the same. Even under the most optimistic budget scenarios, a spacecraft wouldn't arrive at the Jupiter system until the mid 2020s—nearly 10 years from now. But when it does, and you see those first high-resolution images of that fractured, icy surface of one of the solar system's most enigmatic worlds, you can say to yourself, again, "I helped make this happen."

NASA BUDGET HIGHLIGHTS

All numbers in US$ millions.

	2015 PASSED	2016 REQUESTED	DIFFERENCE
NASA	$18,010	$18,529	+2.9%
ALL SCIENCE	$5,243	$5,298	+1%
PLANETARY SCIENCE	$1,438	$1,361	-5.3%
EARTH SCIENCE	$1,772	$1,947	+9.9%
ASTROPHYSICS	$684	$709	+3.6%
COMMERCIAL CREW	$805	$1,244	+54%
SPACE LAUNCH SYSTEM (SLS)	$1,700	$1,356	-20%
ORION CREW CAPSULE	$1,194	$1,096	-8.2%

Source: NASA's FY2016 Budget Request planet.ly/fy16nasa

Help save the *Opportunity* rover and ensure the Europa mission's future. Write to Congress: planet.ly/fy16us

International members can write to the White House: planet.ly/fy16intl

GOODBYE TO 2015…

In December, Congress wrote the final chapter of the yearlong 2015 NASA budget story. It passed the so-called CRomnibus bill, which funded nearly the entire federal government and provided NASA with a boost of nearly $450 million above the president's request for the year. It included significant increases to the Space Launch System/Orion programs as well as to planetary science, funding the division at $1.44 billion—just shy of our recommended $1.5 billion per year and nearly $157 million more than requested. Read all about it at planet.ly/cromnibus.

…AND HELLO TO 2016!

The story of NASA's 2016 budget is just beginning. The president wrote the first chapter with the release of his formal budget request for the federal government on February 2. Generally, the news is very good for NASA, which gets its highest funding request in four years. But despite this overall increase, the administration once again targeted planetary science for spending cuts, proposing $77 million worth of cuts and the premature termination of Mars Exploration Rover *Opportunity* and *Lunar Reconnaissance Orbiter*. Action now moves to Congress, which faces a showdown over spending limits imposed by sequestration. Get full coverage at planet.ly/nasafy2016.

Have you seen our new web series with Casey Dreier? If you want to hear the latest space policy news, check out planet.ly/thespaceadvocate

THE PLANETARY SOCIETY
85 SOUTH GRAND AVENUE
PASADENA CA 91105-1602 USA

Photo: Ben Cooper/launchphotography.com

It's Rewarding to Be a Member

We're excited to be adding a new benefit for members of The Planetary Society. In collaboration with NASA Federal Credit Union, we can now offer you **THE PLANETARY SOCIETY PLATINUM ADVANTAGE REWARDS CREDIT CARD**. I'm a huge fan of credit unions, and I've banked exclusively with them for over two decades. Credit unions exist solely for the benefit of their owner-members, so they offer better customer service, lower fees and penalties, lower rates on loans, and higher rates on savings. They are generally better capitalized than banks, and federally insured to boot.

You won't be surprised, then, that I've already applied for and received my own Planetary Society card. I'm excited because, in addition to the card, I am now a member of the NASA Federal Credit Union and have access to even more services such as checking and savings accounts, loans, certificates of deposit, and more.

The Planetary Society card offer includes no annual fee, and no balance transfer fee with 7.9% APR for life on those transfers. It also provides rewards points: one point for every dollar in purchases made with the card, with double the points for all Planetary Society-related purchases, including membership, conferences, events and donations. And you can redeem those points for Planetary Society membership, conferences, events, and donations, along with brand-name merchandise, gift cards, and travel.

While you receive these great benefits, The Planetary Society benefits, too. As members sign up and make use of the cards, The Society will benefit from a portion of those transactions—and at no cost to you.

Interested? Just visit NASA Federal Credit Union online at **nasafcu.com/TPS** to learn more and sign up. Why not be a member of not just one, but two great space organizations?

Regards,

Richard

Richard Chute
Director of Development
richard.chute@planetary.org
626-793-5100 x214