THE PLANETARY SOCIETY

THE PLANETARY REPORT

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ORIGINS ON ICE

STUDYING THE SOLAR SYSTEM'S FROZEN FINGERPRINTS

LIGHTSAIL TO LAUNCH! ✻ PUSHING THE BUDGET BOULDER ✻ VITAL VOLUNTEERS

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.

Farewell, Neptune

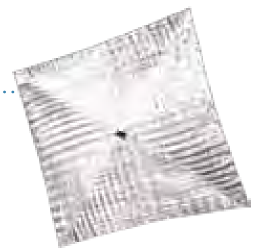
NEPTUNE WAS THE *VOYAGER* mission's final planetary encounter. On September 3, 1989—about nine days after its closest approach—*Voyager 2* captured the images that I composed into this color composite of Neptune and Triton. As the planet rotated between shots, clouds moved and smeared into rainbow spots on Neptune's crescent. Many of *Voyager 2*'s departing photos of Neptune were blurred due to spacecraft jitter during the long exposures required to image anything at all at Neptune's vast distance from the Sun. This view is composed of three of the sharpest images.

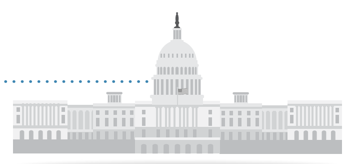
—Emily Stewart Lakdawalla

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

SEE MORE EVERY DAY! PLANETARY.ORG/BLOGS

Image: NASA/JPL/Emily Lakdawalla





ON THE COVER: From the shadowed craters of Mercury, to the outer edges of the Oort cloud, ice is ubiquitous across our planetary neighborhood. Variations in chemistry, temperature, and pressure have produced the roughly two-dozen types of ice we've observed, or expect to see, in our solar system. By reading the stories trapped in their ices, scientists gain valuable insights into the interior evolution and climate regulation of planetary bodies. The graceful contours of this deep crevasse are the result of melting in an Antarctic iceberg. *Photo: Mint Images–Art Wolfe/Science Photo Library*

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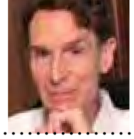


BILL NYE *is chief executive officer of The Planetary Society.*

Investing in the Future

That's What We Do at The Planetary Society

WE'RE GETTING READY to fly our *LightSail*® in 2016!

Things are humming along in the lab for our *LightSail* spacecraft and it is nearly ready for flight. I'm excited to announce that we have secured a rocket launch for our *LightSail*! This launch will take place, by the way, on an American-made rocket: SpaceX's Falcon Heavy. Getting our small but mighty *LightSail* spacecraft built and ready to go has taken us several years, but we're closer to finishing it.

We're getting ready to do the day-in-the-life testing essential to any successful mission. We're using our test spacecraft to change operating modes while its systems are all running, a vital task. We'll check that it can receive and transmit commands and telemetry. We'll deploy the sails on a surprisingly large, x-shaped test fixture. We'll make sure the solar panels are providing power and that the cameras take pictures and process them properly. Using an elegant simulator, we'll give the navigation and attitude control systems a check ride. If we find any problems, we'll have time to fix them. Then, we can start testing our flight spacecraft.

PICTURES FROM EARTH AND SPACE

LightSail pictures alone are going to be worth the trip. And by pictures, I mean the ones taken by the onboard cameras, as well as the ones that people like you will take from the ground. This solar sail is big enough and shiny enough to be naked-eye visible from the ground. It's exciting.

In Spring of 2016, we'll send *LightSail* to an orbit where we can control and operate our spacecraft over many months. On that mission, we'll be flying close to another spacecraft, *Prox-1*, which will be able to take images of the sail from a distance. These pictures will give us a special view of our spacecraft flying free in space.

Thanks to all of you for making these *LightSail* missions possible.

AT WORK IN WASHINGTON, D.C.

Recently, several members of the staff and I traveled to Washington, D.C. to represent The Planetary Society in force at the third USA Science and Engineering Festival. This year, there were about a third of a million attendees. Emily Lakdawalla gave some great presentations about the planets and nearby worlds using the spectacular pictures she has access to. Mat Kaplan conducted several fascinating interviews.

It was a highlight as well to broadcast *Planetary Radio Live* right from the floor of the Walter E. Washington Convention Center. We had great guests: Lockheed Martin Chief Technology Officer Ray Johnson, Mike Rowe, from Discovery Channel's *Dirty Jobs*, and Emily. They talked about all the skilled workers—the welders, technicians, electricians, and you-name-it—that the United States needs for space exploration. We had a great time. (If you haven't yet heard the show, you can find it at **planetary.org/radio**.)

There is an old saying about Washington, D.C., that it's a small town based on relationships. We are establishing excellent ties with members of the U.S. Congress and the administration, especially the all-important Office of Management and Budget (the OMB). As I often remark, even if you don't live in the United States, what goes on at NASA affects you, because it is by far the single largest space agency in the world.

Three of us made the rounds recently, going from one congressional member's office to another. Our team included our director of advocacy Casey Dreier, our lobbyist in Washington Bill Adkins, and me. People know who we are now in a way that they didn't before.

More importantly, they know our message. We want NASA and U.S. space policy to support and follow the National Research Council's Planetary Science Decadal Survey. We want $1.5 billion for planetary science. And we very much want a mission to Europa, the Jovian moon, which last year was found to be spewing water into space. The geysers on Europa are, first of all, amazing. Secondly, they present us with an extraordinary opportunity to sample an ocean on another world without the enormous expense of designing a lander and getting it onto the surface. As I so often point out, if we were to discover evidence of life on another world, just think what it would mean to humankind.

Each time we visited the office of a congressperson or administration official, I made the pitch about the value of planetary exploration writ large. We are the first generation of humans that can send instruments out to these other worlds—Mars, Mercury, Venus, Pluto and, I hope soon, Europa—to look for signs of something that replicates itself; to look for signs of water and life.

On this same recent trip, Casey, Bill Adkins, and I met with NASA Administrator Charles Bolden, the man himself, along with his chief scientist Ellen Stofan. We talked plainly about our desire to rebalance the NASA budget to accommodate a little more for planetary science. We reminded him of what a good value it is and how it might change the world. He's got a lot on his plate, and a great many people to appease. But our case is pretty compelling. Watch this space; I have a very good feeling about the mission to Europa.

ABOVE *Mike Rowe (second from right), host of Discovery Channel's hit show* Dirty Jobs, *and Ray Johnson (center), Lockheed Martin's Chief Technology Officer, joined Emily, Bill, and Mat onstage at the USA Science and Engineering Festival to talk about careers in space. Here, Mike describes the need for skilled tradespersons, such as welders and electricians.*

Photo: Loren A. Roberts/Hearken Creative

INVESTING IN OUR FUTURE

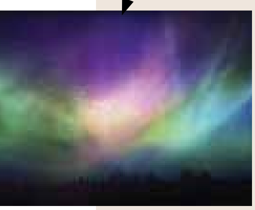
Perhaps the most significant thing for me as your chief executive is that I'm very proud to report that we have reinvigorated the Carl Sagan Fund for the Future. My goal is to one day have the interest produced by the fund provide for all of the Society's operating costs—all the salaries, the building lease, the utility bills, etc. I anticipate this may take the better part of a decade, but we are off to a great start. When you receive our mailing about the Carl Sagan Fund, please think of it as a real investment in the future of space science and exploration.

To advance space science and exploration, I have taken an apartment in New York City. It's only been a couple of months, but already my trips to Washington, D.C. have been short day trips. I've also been able to meet with several of our Members who live along the Eastern Seaboard. I stay in close touch with the Society's staff and board. So far, so good. Meanwhile, back at the office in Pasadena, Jennifer Vaughn continues to do an outstanding job as our chief operating officer. I believe we are offering better service to our Members and being more effective than ever in all that we do. Thank you for your support.

Let's change the world.

Bill Nye

HAPPENING ON
PLANETARY RADIO
planetary.org/radio



ROCKETING INTO THE AURORA
Listen as Neal Brown and his staff launch sounding rockets into the heart of the Aurora Borealis from the Poker Flat Research Range in Alaska. bit.ly/1goY3St

LIVE AT THE USA SCIENCE AND ENGINEERING FESTIVAL
Join us at the world's biggest public science event in Washington, D.C., where we talk about dirty jobs in space with television's terrific Mike Rowe. bit.ly/1mWZsWy

NEIL DeGRASSE TYSON
The host of *COSMOS: A Spacetime Odyssey* returns to our show with a behind-the-scenes look at the spectacular television series. bit.ly/1iUEHvi

SPACEFEST VI WITH APOLLO ASTRONAUT GENE CERNAN
We eavesdrop on *Apollo 17* Commander Gene Cernan and his lifelong fan, Griffith Observatory Curator Laura Danly. bit.ly/RxmSX7

WAS A NATURAL FUEL CELL KEY TO THE ORIGIN OF LIFE ON EARTH?
Researcher Laurie Barge simulates the natural formation of a fuel cell that may have taken place in Earth's primordial oceans. bit.ly/TMW6LZ

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

ON *PLANETARY.ORG*

INVESTIGATION

DARK FLIGHT DEBUNKED Did you see the skydiver video with the meteorite in the background? Philip Metzger explains. bit.ly/1eVnscm

NEWS

GREEN BANK TELESCOPE takes up slack when Arecibo has a "warming event." bit.ly/1tVjwfV

SCIENCE UPDATE

LUNAR RECONNAISSANCE ORBITER continues to do amazing science on our own Moon, including finding evidence for evolved, silicic volcanism and an incredible complexity of the lunar impact cratering process. bit.ly/1kPdIko

SCIENCE

THE 5-MILLISECOND COSMIC RADIO BURST Katherine Mack explains some of the research going into explaining this "fast radio burst" from space. bit.ly/1qDpByz

MEDIA

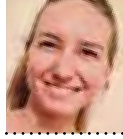
UNIVERSE MODELING Illustris is an internationally developed software model that watches the virtual interaction of galaxies... amazing! bit.ly/1l37bla

PHOTOGRAPHY FROM SPACE Emily Lakdawalla is amazed at the photos from the High Definition Earth Viewing (HDEV) experiment. bit.ly/1j6ad41

EDUCATION

ONLINE ASTRONOMY COURSE Bruce Betts' most recent astronomy course is now online and completely free at bit.ly/1o02pbN

Green Bank Telescope: NRAO/AUI/NSF; Moon image: NASA/GSFC/ASU



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

Science Festival Mania

Thousands of People Excited About Planetary Exploration!

IN APRIL The Planetary Society went to Washington, D.C. for the 2014 USA Science and Engineering Festival.

Staff and local volunteers manned a booth in the immense Washington Convention Center, armed with stacks of magazines, petitions, bookmarks, stickers, and anything else we could get into the hands of the 300,000 people who attended over the course of the weekend. We talked with thousands of people about the Society and about space exploration, met countless space enthusiasts, and converted more people into new space enthusiasts.

Our time at the festival was exciting and encouraging. It was incredible to see so many people come from all across the country to learn more about science, engineering, and technology. The energy in the festival was powerful and pointed toward a great future.

It was also fantastic to meet and work with our D.C.-area volunteers. They were the face of The Planetary Society to the thousands of people who came to our booth, and they did us proud. In conversations throughout the weekend they shared their passion for space exploration and showed people that they could have a real place in space. It was inspiring to see the impact these conversations had on people, especially kids, who left our booth eager to learn more about the universe around them.

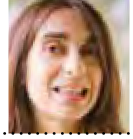
Volunteers like these are instrumental to our mission, and they represent one of the best ways in which we can empower the world's citizens to advance space exploration. I urge you to join us as a volunteer in whatever capacity you can. Explore ways to pitch in at **planetary.org/get-involved/volunteer**.

ABOVE LEFT *In April, more than 300,000 enthusiastic people packed the USA Science and Engineering Festival in Washington, D.C.*

TOP RIGHT *Planetary Society volunteers are an essential part of our efforts to engage the public in space exploration.*

BOTTOM RIGHT *The work of volunteers at our well-stocked booth paid off in plenty of new Planetary Society Members.*

Photos: Mike Colella [top], Loren A. Roberts [insets]



JULIE CASTILLO-ROGEZ *is a geophysicist and investigator at the Jet Propulsion Laboratory's Ice Physics Lab.*

Ice In the Solar System

Deciphering Clues to Planetary Origins and Habitability

ABOVE AND BELOW RIGHT *Ice across our solar system takes on a variety of forms depending on chemistry, temperature, and pressure. When water molecules freeze around gas molecules they form cage-like structures called clathrate hydrates. Here water molecules (red and white) surround a molecule of methane (black and white). Methane hydrates can be ignited to create "burning ice."*

OPPOSITE PAGE *Mars' southern polar cap consists mostly of water ice overlaid with a permanent 8-meter-thick layer of frozen carbon dioxide, or dry ice. European Space Agency's* Mars Express *orbiter captured this portrait of Mars' south pole in infrared, green, and blue light.*

ICE PLAYS A MAJOR ROLE in the interior evolution of planetary bodies and in climate regulation. On Earth, the amount of ice is an important marker of climate change. On other planetary bodies, depending on their distance from the Sun and hence their surface temperature, other types of ice are found, including carbon dioxide ice, mixtures of methane and nitrogen ices in the far outer solar system or, in Io's case, sulfur dioxide ice! In fact, ice has been observed on all large solid bodies, including the shadowed craters of the Moon and Mercury, and it is a major component of bodies beyond Jupiter's orbit. More recently, the discovery of a plume of water vapor at Ceres confirms the long-held hypothesis that this dwarf planet has an icy shell. Even Venus, despite its inferno-like climate, exhibits possible evidence of the presence of ice.

About two dozen types of ice have been observed or are suspected to exist inside solar system bodies, from the ultra cold to the ultra compact, pure compounds or mixtures with other ices. Most ices exhibit a crystalline structure, except when an ice is "amorphous" because it froze so quickly that the molecules did not have enough time to get organized. Under pressures found in the deep interiors of icy satellites like Titan or Ganymede, crystalline ice becomes more and more compact and shows a variety of structures. Under pressure, ice molecules can also organize themselves around molecules of gas in a structure called "clathrate hydrate." There's no need to travel to the outskirts of the solar system to search for this material; clathrate hydrate is found in abundance on Earth's sea floor, where it traps methane. You could light a match next to it and see "burning ice"!

WHY DO WE STUDY ICE?

Ice represents a thermometer of the early solar system. When the solar system formed, the Sun was embedded in a thick cloud of hot gas. Together, these elements formed the solar nebula. When the gas started cooling down, it condensed into minerals, similar to snow condensing from clouds when the right conditions of temperature and pressure are met. Close to the Sun, material condensed mostly water-free. Farther away from the Sun, water and a variety of volatiles were able to become stable and comprise more than 50 percent of the content of planetary bodies. A few million years later, the stage for ice formation was set. Water ice as well as ices from minor volatile compounds, such as ammonia, were formed starting from about the middle of the main asteroid belt in a

Graphic: Science Photo Library

frontier called the “snow line.”

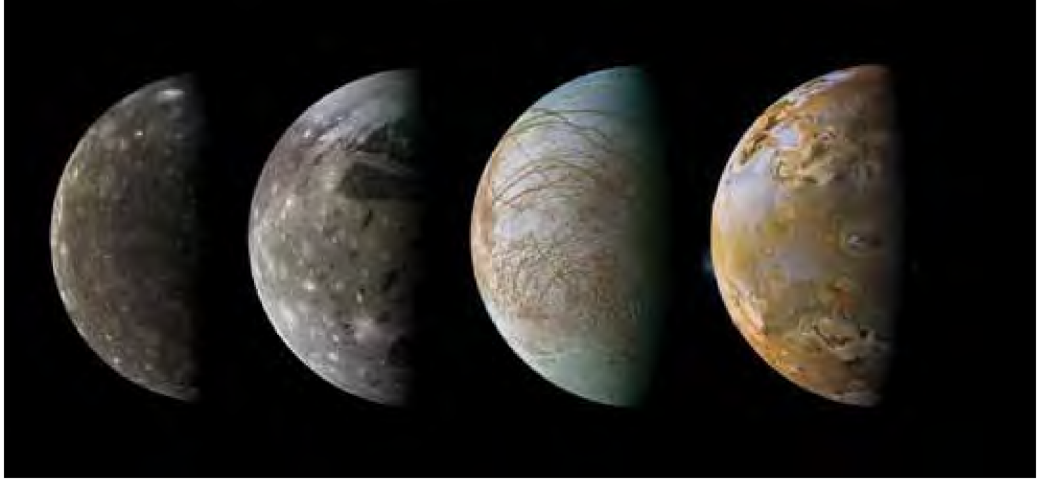
However, this situation did not stay quiet for long because the giant planets wandered in their orbital motions. Models of these planetary motions indicate that dynamic interactions between Jupiter and Saturn resulted in a reshuffling of the large belts of planetesimals–such as comets and asteroids–associated with giant planets. This theory of early solar system evolution is called the “Nice” model, and was introduced about ten years ago. As part of this process, a significant number of planetesimals migrated toward the inner solar system, delivering water to it. New reservoirs of ice, such as the Kuiper belt and Oort cloud, formed or reorganized beyond Neptune’s orbit.

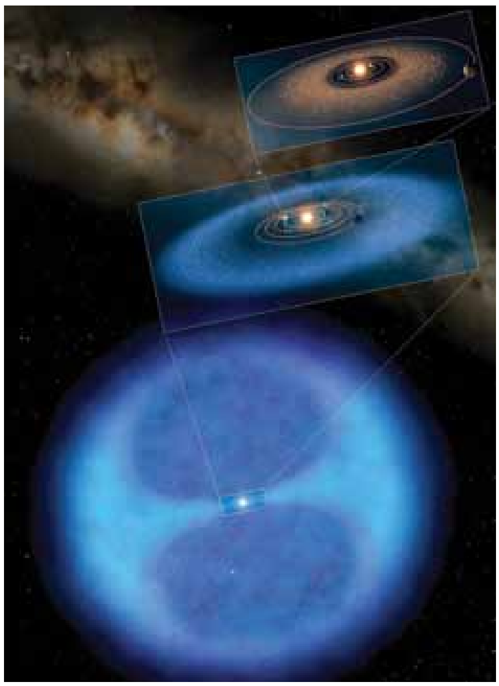
To look back in time, scientists work as detectives who use the composition of planetary bodies as clues to the nature of the early system. Via their elemental composition and mineralogy, the ices have preserved fingerprints of the environment in which they formed. Sampling ices across the solar system for compositional analysis provides a means to decipher the history of the early solar system and to understand how it developed into its present architecture.

WHERE THERE IS ICE, THERE MAY BE LIFE

When ice-rich bodies are several hundreds of kilometers across, models of their thermal evolution show that their interior temperatures could become warm enough for part of the ice to melt. Space missions have detected subsurface water oceans in many objects, such as Jupiter’s satellites Europa, Ganymede, and Callisto, as well as Saturn’s moons Titan and Enceladus. Scientists believe that other

Image: ESA/Gerhard Neukum/Bill Dunford





TOP *Spacecraft observations have detected water ice and subsurface oceans on Callisto, Ganymede, and Europa. Even Io has ice, in the form of frozen sulfur dioxide.*

ABOVE *As the solar nebula condensed, water and other volatiles located far from the young Sun were able to remain stable. Millions of years later, ices began to form, and comets and planetesimals delivered this water to the inner reaches of the infant solar system.*

RIGHT *At the same time, beyond Neptune's orbit, huge reservoirs of ice formed into a vast disk of cometary nuclei known as the Kuiper belt (center). They also formed the Oort cloud, an immense, spherical shell of icy bodies that surrounds the entire solar system (bottom).*

objects held a deep ocean for some of their history but were too cold for liquid to persist over extended periods of time, such as in the case of Saturn's moon Tethys or 100-kilometer-sized objects in the Kuiper belt. The presence of volatile impurities acts as an antifreeze and plays a key role in the long-term preservation of deep bodies of liquid inside these objects, in the same way that salts help the long-term preservation of buried lakes in Antarctica, such as Lake Vostok.

Evidence of deep liquid water comes from studying the surface composition and geologic history of icy bodies. Scientists can reconstruct the history of icy bodies and infer limits on the presence, depth, and composition of liquid water from the features displayed on their icy surfaces. Geophysical techniques, such as gravity and magnetic field measurements, can also probe the deep interior. The presence of deep oceans in Europa, Ganymede, and Callisto were all inferred from the signature of salty water measured by *Galileo*'s magnetometer. Recent interior models inspired by comparisons of Europa's surface with features found in Antarctica suggest that pockets of water may be present within Europa's ice shell.

THE TIME OF ICY BODIES

The next couple of years will be good ones for the exploration of icy bodies. The *Cassini* orbiter will continue its tour of the Saturnian system with 24 flybys of Titan and three close flybys of Enceladus. In addition, the following three missions will unveil the secrets of planetary bodies never before explored:

The *Rosetta* mission will begin mapping comet 67P/Churyumov-Gerasimenko in August 2014. In November 2014, *Rosetta* will deploy a lander, called *Philae*, which will study the comet's surface for at least three months while the main *Rosetta* spacecraft studies its outgassing activity as it approaches perihelion.

After its spectacular survey of Vesta, the *Dawn* spacecraft will reach its second target, Ceres, in the spring of 2015, to perform extensive mapping of the surface for geologic and compositional characterization. *Dawn* will deploy an instrument capable of measuring elements ejected from Ceres' surface as a con-

JULIE CASTILLO-ROGEZ *is a planetary geophysicist specializing in icy satellites and small bodies. She is a cofounder of JPL's Ice Physics Laboratory. She has been involved in the science planning of the* Cassini-Huygens *and* Dawn *missions and was part of the science definition team for the Titan and Saturn System Mission Study.*

Galilean moons image: NASA/JPL/Ted Stryk; Oort Cloud illustration: Mark Garlick/Science Photo Library

Icy Challenges for Explorers

The explorers of today and tomorrow will have many challenges to tackle in order to advance the study of planetary ices. In the area of solar system ices, there are at least five major questions that are important to understanding the origin of the solar system, our place in the universe, and the future of human space exploration.

1 What is the nature and state of ice in giant planets and large exoplanets?

STATE OF THE ART: Scientists have suggested that highly compressed ices represent a major fraction of the cores of giant planets and may also be abundant in large, icy exoplanets. **WHY THIS MATTERS:** Based on available information on the properties of these high-pressure ices, recent models indicate that these objects could host large, deep oceans. However, observing the composition of these ices and their properties under relevant conditions of pressures and temperatures is difficult to achieve in the laboratory. **HOW TO ADDRESS THIS QUESTION:** New testing facilities that can achieve pressures greater than 10 million times that of Earth's atmosphere and temperatures below about -180 degrees Celsius (-300 degrees Fahrenheit) need to be developed in combination with new approaches to modeling material behavior under extreme conditions.

2 What is the role of impurities in the behavior of ice and snow, and does this impact climate evolution?

STATE OF THE ART: Aerosols and certain gases end up embedded with ice in snow packs and marine ice. The concentration of these impurities is believed to impact the ices' physical properties, for example by playing the role of antifreeze or making it easier for the "dirty" ice to deform at low temperatures. **WHY THIS MATTERS:** Alteration of ice properties impacts the stability of ice sheets and temperate glaciers, which can in turn impact regional and global climate patterns. **HOW TO ADDRESS THIS QUESTION:** Sampling and laboratory testing of the composition and physical properties of glaciers and snow can help predict their behavior on various time scales.

3 How many solar system bodies host liquid water under their ice shells and are potentially habitable?

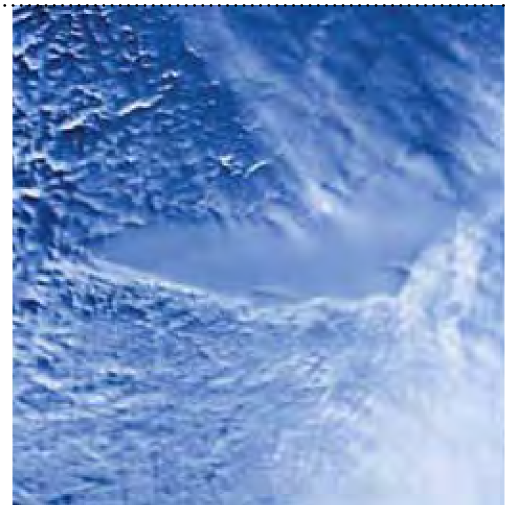
STATE OF THE ART: Using a combination of techniques like gravity and magnetic measurements, liquid water has been detected at five icy satellites so far. Most recently, *Cassini* has confirmed the presence of a sea at Enceladus' south pole. It is likely that liquid water is also present in a variety of large, icy bodies: Neptune's satellite Triton, Pluto and its moon Charon, large Kuiper belt objects, and possibly Ceres. **WHY THIS MATTERS:** As deep oceans may be in contact with rocky material (as Earth's ocean is in contact with a basaltic floor), conditions may be present for life-forming chemistry to develop. This is likely true for those bodies whose ice shells are a few hundred kilometers thick, like Europa, Pluto, or Charon. For bigger satellites, with shell under a few hundred kilometers deep, water pressure becomes significant enough for high-pressure ice to develop at the top of the rocky core. However the presence of salts alters the behavior of water in response to pressure and temperature and one cannot rule out that some liquid could persist down to the core. **HOW TO ADDRESS THIS QUESTION:** Explore, explore, explore!

4 What is the origin of Earth's water?

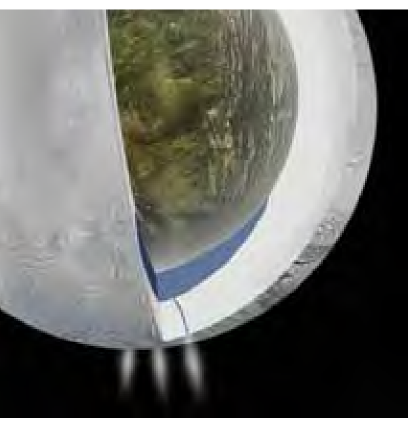
STATE OF THE ART: Multiple possibilities have been proposed for the origin of water on Earth, including various types of comets and main belt asteroids. The most recent results suggest the isotopic signatures for water in Earth's oceans are similar to those found on comets and Enceladus! **WHY THIS MATTERS:** Depending on its origin, water could have brought organics with it. In fact, comets display abundant volatiles of all types as well as organics. Hence, tracking the origin of water is an avenue to tracking the origin of organic molecules on Earth. More generally, this question relates to understanding how the solar system came to achieve its current architecture. **HOW TO ADDRESS THIS QUESTION:** Ices all over the solar system need to be sampled with techniques that allow extraction of the fingerprint that makes each ice unique. Several mission concepts, including the Europa Clipper, involve the transport of mass spectrometers to icy bodies in order to measure their ices' elemental and isotopic makeup. The Planetary Science Decadal Survey also recommends that cometary ice be returned to Earth.

5 How much water is available for human exploration of the solar system?

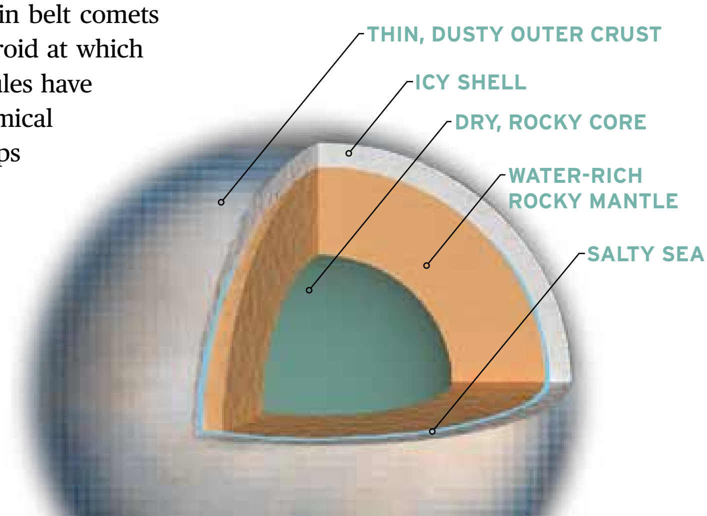
STATE OF THE ART: Certain types of asteroids are believed to be dormant comets that could contain a large fraction of ices. Others exhibit features that suggest water is intimately associated with their rocky material. Mars' moon Phobos also has similar features associated with its large crater Stickney that suggest it could serve as a base for future Mars exploration. **WHY THIS MATTERS:** Water may be harvested for consumption and fuel production, decreasing the mass of resources to be launched with a human crew. Water-rich asteroids can offer pit stops on the way to Mars or other destinations. **HOW TO ADDRESS THIS QUESTION:** Close observations of these asteroids are necessary to confirm the presence and nature of water and to identify operations needed to harvest it. Large-scale surveys of near-Earth asteroids with ground-based and space telescopes can help assess the amount of resources available out there. Water extraction techniques are being developed in the lab to determine the conditions under which water can be collected.



RIGHT *This radar satellite image reveals an area of smooth ice covering Antarctica's Lake Vostok, which lies buried under 4 kilometers (about 2.5 miles) of ice. Volatile impurities keep underground seas on other worlds in a liquid state, much the way salts act to preserve Lake Vostok. Any confirmation of life in Vostok could strengthen the prospect of life in similar bodies of liquid on icy moons.*



ABOVE Cassini*'s gravity studies of Enceladus suggest that it had an ocean of water (blue) at its south pole. The water is sandwiched between its rocky core and a layer of ice beneath the moon's crust. Water vapor escapes from fissures in the surface.*



RIGHT *Surface observations of hydrated minerals and models are coming together to present Ceres as a small planet that hosted a deep ocean in the past, and possibly a salt-rich sea at present.*

sequence of gamma ray impacting, and will map the distribution and depth of water on the dwarf planet.

Finally, in July 2015, the *New Horizons* mission, launched in January 2006, will reach Pluto's system. Pluto exhibits an exquisite variety of ices at its surface and the spacecraft carries instruments capable of accurately measuring the composition of these ices. Pluto's major moon, Charon, is about the same size as Ceres, which offers the prospect of interesting comparisons between these two bodies that are similar in many ways but have evolved in very different environments. These upcoming observations will break new ground in our understanding of the evolution of dwarf planets and their potential for hosting habitable environments.

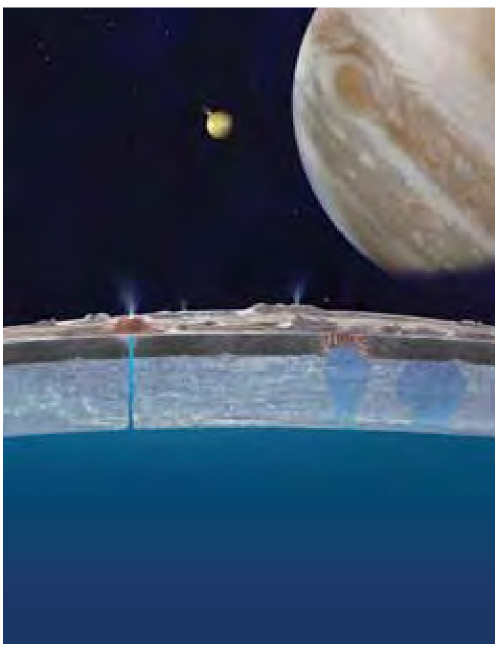
WHAT IS NEXT FOR ICY BODIES?

In 2016, the *Juno* mission will go into orbit around Jupiter and obtain measurements that can help scientists understand whether Jupiter contains a core. In 2017, *Cassini* will accomplish a spectacular plunge inside Saturn's rings and perform the first close observations of the rings.

But after 2017, the icy body exploration roadmap is empty for a few years. Although many fantastic missions are in development, the exploration of icy bodies will reach a stall. In order to complete the sampling of ices and icy bodies across the solar system, several destinations require attention. This includes the outer asteroid main belt, which hosts objects such as the main belt comets and 24 Themis, the first asteroid at which water ice and organic molecules have been detected by astronomical observations, as well as groups of asteroids located along Jupiter's orbit in regions called the "Trojan clouds." These clouds contain an estimated one million bodies believed to be captured by the large reshuffling of the early solar system that is part of the Nice model mentioned above. The origin of these objects can be inferred by measuring their chemical makeup, using ice as a thermometer. Because of the Trojan clouds' scientific importance at the frontier between the inner and outer solar system, a mission there has been highlighted in the National Research Council's current Planetary Science Decadal Survey, which identifies key questions and priorities for space exploration from now until the early 2020s. Another important new mission recognized by the planetary science community is to the Uranian system which, back in the time of the *Voyager* missions, yielded a few major mysteries such as the unusual geologic features on Miranda and Ariel. These strange features express the multiple forms that icy material takes as a function of composition and geological context and, in the case of Ariel, possibly cryovolcanism.

In 2030 the JUpiter ICy moons Explorer (JUICE) mission, in development by European Space Agency and planned for launch in 2022, will follow in the tracks

Lake Vostok image: Canadian Space Agency/RADERSAT/NASA/Science Photo Library; Enceladus image: NASA/JPL-Caltech; Ceres graphic: Julie Castillo-Rogez/Loren A. Roberts/Hubble Space Telescope



TOP LEFT AND RIGHT *The current Planetary Science Decadal Survey calls for a new mission to the Uranian system, enabling a closer look at the strange, icy features on Miranda [left] and Ariel [right]. Ariel could also have cryovolcanoes, as suggested by its smooth relief.*

BELOW LEFT *Pockets of liquid water may rise up out of Europa's saltwater ocean and seep into its icy crust. Recent Hubble Space Telescope observations have detected water plumes rising from its surface, making Europa the second moon in the solar system (along with Enceladus) known to have water vapor eruptions.*

BELOW RIGHT *European Space Agency, in collaboration with NASA, is working on the JUpiter ICy moons Explorer (JUICE) mission which, in 2030, will examine Jupiter, Ganymede and Europa. One of JUICE's primary goals is to study the emergence of habitable worlds around gas giants.*

Miranda & Ariel images: NASA/JPL/Ted Stryk; Europa illustration: NASA/JPL-Caltech; JUICE illustration: ESA/AOES

of *Galileo* for a close-up look at Jupiter, Ganymede, Callisto, and Europa. The Europa Clipper, which recently received a go-ahead for preliminary development, could leave Earth in about a decade and would perform extensive mapping and habitability assessment of Europa.

CONCLUSION

The origins of solar system ices and the evolution of icy bodies are major themes of planetary exploration. Remote and in-situ observations of icy bodies can help scientists look back to the early conditions of the solar system and understand the major dynamic events that shaped our planetary neighborhood as we know it today.

Pushing the frontiers of exploration has also led to the discovery of multiple bodies that may harbor conditions amenable to the development of life forms. Increased knowledge of our solar system environment, both near and far, will in turn help us identify regions in exoplanet systems conducive to the development of that holy grail of space exploration: life.

DOUG STETSON *manages The Planetary Society's* LightSail *program.*

Preparing to Sail

LightSail Has a Launch Date!

ABOVE *Solar sail technology is innovative, simple, and flexible. While it may be the only practical way to achieve interstellar flight, it will also work close to home for Earth science and weather missions. Here,* LightSail *begins its mission, opening its solar arrays and deploying its Mylar sails—a process that will take about two minutes.*

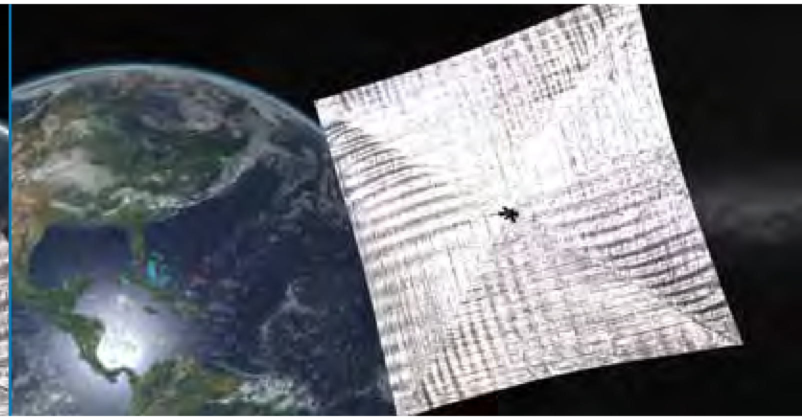
LightSail Illustrations: Josh Spradling

WHILE THE FUNDAMENTAL principles behind solar sailing have been known for a long time, dating back to Jules Verne, it is only recently that spacecraft and materials technology have advanced far enough to make it practical. Solar sailing is conceptually very simple: Build a large, lightweight structure (the sail), attach it to a spacecraft, and put it in space, where it can be propelled by the faint pressure of sunlight. If the sail is big enough, and high enough that it is free of atmospheric drag, the tiny but constant acceleration of solar pressure can be used to generate the very high velocity that every spacecraft needs to travel through the solar system.

There is no doubt that the physics of solar sailing works; the challenge has been in its practical application: to build a sail that is large enough and strong enough yet very lightweight, package it into a spacecraft along with a reliable deployment system, and control the orientation (attitude) of the vehicle in space so that the sail can be used to send the spacecraft where we want it to go. Until these capabilities are demonstrated and tested, no space agency will spend millions of dollars on a mission that relies on this technique, regardless of its many potential benefits. That's where *LightSail* comes in.

LightSail was conceived nearly five years ago by Planetary Society Cofounder Louis Friedman (now retired) and Tomas Svitek of Stellar Exploration as a low-cost method of demonstrating and validating solar sail technology. The goals of the project are straightforward: to successfully deploy and stabilize a solar sail in Earth orbit, demonstrate the ability to control the spacecraft attitude to sufficient accuracy, and use the solar sail to intentionally modify the spacecraft's orbit. To represent a meaningful step toward future missions, the sail must be large enough to provide the needed acceleration, but the overall system must be small and simple in order to be affordable.

Fortunately, around the same time, the class of spacecraft known as Cubesats was advancing rapidly and provided an ideal platform for the *LightSail* demonstration. The *LightSail* spacecraft is designed as a three-unit (3U) Cubesat, meaning it consists of three cubes stacked on top of each other, each cube measuring 10 centimeters (about 4 inches) on a side. All of the spacecraft's functions, including the sail and its deployment system, are packaged into this small space. Keeping the system small and light enough to fit in a 3U Cubesat means that a relatively small sail—



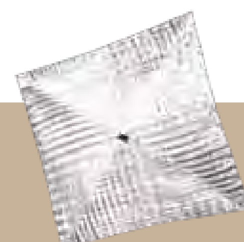
in this case about 32 square meters—can be used to provide useful acceleration. It also results in a very low-cost yet highly capable spacecraft and will make an important contribution to solar sail technology.

While there have been other solar sail missions—most notably the Japanese *IKAROS* mission, which deployed and demonstrated a solar sail in interplanetary space in 2010—*LightSail* will be the first Cubesat solar sail. With their compact design and standard components, Cubesats are within the reach of many universities and other organizations; no longer is it the case that only large companies or government space agencies can afford to build and fly satellites. But because of their small size, Cubesats have no room for the rocket engines or propellant tanks that can allow them to travel independently throughout the solar system, and thus have been limited to Earth orbit. *LightSail* changes all of that. This marriage of solar sails with the Cubesat paradigm is one of the major contributions of *LightSail* and The Planetary Society, and truly is a step toward opening up the solar system to everyone.

LIGHTSAIL MISSION PROFILE

LightSail will launch in April 2016 as a secondary payload aboard the Falcon Heavy launch vehicle now in development at SpaceX. Once it is in Earth orbit and safely ejected from its carrier, *LightSail* will be tracked for several weeks (with the sail still safely stowed inside) to accurately determine its orbit and verify that all subsystems are working properly. About four weeks after launch—the exact time period is still to be determined—a command will be given to deploy the solar sail. This will be done when the spacecraft is known to be in communication with a ground tracking station so we can monitor the deployment in real time. The deployment of the sail itself proceeds rapidly, and in just about two minutes the sail will be fully extended. Onboard systems known as torque rods will automatically align *LightSail* with Earth's

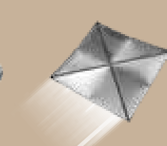
WHY SOLAR SAIL?



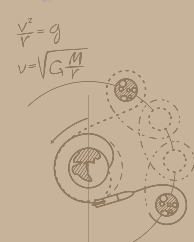
Solar sailing has the potential to revolutionize solar system exploration.

No engines, tanks, valves, or plumbing required

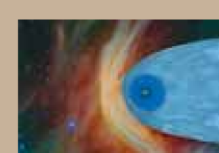
No toxic, heavy propellant



Constant low acceleration builds very high spacecraft velocity



Enables novel "non-Keplerian" orbits for specialized observations



May be the only practical means of interstellar travel

RIGHT *In April 2016,* LightSail *will blast off from Cape Kennedy as a secondary payload on board the world's newest and most powerful rocket, SpaceX's Falcon Heavy launch vehicle.*

magnetic field and stabilize the spacecraft attitude in preparation for the next phase.

After successfully demonstrating sail deployment and stabilization, *LightSail* will enter the orbit modification phase of the mission. During this phase, the spacecraft will be reoriented twice during each orbit to take maximum advantage of the sunlight falling on the solar sail.

By adjusting the spacecraft's attitude regularly over a large number of orbits while carefully monitoring the orbit's size, shape, and angle relative to Earth's equator, we will be able to confirm that the sail is acting as predicted and providing the expected modification of the orbit. This will fully validate the sail system and attitude control process. The entire mission is planned to last about three months, although if the spacecraft remains healthy there is no reason why the mission can't be extended to allow further characterization of the sail system's performance.

ORBIT ALTITUDE CONSIDERATIONS

One of the constraints on solar sailing in Earth orbit is that solar radiation pressure must exceed atmospheric drag, preferably by a factor of 5 to 10 to allow sufficient operational margin. This is partly because the upper atmosphere is variable: it expands or contracts depending on the solar cycle, sunspot activity, and other less predictable factors. An orbit altitude of 800 kilometers (500 miles), is generally considered the optimum for the *LightSail* configuration. In fact, one of the challenges that has kept *LightSail* from being completed in the past was the inability to find an affordable ride to an 800-kilometer orbit–in other words, there was no free launch.

To break the logjam and get *LightSail* into space, we have compromised on orbit altitude, and the current mission plan will place *LightSail* into an orbit of about 720 kilometers (about 450 miles). Preliminary calculations show that solar radiation pressure will exceed atmospheric drag by a factor of at least 2.5 and possibly 5 during the mission, which will be sufficient to allow a demonstration of solar sailing. We will be modifying the orbit in several different respects–not just the orbital energy, which forces us to work directly against atmospheric drag, but also other parameters that are not affected as dramatically by drag. Careful orbit planning and tracking will allow for an effective demonstration of the technology, even at this slightly lower altitude.

LIGHTSAIL'S PARTNER SPACECRAFT

As The Planetary Society was searching for a way to complete an affordable *LightSail* mission, a terrific opportunity was offered to us by the Georgia Institute of Technology, and this has dramatically enhanced the mission. Georgia Tech students won a competition to build and fly a mission called *Prox-1*, which will demonstrate new technologies for close-

DOUG STETSON *works as a consultant specializing in innovative mission and system concepts, strategic planning, and program development for the space science community. Before his current position as head of the Space Science and Exploration Consulting Group, Doug spent 25 years as an engineer and manager in the planetary program at JPL.*

Illustration: SpaceX

proximity operations of two spacecraft in space. To make a long story short, they needed a partner spacecraft that could serve as the target for their experiment. *LightSail* needed a ride to a high orbit, so it didn't take long to conclude that the two are a perfect match.

The new mission plan calls for *LightSail* to be carried and released by *Prox-1* after reaching orbit. For several weeks prior to sail deployment, *Prox-1* will image and track *LightSail* from a safe distance while conducting its proximity operations experiments. When those experiments are complete, *Prox-1* will watch as *LightSail* deploys its sail and conducts its first attitude maneuvers. The images returned by *Prox-1* will be of tremendous benefit in understanding the dynamics of sail deployment, since we will actually be able to see it happen in addition to receiving the usual radio data. We are working closely with Georgia Tech on the combined mission.

THE *LIGHTSAIL* SPACECRAFT

The *LightSail* spacecraft is a marvel of innovative design and intelligent packaging. Two of its three Cubesat units are devoted to avionics and sail storage. The third unit is divided between the deployer section, including the booms to which the Mylar sail is attached, and the payload section, which includes the sail drive motor, the antenna, and other components. The solar arrays are folded down over the sail during launch and checkout and help to hold the sail in place prior to deployment. Before the sails are deployed, the entire system is just 30 centimeters tall and 10 wide, so it's about half the size of your toaster oven. After deployment the sail spreads out to a full 32 square meters. The spacecraft is nearly complete and will be undergoing full system tests later this year.

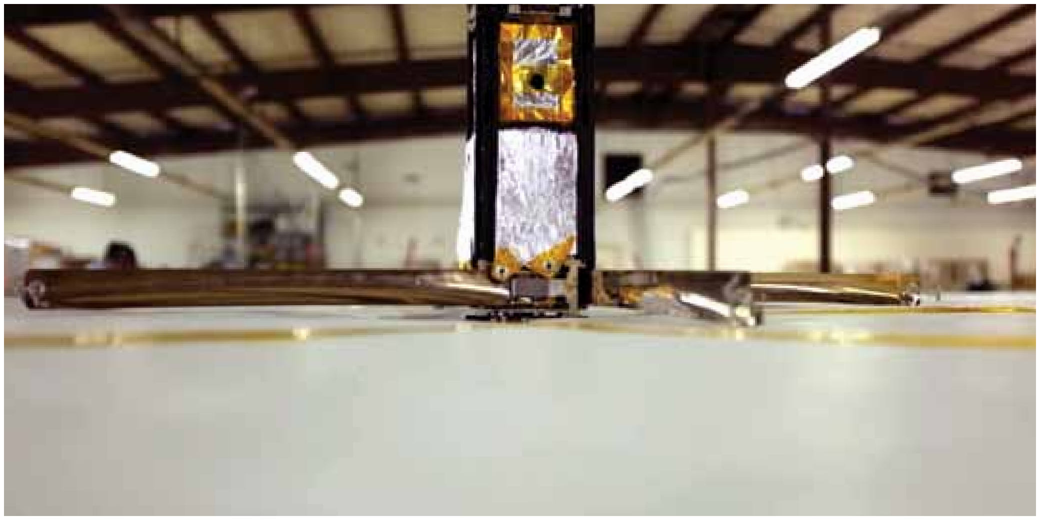
TEST FLIGHT

It is well known that the best way to reduce risk in any spaceflight program is to fly two spacecraft whenever possible, and *LightSail* is very fortunate to have that opportunity. Thanks to some intelligent planning early

LEFT LightSail *carries small cameras mounted on the ends of two of its solar arrays. The Aerospace Corporation, which developed the cameras for us, calls them PSCAMs – short for Planetary Society Cameras. This sample PSCAM shot shows* LightSail *team members Alex Diaz and Barbara Plante at work in the lab.*

BELOW *A serendipitous partnership was formed when the Georgia Institute of Technology invited the Society to fly with their* Prox-1 *mission.* Prox-1 *will test new technologies that monitor the operations of two spacecraft in flight. As a bonus,* Prox-1 *will also take pictures of* LightSail *in space. This graphic depicts the stages of the* Prox-1/LightSail *mission plan.*

Photo: PSCAM; Graphic: Georgia Tech/Hearken Creative



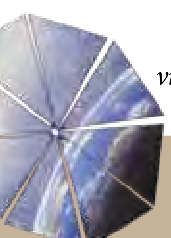
ABOVE LEFT *One Mylar sail blade is visible folded into the middle Cubesat unit in the spacecraft's three-unit body. The sail is attached to one of the retractable booms coiled into the bottom unit.*

ABOVE RIGHT *On June 24, the* LightSail-A *spacecraft performed a series of boom deployments to verify the resolution of problems that occurred during previous tests. The full video is at* **bit.ly/1kbFAf6**.

in the program, two nearly identical copies of the flight system have been built and are simultaneously being brought to flight readiness. We have also been awarded another launch slot, funded by NASA, so we are hoping to perform a test flight of the *LightSail* system in May 2015—a full year prior to the primary mission. This launch is to a lower orbit—too low to allow actual solar sailing—but it will allow us to verify the performance of the sail deployment and attitude control systems, as well as other key Cubesat functions, well in advance of our primary launch opportunity. The test flight system is being prepared to undergo full system tests and, if we are satisfied with the results, in October 2014 it will be packaged and shipped to await launch. The first stop after *LightSail* leaves our hands will be the Naval Postgraduate School in Monterey, California, where it will be mounted (along with other Cubesats) onto a deployment structure; after that the entire system will be shipped to the launch site at the Kennedy Space Center in Florida. Once the sail is deployed in space the test mission will last just a few days, but we'll certainly gain important knowledge about the spacecraft's performance that will help ensure success of our primary mission in April 2016.

YOU HELPED MAKE THIS HAPPEN!

After years of planning, development, and testing, *LightSail* now has firm launch dates and nearly flight-ready spacecraft. With a possible test flight in May 2015 and a primary launch in April 2016 in partnership with the Georgia Tech *Prox-1* mission, *LightSail* is poised to fully demonstrate Cubesat solar sailing and make the technology available for low-cost missions throughout the solar system. During their flights, both spacecraft should be visible to the naked eye, giving the public a clear view of what The Planetary Society has been able to accomplish, thanks to the generous support of people like you, our Members and Donors.



THE BEGINNING: *COSMOS 1*

On June 21, 2005, The Planetary Society launched *Cosmos 1*, our first solar sail. Built in partnership with Cosmos Studios and assembled by Russia's Space Research Institute (IKI), this groundbreaking spacecraft was to be the first to sail around the world, powered only by the pressure of light. Instead, it ended up at the bottom of the Barents Sea when its launch vehicle, a Russian Volna rocket, failed to separate.

Undaunted, and buoyed by our Members' calls to try again, we learned from the experience. We took note of what we did wrong—and right—and vowed not to give up. So, nine years later, here we are, getting ready to test our Mylar wings once more.

We honor *Cosmos 1* and are thankful to all who worked on it with us. It was another first step for an organization that has taken many first steps in finding creative ways to take humanity into space.

—Donna Stevens, Senior Editor

Photos: The Planetary Society; *Cosmos 1* Illustration: Rick Sternbach for The Planetary Society

Total Lunar Eclipse in Hawaii

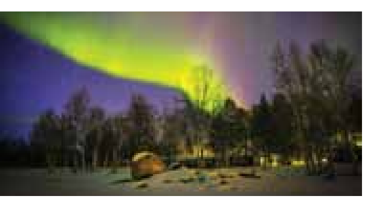
OCTOBER 5-13, 2014

Join us in Hawaii on October 7 to see the Total Lunar Eclipse and to explore Hawaiian natural wonders—from lava flows to massive tree ferns. We will also show you some of the astronomical observatories that generate an enormous amount of information about our solar system, galaxies, black holes ... and beyond!

Iceland: Total Solar Eclipse & Aurora Borealis

MARCH 15-23, 2015

Travel with The Planetary Society and enjoy two breathtaking astronomical events in one expedition! We will also explore famous Icelandic sites, including the renowned Geysir (after which all of the world's geysers are named), plus geothermal wonders such as the Blue Lagoon and Myvatn in Iceland's northeast.



Alaskan Aurora Borealis Expedition

MARCH 26-APRIL 1, 2015

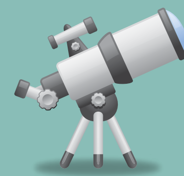
No need to leave the United States to experience the wonders of the Aurora Borealis! Join us as we enjoy the Northern Lights in the snowy wonderland that is Alaska in winter from three of Alaska's best viewing locations. Plus, take a classic train journey from Anchorage to Fairbanks, and attend the annual winter World of Ice Art Festival.

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)

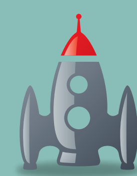
Betchart Expeditions
17050 Montebello Rd., Cupertino, CA 95014 USA
info@betchartexpeditions.com
betchartexpeditions.com

WHAT'S UP? *by Bruce Betts*



IN THE SKY

In the pre-dawn east, very bright Venus is getting lower over the weeks and bright Jupiter joins it in August, getting higher. The two are very close on August 18, very low to the horizon. Yellowish Saturn and reddish Mars are in the early evening west, getting lower and growing closer to each other through August. The Perseid meteor shower peaks August 12–13, with increased activity several days before and after the peak. The Perseids are typically one of the best showers of the year, with an average of 60 meteors per hour visible from a dark site. A total lunar eclipse is visible October 8 from most of North America, South America, eastern Asia, and Australia.



RANDOM SPACE FACT

Since going into orbit at Saturn ten years ago, the *Cassini* spacecraft has traveled more than 3 billion kilometers (2 billion miles).

TRIVIA CONTEST

Our December Solstice contest winner is Bonnie Allen of Los Angeles, California. Congratulations! **THE QUESTION WAS:** What is the name (or one of the common names) of the Milky Way Galaxy arm in which we live? **THE ANSWER:** The Earth lies within the Orion Arm, also known as Local Arm, or the Orion-Cygnus Arm.

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

What is the name of the set of buttes on Mars that the Curiosity rover will pass by on its way to Mt. Sharp?

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 September 1, 2014. 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*.

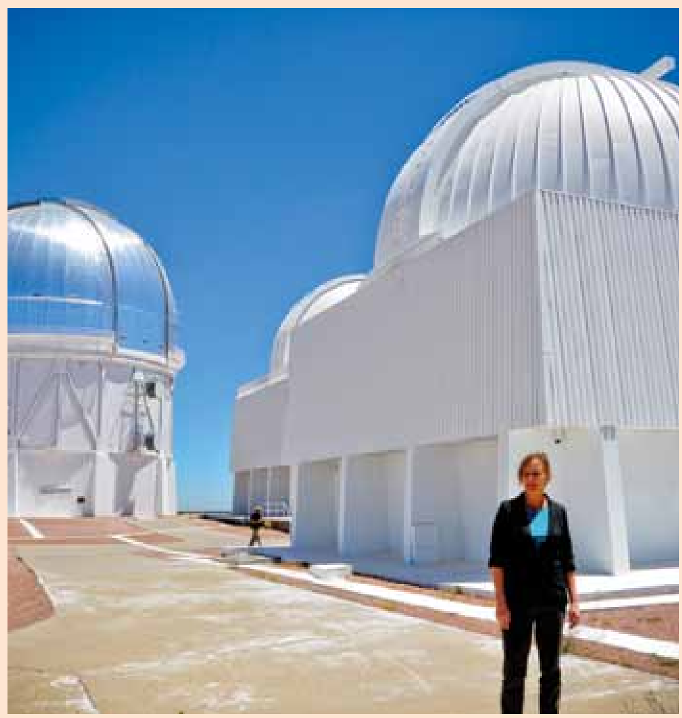
BRUCE BETTS *is director of science and technology for The Planetary Society.*

Planets at Alpha Centauri?

An Update on the Search

Thanks in part to the support of our Members, Yale University's Debra Fischer and her team were able to secure many nights of observations of our nearest stellar neighbors–the main Alpha Centauri stars–to look for planets using an improved system (see "Upgrades to the Search" in the September 2013 issue of The Planetary Report*). They also tried to confirm the discovery announced by another team of an exoplanet around one of the Alpha Centauri stars. Below is a shortened excerpt from Debra's report on results and status. The full text of her update is at* **bit.ly/QLrjOu**.

IN 2007, we started planning the search for planets around our nearest neighbors. We focused our attention on the two bright stars, α Cen A and B, where we knew that we could obtain planet-detecting precision in



our velocity measurements. We understood that we were racing against time: the orbit of α Cen A and B is oriented in such a way that the two stars appear to be getting closer to each other. This is a problem because we needed to clearly resolve the stars in order to obtain good velocity precision. In 2007, the stars were a respectable 10" (10 arc seconds) apart and easy to separate with a decent telescope.

In 2008 we refurbished an old spectrograph and reached a modest 5-meters-per-second precision at the 1.5-meter telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile. In parallel, we began designing CHIRON, the CTIO High Resolution spectrometer. With funding from

Photos: courtesy of Debra Fischer

Thanks! Planetary Society Members have helped make this project—and many others—possible! Thank you.

We modified our search strategy to specifically look for the 3.24-day signal by observing α Cen B "all night, every night." We again had help from The Planetary Society to purchase extra nights that allowed for this intense observing strategy.

the National Science Foundation in 2009, my team designed, built, and commissioned the instrument by March 2011.

Because our precision was "only" 1 meter-per-second, we decided to try to further stabilize the instrument. In 2012 we added a new octagonal fiber scrambler, developed with help from The Planetary Society, and our precision improved. The stars were getting closer—now a worrisome 6" apart, but the quality of our data was excellent and we obtained hundreds of measurements of α Cen A and B.

In October 2012, the Geneva team surprised us by announcing the detection of a 1-earthmass planet in a scorching 3.24-day orbit around α Cen B, using the HARPS spectrometer (see bit.ly/1tp8GRz). We examined our data from 2012 and did not see the 3.24-day signal. However, the weak signal was a challenging detection.

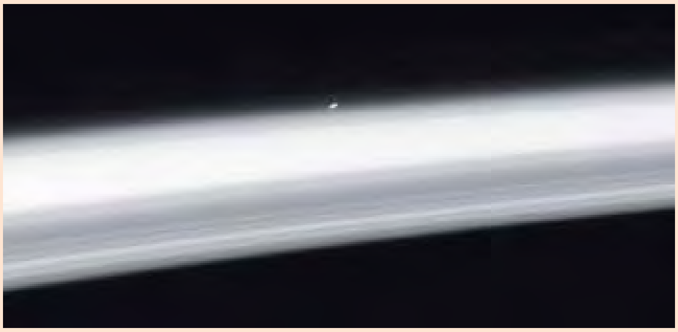
As soon as α Cen A and B emerged from behind the Sun in 2013, we set out to confirm the detection. We modified our search strategy to specifically look for the 3.24-day signal by observing α Cen B "all night, every night." We again had help from The Planetary Society to purchase extra nights that allowed for this intense observing strategy. We coordinated our observing runs with the Geneva team; Yale graduate student Matt Giguere observed from Cerro Tololo while Xavier Dumusque was observing with HARPS on a neighboring peak in the foothills of the Chilean Andes. In May 2013, the stars were only 5" apart. On the clearest nights, we were able to obtain good quality data; on marginal nights, we began to see significant contamination from the other star.

So what did we find? We have examined all of our data from 2012 and 2013 and we still do not see evidence for the planet that was detected by the Geneva team. I am often asked if this null result is consistent with an analysis of the Geneva HARPS data by Hatzes (2013), which did not find a statistically significant 3.24-day signal. Our simulations suggest that we should have seen this signal in our data—but only at a marginal level.

α Cen A and B are now at their closest projected separation—less than 4". It is now no longer possible to use either CHIRON or HARPS to observe one star without significant contamination from the other star. In 2015, the two stars will begin pulling away from each other so that in a few years, we will be able to search again.

Both the Geneva team and my team will use the next few years to develop innovative instruments with the goal of reaching 10-centimeter-per-second precision—a gain over current precision by a factor of ten.

We are both aiming for the extreme precision needed to robustly detect earthmass planets orbiting at habitable-zone distances.



ABOVE *The stars Alpha Centauri A and B glow just above the atmospheric limb of Saturn, as seen by* Cassini *on May 17, 2008. Saturn's rings cast shadows on its upper atmosphere toward the bottom of the image.* Cassini *captured this view from a distance of about 534,000 kilometers (332,000 miles).*

LEFT *Debra Fischer at Cerro Tololo Inter-American Observatory (CTIO) in Chile. The middle dome houses the 1.5-meter telescope that Debra and her team have used to hunt for planets around Alpha Centauri.*

Image: NASA/JPL/Space Science Institute

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

Breaking Sisyphus' Curse

Pushing NASA's Budget Up Capitol Hill

I'M HARDLY THE first person to invoke Sisyphus when discussing the yearly effort to adequately fund planetary science and NASA, but it's hard not to feel a connection with the mythological Greek king who, under great strain, was condemned to an eternity of pushing an immense boulder uphill only to watch it tumble down upon reaching the peak.

ABOVE *Bill Nye holds thousands of petitions from Society members asking Congress to support planetary exploration and NASA.*

THE PEAK

Last year, Congress approved $127 million more for NASA's Planetary Science Division than originally requested by the White House. It didn't fully restore the cuts first enacted in 2013, but it was the second year in a row that funding had been added to the program, and we hoped that this unambiguous signal would prevent the White House from attempting cuts again.

THE TUMBLE

This past March, our boulder tumbled down with the release of President Obama's 2015 NASA budget request. It proposed cuts to nearly every science division, including planetary science, and cut funding to NASA as a whole. Operating funds for the *Opportunity* rover and the *Lunar Reconnaissance Orbiter* were missing, as was a new mission to explore Europa. Under this budget, fewer planetary missions would be in development by the end of the decade than at any point in the last 25 years. The boulder had tumbled far.

PUSHING UPHILL

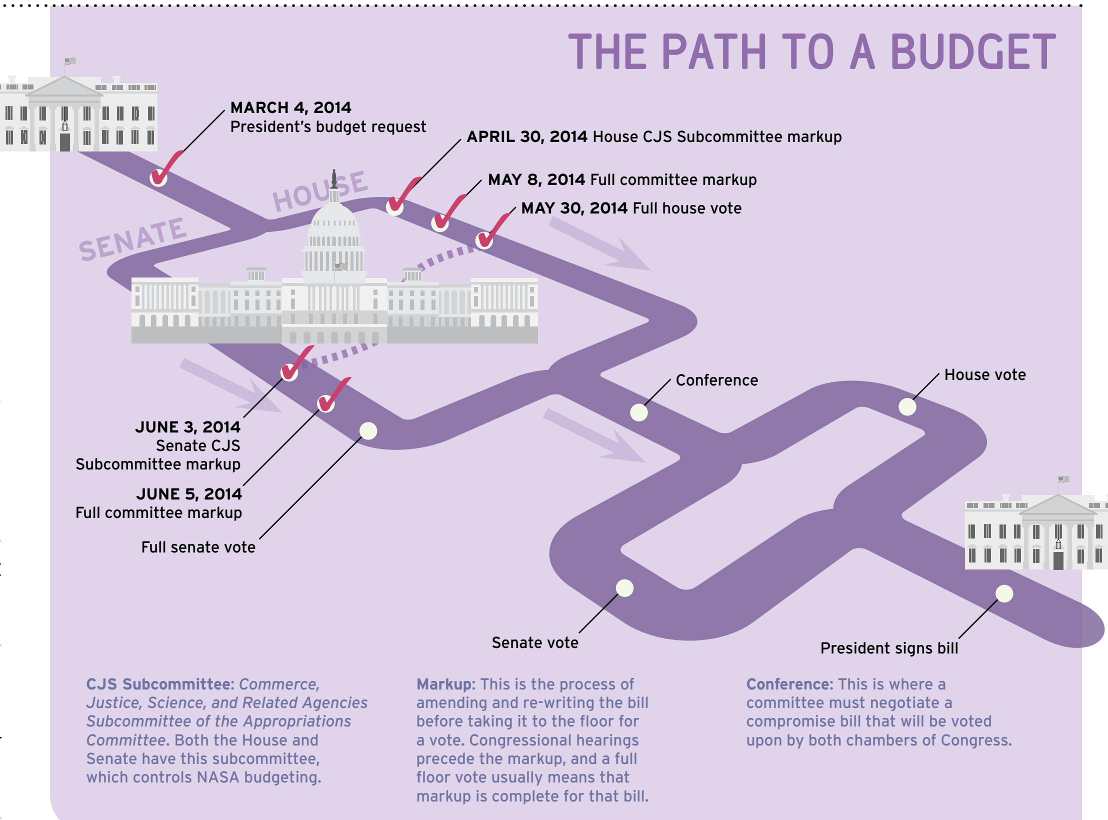
So we began the push again. We e-mailed our Members with a call-to-action just days after the president's budget was released. Physical petitions arrived in the mail shortly after. Within a week we generated over 15,000 messages to Congress; by the end of April, over 28,000.

The Society has made four trips to Washington, D.C. since March to meet with key congressional staff and to hand-deliver your petitions. Bill Nye and I met with senators and representatives to push planetary exploration and NASA, particularly a mission to Europa (Bill summarizes this visit at **bit.ly/1ujoum9**). We were able to point to the tens of thousands of letters from you, our Members, as proof of the great public interest and support for these scientific endeavors.

The House of Representatives responded first and responded well. Not only did they reverse the cuts to NASA, they actually increased NASA's budget to $17.9 billion, nearly $435 million more than the President's request. A good portion of this increase was directed toward NASA's science programs, which allowed for a fantastic $1.45 billion for planetary science–just shy of our long-stated goal of $1.5 billion per year for the program. On May 30, the full House passed this increase to NASA.

Then, in early June, the Senate released details of its draft NASA budget. The good news was that the Senate followed the House's lead in increasing NASA's top-line to $17.9 billion. The bad news is that planetary science saw only a minimal increase. As of July, the Senate has yet to

Photo: The Planetary Society



Graphic: Casey Dreier/Loren A. Roberts

pass its bill due to unrelated election-year politics.

THE COMING PEAK

Once the Senate passes a budget, they will work out their differences with the House. The compromise bill will then get sent back to each chamber of Congress for one more vote, hopefully before September 30, the last day of the federal fiscal year. We are working hard to ensure that the House's version of planetary funding makes it into the compromise bill, but either way there will be an increase over the President's request.

BREAKING THROUGH

This is the third year in a row that the White House has tried to cut planetary science. It can be frustrating to retread the same ground, the same arguments, and the same battles. But what gives me strength (and I hope you as well) is that, for all the solidarity we feel with Sisyphus, we are not condemned to his fate. Each year the fall has been less and the response from the public and Congress has been stronger.

In the meantime we continue the push. Albert Camus argued that the struggle itself was enough for Sisyphus. It was only during the brief period of walking down from the cursed peak to once again face the boulder that he was truly conscious and aware. And in that moment, he could reflect upon himself.

We, too, can take the brief intervals between budget seasons to truly appreciate why we work to fund planetary exploration and NASA: *Curiosity* capturing a lonely, blue Martian sunset; *Cassini* revealing the delicate reflection of ringlight off the dark side of Saturn; and the possibility of soaring through the plumes of Europa. The promise of the future allows us to break through Sisyphus' curse. Unlike him, we have the power to alter that hill so we don't tumble again.

DIFFERING PRIORITIES: THREE BUDGETS FOR NASA

in millions of dollars

	2014 budget as passed by Congress	2015 President's budget request	2015 budget as passed by the House of Representatives	2015 budget as proposed by the Senate
NASA	$17,647	$17,461	$17,896	$17,900
All Science	$5,151	$4,972	$5,193	$5,200
Planetary	$1,345	$1,280	$1,450	$1,301
Europa	$80	$15	$100	$0
Astrophysics	$668	$607	$680	$708
Stratospheric Observatory for Infrared Astronomy (SOFIA)	$87	$12	$70	$87
Space Technology Directorate	$576	$705	$620	$580
Space Launch System	$1,600	$1,380	$1,600	$1,700
Commercial Crew	$696	$848	$785	$805

All numbers in millions of dollars. Note: The Senate does not specify Europa funding, but cuts the increased level requested by NASA for Europa studies. The Senate would also impose strict new accounting requirements on the Commercial Crew program, which could delay the program by up to a year. Sources: NASA FY 2015 President's Budget Request Summary, Committee Report on House CJS Bill (HR4460), Committee Report on Senate CJS Bill (S2437).

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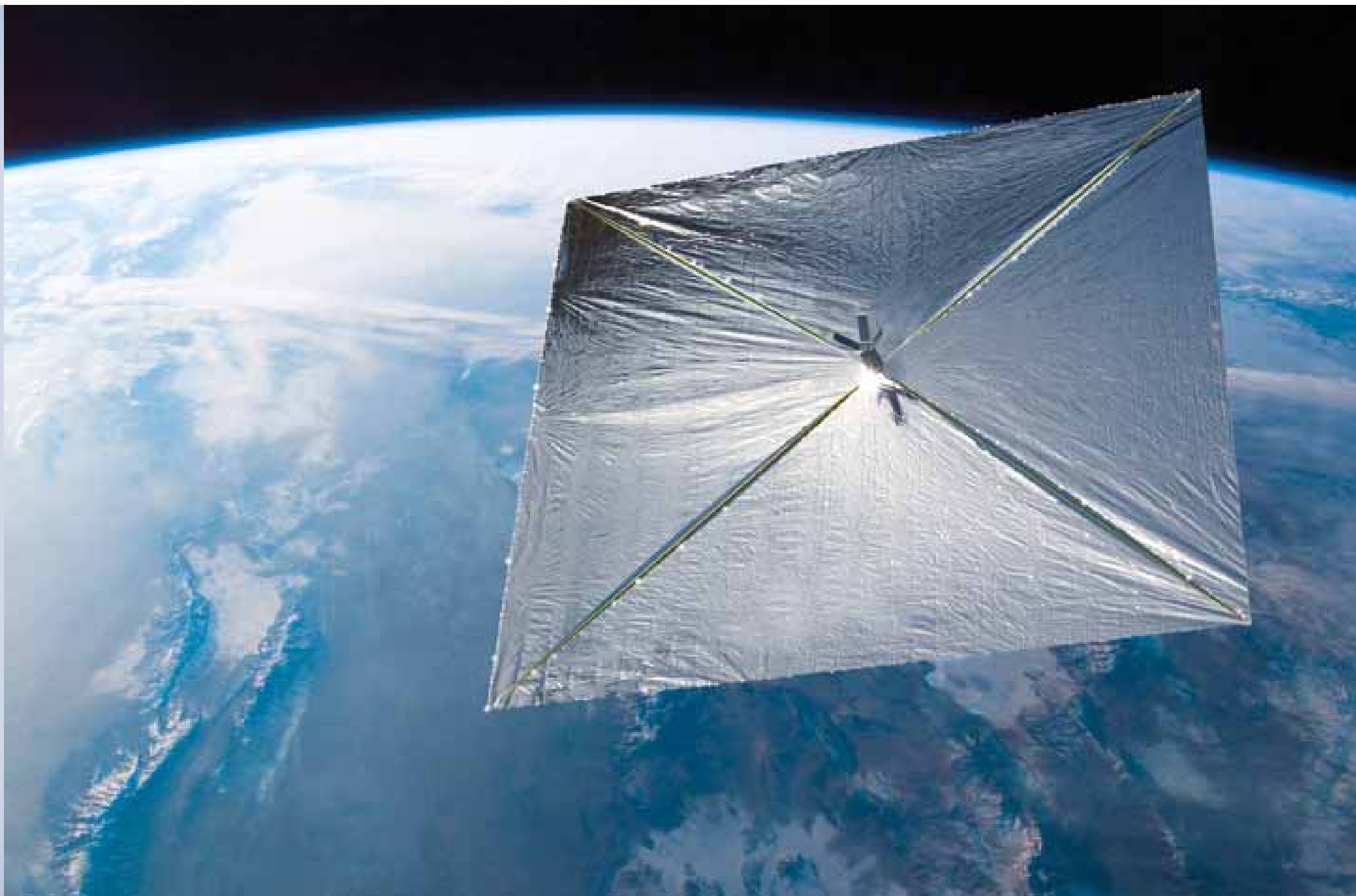

Illustration: Rick Sternbach for The Planetary Society

Thank You!

To all of our Members and Donors who've supported us as we built *LightSail*, we want to express our heartfelt appreciation. Thank you for your financial contributions, your patience, and your partnership as we work together to advance the technology of solar sailing.

When *LightSail* launches in 2016, you'll be able to look up and see another light sparkling in the night sky. It will be our spacecraft, in orbit around Earth!

You'll have every reason to be proud. You made it possible.

Sincerely,
The Planetary Society