The Planetary Society

THE PLANETARY REPORT

MARCH EQUINOX 2013
VOLUME 33, NUMBER 1
planetary.org

THE LURE OF EUROPA

A NEW MISSION COULD TAKE US BACK

OTHERWORLDLY WEATHER ✻ FIGHTING FOR EXPLORATION ✻ PLANETS AT ALPHA CENTAURI?

I took this image of an evening sky on September 18, 2010 with my Panasonic/Lumix DMC-FZ18 digital camera while driving from Saguaro National Park to Tucson, Arizona. I took this trip with Fred, a very good friend and travel companion. All I can remember are the striking colors of the sky contrasting with the buzzing cars and traffic lights. It looked unreal, almost out of this world. Every year, Fred and I take a couple of trips together, to locations all over the world. Each time, Fred brings an issue of *The Planetary Report* with him, knowing of my passion for anything to do with the universe and science.

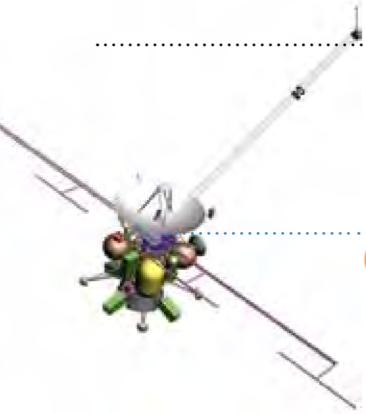
I became a member of The Planetary Society in March 2012, soon after taking an Aurora Borealis trip to Alaska with Betchart Expeditions that truly lived up to my expectations. I had the opportunity to see the magnificent aurora over the skies in Fairbanks, to experience the "buzz" of dogsledding, and to meet a few of the great people who form The Planetary Society—and who contributed to my enthusiasm for anything sky-like. —*Lenka Panackova, Amesbury, United Kingdom*

I took this photograph in December 2003 while encamped at the LaPaz Icefield of Antarctica, where I was part of the Antarctic Search for Meteorites (ANSMET), an annual expedition funded by the U.S. government. I joined ANSMET, funded by the National Science Foundation's Artists and Writers Program in Antarctica, in order to chronicle the expedition for a book I wrote titled *The Fallen Sky: An Intimate History of Shooting Stars*. It was thrilling to discover meteorites.

This photograph captures, for me, the weird sense of scale, scope, and isolation one can feel in an extreme environment. One of my expedition co-members, planetary scientist Andrew Dombard, is slowly walking back to the tents that were our temporary home at LaPaz—a place remembered by ANSMET members as the coldest, windiest place anyone had ever been while looking for rocks from space. I took the photo with a tiny Nikon film camera, long since lost to the ages (and the bins of a Goodwill store somewhere). —*Christopher Cokinos, Tucson, Arizona*

Planetary Society Members are united in their love of space exploration—which has its origins in Earth's skies. Thank you for sharing your views with us! To see more, go to **MYSKY.PLANETARY.ORG**.

WANT TO SHARE YOUR SPACE IMAGE? Send us an e-mail with a jpeg (less than 5 MB) attachment of your image to *planetaryreport@planetary.org*. Please use the subject line "MySky" and include a short caption (such as where you took the image and, if appropriate, with what equipment) and credit line for the image. Please include just one MySky image per submission. Also, be sure to include your name, contact information, and membership number (it's on your membership card and on the mailing label of your magazine). We'd also love to receive a picture of you and to learn more about what is most important to you about being a Planetary Society Member. Questions? E-mail *planetaryreport@planetary.org* or call (626) 793-5100, extension 218.



THE PLANETARY SOCIETY

ON THE COVER: With its probable ocean of liquid water and its geologic dynamism, Jupiter's moon Europa is one of the most promising places in our solar system to search for signs of life. Scientists continue to use *Galileo* data, as exemplified by these enhanced color views (in various resolutions) of Europa's fractured and mottled surface, to refine our view. Only a new mission, however, can bring us fresh, close-up views of this tantalizing world. Now on NASA's drawing table, the Europa Clipper could do that—and more. *Image: University of Arizona/NASA/JPL*

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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.

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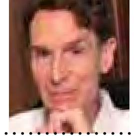


BILL NYE *is chief executive officer of The Planetary Society.*

Bringing Out the Best in Us

Our Fight to Preserve Exploration

THERE IS GOOD NEWS on Mars; actually, it's good news here on Earth: After months of cries from the scientific community, members of The Planetary Society, and the larger public, NASA finally announced the next major mission to Mars, slated to fly in 2020 and built from spare parts left over from the *Curiosity* rover. The year 2020 may sound like a long way off, but in the space business, it's coming right up.

Coming up sooner, the *Maven* spacecraft will get aloft late this year. It's going to sniff the Martian atmosphere to exquisite precision. NASA also will send *InSight* to land on Mars in 2018. This lander, equipped with a seismometer, will study the geologic evolution of Mars. The combined European/Russian Exo-Mars programme (*sic*) is slated to launch two spacecraft, one in 2016 and one in 2018, to search for signs of past or present Martian life.

Whatever task ends up being assigned to each of the spacecraft, scientists hope they will be coordinated into a scheme to carefully find good places to gather and store, or cache, the samples. Then, a subsequent mission would carefully take the rock samples off the caching spacecraft, pack them securely inside itself, and launch them up to an orbit around Mars suited to having another spacecraft bring them back here for scientists to study up close. Journeys like this are expensive, but just think of what we might discover. The next place to look for life? The secret to the loss of nearly all of Mars' water? The mind boggles. It takes extraordinary discipline and planning, but that's the business planetary explorers are in.

Right now, no matter where you are on Earth, the affairs of the U.S. Congress affect your view of the cosmos. NASA spends a great deal more money in space (or on space exploration) than all the other space agencies around the world combined. When the United States pulls out of a mission to Mars, space explorers around the world are affected. When the U.S. Congress delays approving the budget for the next fiscal year, explorers around the world hold their collective breath. Read a little further in this issue to find Casey Dreier's report on how budget cuts have already affected future missions of exploration.

After my first trip to Congress in the new year, I was invited right back the following week to attend a meeting of the newly formed "bipartisan science caucus." Fellow board member Neil deGrasse Tyson and I made our strong pitch that investments in science education, basic scientific research, and especially space exploration are vital to the economy of any country—in this case, the United States. We'll see if history becomes redirected in some way, after they mull over what we showed them.

The *New York Times* contacted me recently, asking, "What should be the response to rocket-building activities in Iran, South Korea, and China?" It struck me as a question from a bygone era. At The Planetary Society, our response is, "Let's work together for the betterment of humankind." There is no future for any of us in trying to suppress space exploration. Space inspires citizens in every country.

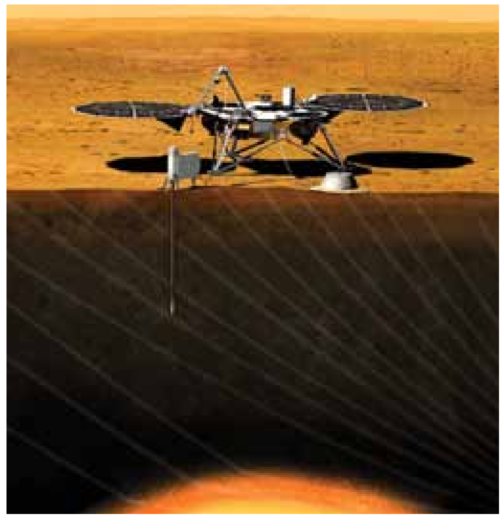
We all use space now for weather forecasting, communication, and security. Having other agencies flying may compel us to share in the adventure and economic advantages of space exploration. If space is seen as the ultimate high ground for military endeavors, we are all in enormous trouble.

People who study the history of space have expressed deep concern about the cost of competing rather than cooperating with

China in space. If nothing else, low Earth orbit has become cluttered—dangerously so. International cooperation is vital with regard to space debris. The cost of missions to distant worlds can be lowered tremendously through cooperation. Since its beginning in 1980, The Planetary Society has supported international cooperation.

NASA is still the world leader in space, and U.S. investment in space is vital to both human and robotic missions. We at The Planetary Society advocate strongly for planetary science, especially the exploration of other planets and moons in our solar system. As I write, we await the release of NASA's 2014 budget. We remain hopeful that funding will be restored for planetary exploration, but we also will prepare for the next step in our relentless efforts to "Save Our Science." Expect to hear more from us soon.

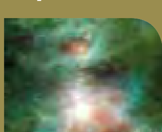
Space brings out the best in us. People the world around want to know what's over the next horizon; they, too, want to know: Where did we come from? And are we alone in the cosmos? Think about how different the world would be without the discoveries of Copernicus or Galileo. Perhaps an upcoming discovery will change the way each of us thinks of our place among the stars, our place in space.



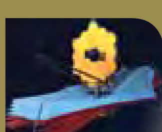
ABOVE *NASA's two upcoming Mars missions,* InSight *(left) and* Maven *(right).* Maven *will have special instruments to analyze the atmosphere of Mars, while* InSight *will be built to take core samples and test them.*

Maven illustration & *InSight* photo: NASA

If you've missed *Planetary Radio* lately, here are some recent highlights:



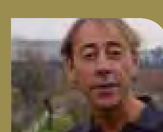
Society experts review the challenges of 2012 and look forward to 2013.



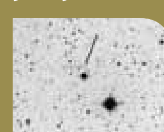
The James Webb Space Telescope with Jason Kalirai and Dean C. Hines.

Alison Peck and Al Wooten tell us about ALMA in Chile's Atacama desert.

Debra Fischer hunts exoplanets, and has set her sights on Alpha Centauri.



Jaime Nomen of Spain's La Sagra Observatory talks about 2012 DA14.

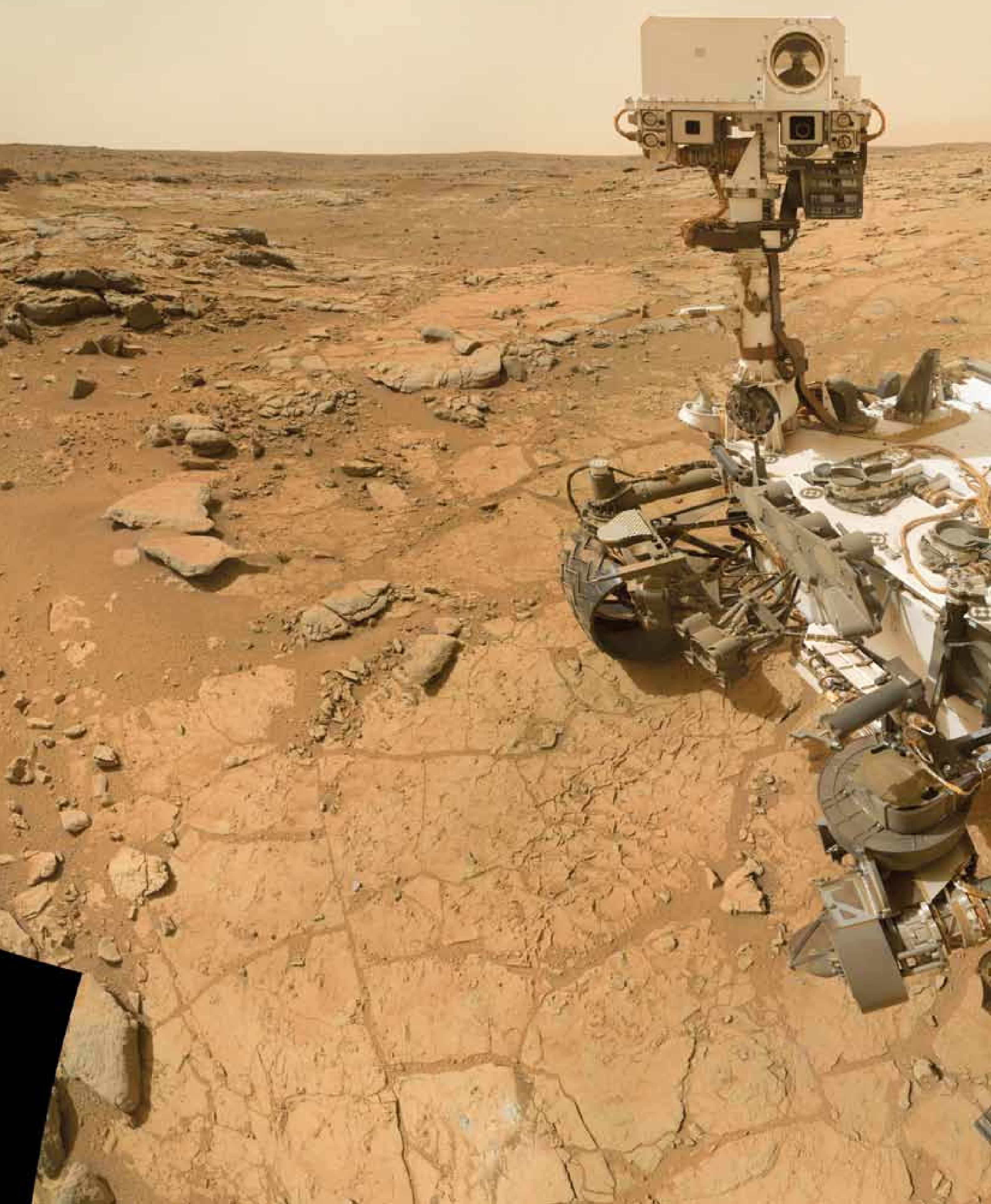


Tracking comet 2012 DA14 with an all-star cast of scientists.

Chris Lewicki with Planetary Resources finds and delivers asteroids!

SETI researcher Andrew Siemion talks about the odds.

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



Credit: NASA/JPL/Malin Space Science Systems/Ed Truthan

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.

Wish You Were Here!

BEAUTIFUL MARS

ONE OF *CURIOSITY*'S COLOR CAMERAS is mounted on the end of its robotic arm. The Mars Hand Lens Imager, or MAHLI, is purpose-built for close-up examination of Martian rocks and soils. Its ability to focus on targets at any distance means that it can also shoot beautiful photos of almost anything *Curiosity*'s controllers desire—including the rover itself. On sol 177 (February 3, 2013), *Curiosity* stretched out its arm and turned MAHLI toward itself, capturing 64 images that amateur image processor Ed Truthan assembled into this mosaic. In front of *Curiosity*'s wheels is the site, named "John Klein," where the rover drilled into Martian rock for the first time. You'll find more information about how this picture was made at **planetary.org/ss331**.

—*Emily Stewart Lakdawalla*

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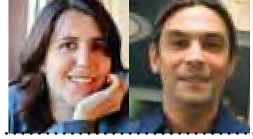


ALYSSA RHODEN *is a NASA Postdoctoral Program fellow at NASA's Goddard Space Flight Center.* **ROBERT PAPPALARDO** *is a Senior Research Scientist at the Jet Propulsion Laboratory-California Institute of Technology.*

Turning the Tides

Setting Sail With the Europa Clipper

IN THE LATE 1990s, the *Galileo* spacecraft reached Jupiter, where it performed about a dozen flybys of Europa, the smallest of Jupiter's four large moons. *Galileo*'s magnetometer detected an induced magnetic field, which meant that a conducting fluid exists at shallow depths within Europa's interior. Combined with measurements of Europa's surface composition and internal structure, these observations made an indirect but very

RIGHT *Many of the ridges that crisscross Europa's face are actually "double" ridges. Androgeous Linea, shown here in exaggerated color, is a prominent double ridge. Tides raised by Jupiter shape the surface of Europa.*

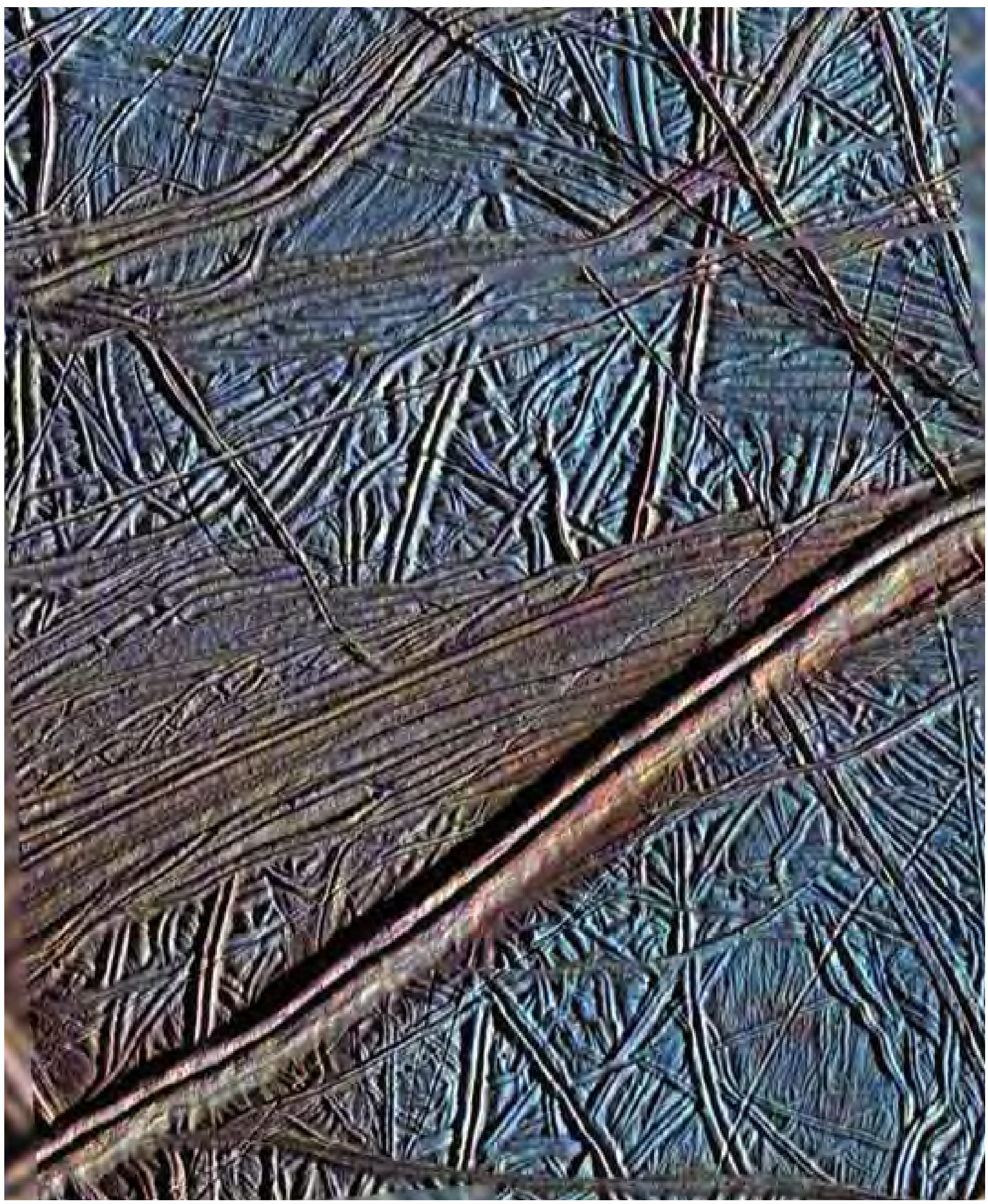


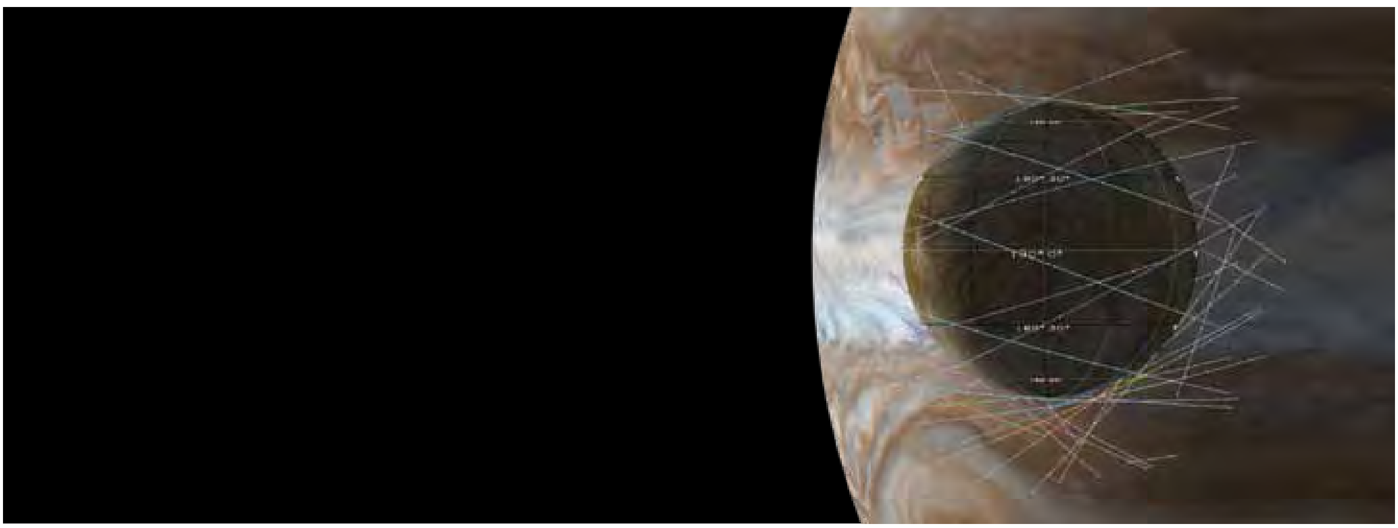
Image: NASA/JPL, processed by Paul Schenk, Lunar and Planetary Institute convincing case that liquid water persists within this outer solar system moon. In fact, researchers believe that there may be twice as much liquid water within Europa as there is here on Earth. The implications for Europa's habitability became obvious and compelling to scientists and planetary enthusiasts around the world. Now, more than a dozen years later, those of us who were inspired by those early findings still await the chance to revisit Europa and the rest of the Jovian system.

Europa participates in the solar system's only known "Laplace" resonance, a 2:1 resonance with neighboring moons Io and Ganymede. What this means is that every time Europa completes one orbit of Jupiter, it aligns with Io, and every second orbit, it aligns with Ganymede. Gravitational interactions among these resonant moons keep their orbits slightly elliptical. This means that throughout each Europan orbit, the distance to and direction relative to Jupiter change, raising tidal bulges that constantly modify Europa's global shape. Europa's rich and diverse geologic record and its probable subsurface liquid water ocean both result from strong tides that heat the interior and flex the surface to its breaking point. A similar process operates on Io, the closest of Jupiter's large moons, and leads to frictional heating of its rocky interior, generating the most active volcanism anywhere in the solar system. The bright, sulfurous eruptions of Io can even be observed using Earth-based telescopes.

WHAT WE KNOW—AND DON'T KNOW—ABOUT EUROPA

Based largely on the data collected by the *Galileo* spacecraft, researchers have been able to deduce a great deal about Europa's surface and interior. By analyzing the shapes and distributions of fractures and ridges that likely formed in response to tidal stress, we have learned that Europa's rotation state is complex. Europa's fractures and ridges suggest "non-synchronous rotation" (a slow eastward drift of the ice shell relative to the direction of Jupiter), a small "obliquity" (tilt of the spin axis) that may result in additional tidal heating, and even ancient "polar wander" (motion of the entire ice shell compared to the spin axis).

Europa's chaotic terrains—regions of disrupted surface ice—display many features similar to those in Antarctica, which suggests that they are surface manifestations of shallow subsurface lakes. If that is true, these are possible abodes for life at Europa. Europa's chaotic regions are commonly reddish in color, with infrared signatures that are suggestive of salts, perhaps derived from the ocean below.



ABOVE *Skillful mission design would enable the Europa Clipper to obtain nearly global coverage of the Jovian moon over the course of 32 flybys.*

Graphic: Brent Buffington, JPL

32

orbits of Jupiter, each time swooping within 100 kilometers of Europa. With each pass, the spacecraft would image strips of Europa's surface with a stereo camera.

Unfortunately, the limitations of the *Galileo* data set make it impossible to determine some of the most important characteristics of Europa. Global imagery is unavailable at sufficient resolution for comprehensive geological mapping of Europa, and topographic information is sparse and coarse. Compositional data are ambiguous, evidence for an ocean is indirect, and, despite our expectations, the presence of organic molecules has not been confirmed.

We now know that many of the processes at Europa are not unique. The ongoing *Cassini* mission to the Saturnian system has revealed that tidal interactions may also explain the behavior of Europa's tiny cousin, Enceladus. Geyser-like eruptions from Enceladus' south polar region may correlate with tidal stresses that open and close long fissures called the Tiger Stripes. Our knowledge of Europa has enhanced our ability to interpret observations of Enceladus, and vice versa. The magnitude and level of detail of the data being collected by *Cassini*, however, also highlight just how little information there is about Europa.

CHALLENGES TO LEARNING MORE

The scientific lure of Europa is strong, but missions to the outer solar system are expensive. Scientists and engineers have been hard at work to determine how we can best go about exploring Europa, especially in this era of budgetary belt-tightening. NASA recently charged the Jet Propulsion Laboratory, working closely with the Johns Hopkins Applied Physics Laboratory, to consider all options for exploring Europa.

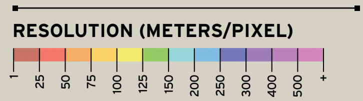
Over the past decade, the leading contender for a dedicated Europa mission was a well-equipped orbiter. Similar to *Mars Reconnaissance Orbiter* at the Red Planet or the *MESSENGER* spacecraft at Mercury, an orbiting spacecraft could turn a bevy of remote sensing instruments toward the surface below. It could image the surface, acquire remote compositional measurements, and scout out the best places to send a future lander. A unique challenge to a spacecraft in orbit, however, comes from Europa's intense radiation environment, which can render ordinary unshielded electronics useless.

Jupiter's magnetic field is the most powerful in the solar system, accelerating particles to near-relativistic velocities. A spacecraft that orbits Europa would be constantly bathed in this radiation, so it would need to be constructed from highly radiation-tolerant parts and carry significant amounts of shielding. What's more, the nearly two years of celestial billiards required to transition a spacecraft from Jupiter orbit to Europa orbit means that a large dose of radiation would accumulate even before arrival at Europa. Much of the mission's precious radiation allocation would be spent in transit, shortening its lifetime at the moon.

A more economical approach is that used by the *Cassini* spacecraft at Saturn, which has succeeded in making spectacular discoveries at Enceladus. Outstanding science can be achieved by going into orbit about the parent planet and making numerous flybys of a moon. At Jupiter, this approach also has the advantage that a spacecraft can dip briefly into the high-radiation region near Europa, gather lots of data quickly, and then zip off

ALYSSA (SARID) RHODEN*'s early experiences studying Europa motivated her to pursue a PhD in Earth and Planetary Science. She is now a NASA Postdoctoral Program fellow at NASA's Goddard Space Flight Center, studying the geophysics of icy satellites, dwarf planets, and asteroids.* **ROBERT T. PAPPALARDO** *researches processes that shape the icy satellites of the outer solar system, with an emphasis on Europa and its probable subsurface ocean. He is a Senior Research Scientist as well as the Study Scientist for Europa mission concepts at NASA's JPL/Caltech.*

A PORTION OF THIS WORK WAS CARRIED OUT AT THE JET PROPULSION LABORATORY-CALIFORNIA INSTITUTE OF TECHNOLOGY UNDER A CONTRACT WITH THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.



LEFT *With each close pass, the Europa Clipper would image strips of the satellite's icy surface with a stereo camera, obtaining three-dimensional pictures at resolutions better than 50 meters per pixel. Each of these rainbow-colored swaths represents the stereo imaging coverage of one sunlit flyby.*

Graphic: Erick Sturm, JPL

to broadcast the precious data back to Earth from a safer distance. This is the basis for a new, low-cost mission concept to explore Europa—the Europa Clipper.

A EUROPA CLIPPER MISSION

The Europa Clipper would make at least 32 orbits of Jupiter, each time swooping within 100 kilometers (60 miles) of Europa. With each pass, the spacecraft would image strips of Europa's icy surface with a stereo camera, capturing the three-dimensional scenery at better than 50 meters per pixel. The spacecraft would also snap images at a stunning half-meter per pixel—sufficient to see large boulders (or even Arthur C. Clarke's monoliths, if they are there!)—to aid the design of a future lander mission to Europa. At the same time, spectra of the surface would be captured in infrared light, in search of traces of salts and organic compounds on the surface that may have originated in Europa's ocean.

By Earth standards, Europa has no atmosphere; however, molecules are continually knocked off the surface by radiation. A spacecraft whizzing by could "sniff" this pseudo-atmosphere with a mass spectrometer to understand its composition. Thus, the Europa Clipper could collect complementary compositional information from both Europa's surface and its tenuous atmosphere.

Ice-penetrating radar is envisioned as a key part of the Clipper's payload. Ice is essentially transparent to radar waves that are several meters in wavelength, but liquid water is not. A spacecraft could "ping" the icy surface with radar, and the returned signal would tell of its travel through the ice and its reflection by any water lying beneath. In this way, a radar instrument could map out the plumbing within Europa's ice shell, identifying shallow lakes inside chaotic zones and spying on the ocean beneath.

Gravity and magnetic measurements are additional ways that the Europa Clipper could probe a hidden ocean. As Europa executes its elliptical orbit around Jupiter, every 3.55 Earth days, its ice shell alternately stretches and contracts as the ice and probable ocean beneath it respond to Jupiter's gravitational pull. A thick ocean would generate 30-meter tides, but without an ocean, tides would reach only about 1 meter. Tidal flexing could be detected by measuring the gravitational tug of Europa on the spacecraft as it flies past the moon. Repeating the measurement over many flybys, performed at different times in Europa's orbit, would reveal Europa's changing shape and at last confirm the presence of the suspected ocean, if it indeed exists. In addition, measuring magnetic variations throughout Europa's orbit could independently determine the thickness and salinity of the ocean.

The Europa Clipper is estimated to cost about $2 billion, less than half the estimate for a similarly equipped Europa orbiter. The mission concept has received high praise from the scientific community, but the project is awaiting NASA approval in order

"Exploring the outer solar system takes much patience and perseverance. It also takes forward thinking and planning for the next generation."

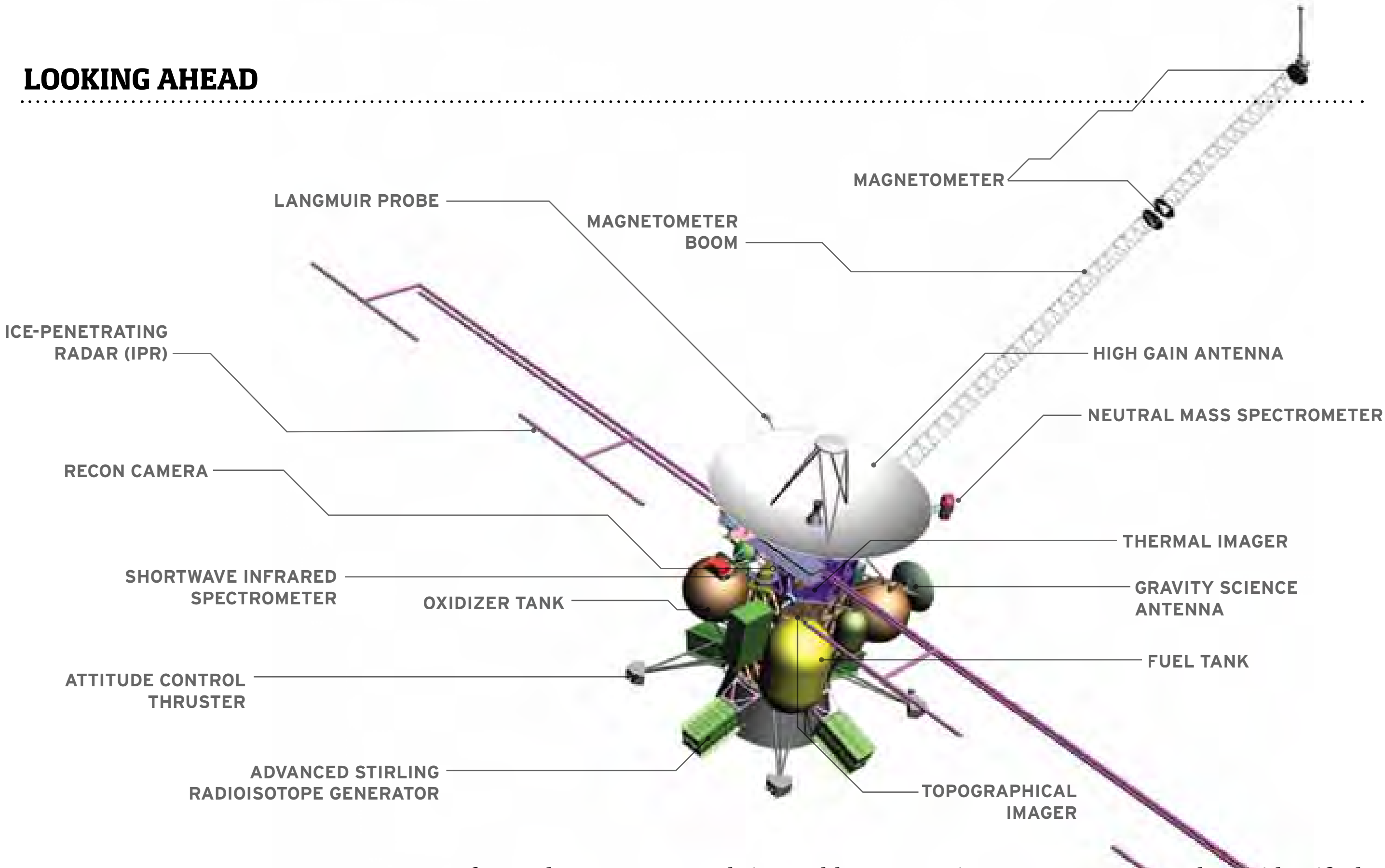


Illustration: APL/JPL-Caltech

ABOVE *NASA's current concept for the Europa Clipper spacecraft.*

to move forward. Once approved, it would take about six years to fully develop, build, and launch the Europa Clipper, then about six more years before it would arrive in Jupiter orbit. This means that if NASA gives a go-ahead in 2015, which is probably the soonest that Congress could approve funds to cover the cost of the mission, the Clipper could launch around 2021 and arrive at Jupiter around 2027.

Exploring the outer solar system takes much patience and perseverance. It also takes forward thinking and planning for the next generation. Already, scientists and engineers are considering the possibilities for a lander mission, which could follow up on the discoveries of a mission like the Europa Clipper. A Europa lander could set down softly on a smooth spot on the surface, perhaps on the reddish ice of a chaotic zone where the Europa Clipper's radar showed promising evidence of subsurface water. Scooping up the reddish icy particles, it could search directly for organic materials, or even life.

Europa is among the most geologically dynamic and astrobiologically promising bodies in our solar system. Simple processes of gravitational interaction appear to have yielded a liquid water ocean and widespread tectonism. At Europa, we have identified ways of maintaining geologic activity and creating a potentially habitable world entirely different from those in the inner solar system.

By finding the locations of sub-ice lakes, probing the composition of the suspected ocean, and assessing just how geologically active Europa is today, the Europa Clipper would provide a wealth of new data that would enable scientists to determine the detailed structure of the moon's ice shell and interior. In addition, valuable information obtained regarding tidally driven geological processes will aid us in interpreting observations of Enceladus and other icy ocean bodies. In these ways, we will learn how life might exist and thrive in unexpected places, in this solar system and beyond.

As the only creatures that we know of with the ability to appreciate and understand the natural world, including worlds beyond Earth, we have not only an option but also an obligation to explore and discover the richness of the solar system, and to permit ourselves to be dazzled by it. Europa is as compelling a destination as we could hope for, and we have identified, in the Europa Clipper, the mission that can get us there. The sooner we get started, the sooner we will arrive.

To learn more, visit
europa.seti.org
and
bit.ly/europamissions

ON THE WEB

Q According to many articles on the subject, planets likely to be considered as potential candidates for life-sustaining possibilities need to be within a star's "Goldilocks" (habitable) zone and be roughly the same size as Earth. I understand the Goldilocks issue, but why is Earth size such an important criterion? *—Ken Boyce, Downers Grove, Illinois*

A It is a good bet that the important conditions for habitability on planets around other stars include what we have here on Earth: an atmosphere, a surface laden with oceans of liquid water, plate tectonics that are part of a positive feedback loop that stabilizes the carbon concentrations in the atmosphere (thus maintaining a stable greenhouse), and magnetic fields to deflect the solar wind.

Planets that are much smaller than Earth cannot maintain a gravitational hold on their atmospheres—Mars is a good example of this. They also cool more quickly and, as their liquid cores solidify, the process can shut down any protective global magnetic fields they have. This presents a second problem for a planet with weak gravity: its host star is releasing fast-moving charged particles (a "solar wind") that can accelerate the erosion of its atmosphere.

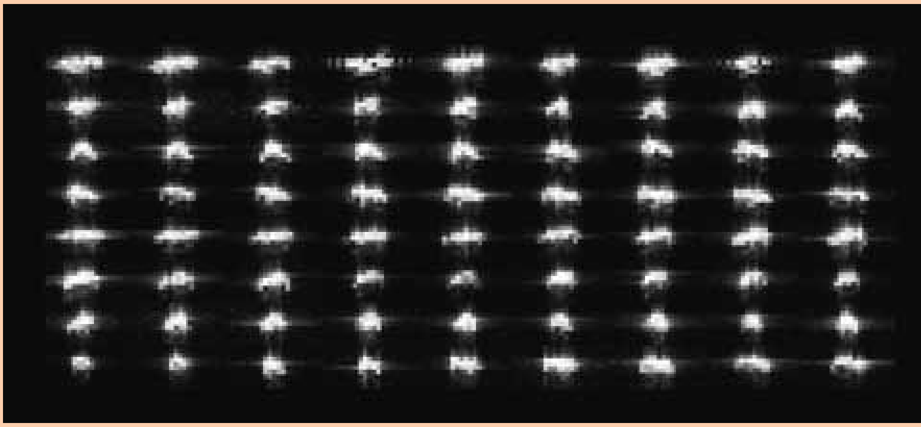
Planets that are much larger than Earth may be problematic as well. These planets can acquire massive atmospheres with crushing surface pressures. It is less clear what the upper boundary is for planet mass. Planets only twice as massive as Earth may well be habitable worlds. Our knowledge about planets that are several times Earth's mass is extremely limited, however, because we do not have any good examples in our own solar system.

Our assessment regarding a planet's habitability is based on our understanding of what makes Earth such a fertile world. One of the great questions that I hope will be answered in the next decade is how life emerges from an organic soup. An Earth-centric view often bothers people who suspect that scientists are geeks with limited imaginations. In fact, we're playing the odds in the race to find inhabited worlds, and we're starting with what we know (but, we hope, keeping an open mind). Let other scientists take the long shots ... I'm going for 100 Earth-like planets!

—Debra Fischer, Yale University

FACTINOS

Asteroid Imaging



ABOVE *NASA's 72-frame animation of 2012 DA14 as it headed back into the solar system on the night of February 15/16, 2013.*

ON THE NIGHT OF FEBRUARY 15/16, 2013, NASA scientists used the 70-meter Deep Space Network antenna at Goldstone, California to capture a sequence of radar images of asteroid 2012 DA14 as it sped away from Earth. The researchers then compiled the individual images into a 72-frame animation of 2012 DA14's rotation. The 72 images show the asteroid undergoing roughly one full rotation over a time span of close to eight hours. The resolution of each of these frames is four meters per pixel.

For more detailed information on 2012 DA14's flyby and a look at the movie, go to bit.ly/tpr1301.

Images: NASA/JPL-Caltech

CASEY DREIER *is advocacy and outreach strategist for The Planetary Society.*

An Ode to Discovery

IT COULD HAVE MADE A GREAT book cover: a nuclear-powered robot floats on a shining methane sea toward a distant shore as a massive, ringed planet dominates the murky yellow sky. This scene, however fanciful, wasn't the product of pure fantasy. The Titan Mare Explorer (TiME) was real, or at least as real as any other of the 28 mission proposals vying for selection by NASA's Discovery program in 2010.

BELOW *In this illustration, the Titan Mare Explorer, a proposed Discovery mission, floats on a methane lake on Saturn's largest moon.*

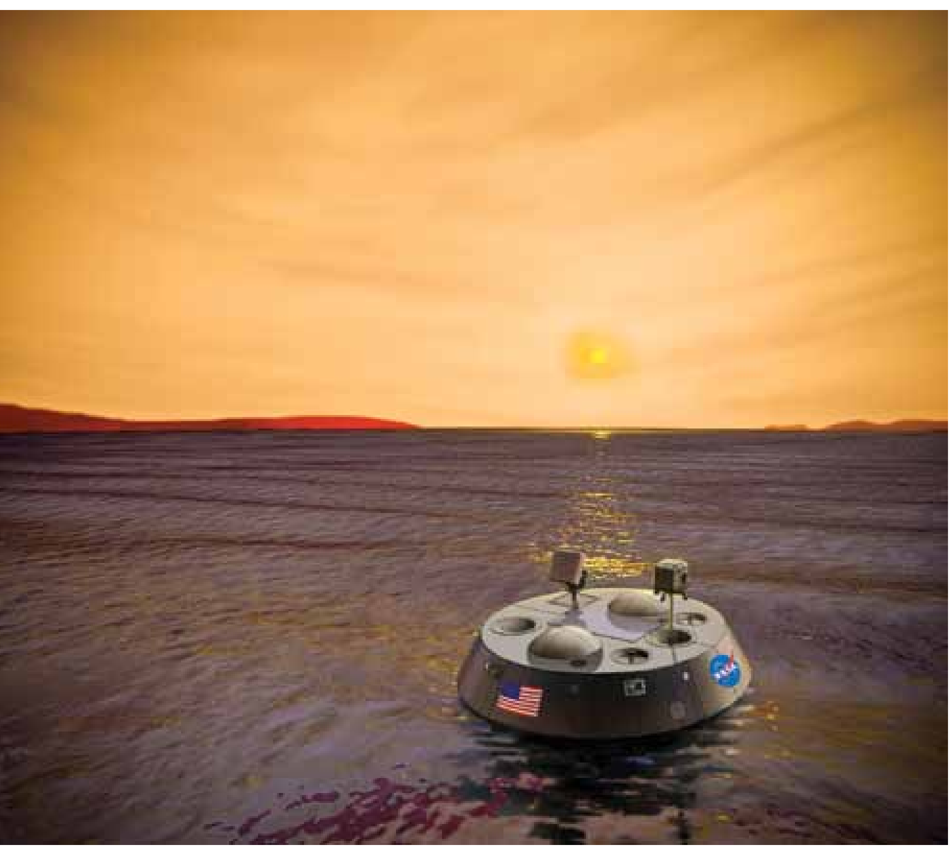


Illustration: NASA

Discovery is a program managed by NASA's Planetary Science Division and exists to fund small, focused, robotic missions in the solar system. Teams of scientists compete for funding every few years, working closely with academic institutions and aerospace companies to create painstakingly detailed mission concepts. These missions are capped at a fixed cost—currently $425 million—and must have a strong scientific rationale and meet basic engineering guidelines, but otherwise their destinations and goals are anything a motivated and creative scientist (or her team) can dream up. A single scientist leads the team in the role of principal investigator.

NASA's planetary missions did not always work this way. Back in what is often called the golden age of planetary science, missions like *Viking*, *Pioneer*, *Voyager*, and *Galileo* were announced by NASA headquarters after an opaque decision-making process. Missions tended to be large and expensive. This led to imbalances in the overall program, as one or two major missions would suck up resources at the expense of others. Decades might pass before a scientific goal would be reached.

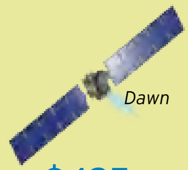
This system changed after the Discovery program began in the early 1990s. Modeled after other successful competitive programs like Explorer in astrophysics, Discovery would increase the frequency of missions by keeping costs low. The first mission in the Discovery program, *Near-Earth Asteroid Rendezvous (NEAR)*, became the first spacecraft to orbit an asteroid. It was followed shortly by *Pathfinder*, the first successful lander on Mars in nearly 20 years. To date, there have been 11 missions; all but one, *CONTOUR*, were successful.

Discovery missions were popular and productive. In response, NASA expanded on the scientist-led, competed mission concept

FREQUENCY VERSUS COST

NASA has divided its missions by cost and scale, in order to get a handle on budget constraints. Unfortunately, this often pits worthy missions—especially the smaller ones—against each other.

SMALL
DISCOVERY MISSIONS



$425m
Recommended schedule:
launch every **24** months
Actual schedule:
launch every **50** months

MEDIUM
NEW FRONTIERS MISSIONS

$1,000m
Recommended schedule:
launch every **5** years
Actual schedule:
launch every **7** years

LARGE
FLAGSHIP MISSIONS

+$1,500m
Recommended schedule:
launch every **10** years
Actual schedule:
launch every **10** years

and in 2003 developed the New Frontiers program, which funds "mid-size" missions with a budget of $1 billion. Unlike Discovery, New Frontiers mission proposals must fulfill a specific goal from a list defined every 10 years by the scientific community. The latest New Frontiers mission, *OSIRIS-REx*, will return a sample of material from an asteroid and is currently in development.

In 2011, NASA announced that TiME had crossed its first hurdle. Among the 28 initial proposals, it was one of the three selected for additional study. A mission first called Geophysical Monitoring Station (GEMS), but later renamed Interior Exploration using Seismic Investigations (InSight), was the second; and Comet Hopper (CHopper), a nimble spacecraft that would make large, graceful jumps around the surface of a comet, was third. All three missions entered a final evaluation phase, where they faced intense scrutiny for engineering flaws, scientific return, and technical and budgetary risk. Only one would be selected.

The peculiarities of funding within NASA almost always stand in contrast to the recommendations of the scientific community and desires of the public. The Planetary Science Decadal Survey—the consensus report prepared for Congress and NASA that presents the science community's goals for planetary exploration in the coming decade—recommended that Discovery missions occur with "a regular, predictable, and preferably rapid" frequency of once every 24 months. The larger and more complex missions of New Frontiers were recommended to have a frequency of twice per decade.

President Barack Obama's budget request last year upended these recommendations. The proposed $309 million cut to the Planetary Science Division precludes rapidity or regularity. Discovery now limps along with a new mission opportunity every 50 months, and New Frontiers' frequency decreased to once every seven years.

TiME lost. So did CHopper. InSight will be the next Discovery mission, launching in 2016. Selecting only a single mission from these three was a sad necessity, though completely avoidable had better funding existed.

Normally, this would not be the end of the story. TiME would have been primed for resubmission to the next Discovery mission opportunity, had it occurred soon enough, but the unforgiving laws of orbital dynamics will prevent a direct line of sight to Earth after 2025, requiring an additional—and costly—companion orbiter to return data. With an Earth-to-Titan travel time of seven years on top of the four years required to build, test, and launch the spacecraft, the next Discovery mission selection would have to be made immediately in order to meet this deadline.

Discovery and New Frontiers missions are vibrant and productive components of NASA's solar system exploration program. Without them, the public faces a sharp decline in the number of new missions and new discoveries. Once again, we face a future of imbalance without the steady pace of our workhorse explorers. These creative, ambitious, and affordable missions are yet another victim of the continued lack of commitment to planetary exploration in the United States. Maybe one day a boat will sail the seas of Titan, but for now it remains only a dream, a compelling cover to a work of fiction.

BILL NYE ON THE CURRENT PROPOSED 2013 BUDGET:

"The priorities reflected in this budget would take us down the wrong path. Science is the part of NASA that's actually conducting interesting and scientifically important missions. Spacecraft sent to Mars, Saturn, Mercury, the Moon, comets, and asteroids have been making incredible discoveries, with more to come from recent launches to Jupiter, the Moon, and Mars. The country needs more of these robotic space exploration missions, not less."

Images: NASA

MICHAEL CARROLL *is a science journalist and astronomical artist who lives and works in Littleton, Colorado.*

ABOVE *Weather on Uranus has seen some dramatic changes since* Voyager*'s 1986 encounter, but limited observing time keeps scientists hungry for more data. In this artist's view, methane wells up from Uranus' lower cloud deck. Once an anvil shape forms, high-altitude winds shear the cloud into a long structure informally called a "tadpole."*

Storms of Distant Skies

A Glimpse at Solar System Weather

WHEN HURRICANE SANDY CAME ashore last October, she reminded all of us of the brute power of weather. Her horrific winds and devastating storm surges, however, paled in comparison to the weather on other planets and moons of our solar system.

When it comes to Sandy-on-steroid storms, Jupiter's Great Red Spot naturally comes to mind. The cosmic cyclone could swallow nearly three Earths and has been raging for at least 340 years. Saturn has winds that are far more terrifying, however, a fact that mystifies investigators. The golden giant receives one fourth of the solar energy received by Jupiter (one hundredth that of Earth). Early predictions held that its meteorology would be less vibrant than Jupiter's because of its distance from the Sun. With less heat to drive air currents, researchers expected Saturn's winds to be more subdued than Jupiter's. They reasoned that Uranus and Neptune would continue the trend toward quieter weather.

Distance from the Sun does not bring calm, however, cautions Caltech's planetary scientist Andrew Ingersoll. "Actually, the winds *do not* decrease as you move out in the solar system. That's quite dramatic for Neptune because it gets only five percent of the amount of energy that Jupiter does on a per-area basis. All the giant planets have stronger wind fields than Earth," he said.

Saturn's air masses race in west-blowing jets, moving opposite—or retrograde—to the direction of the planet's spin. These currents generate bizarre storm systems. A line of features called the "string of pearls" spreads a 60,000-kilometer (37,000-mile) parade of windows in Saturn's upper cloud deck. Strange, doughnut-shaped clouds occupy another retrograde jet. The clouds there resemble smoke rings, with clear air in the center. In the south,

smack in the middle of one of those retrograde wind streams, simmers lightning-laced Thunderstorm Alley. When *Cassini* arrived in 2004, lightning was limited to this blustery line along the southern latitude of 30 degrees.

The lightning appears to be associated with water clouds, according to Goddard Space Flight Center's Anthony Delgenio. "From what we know about the composition of the atmospheres of Jupiter and Saturn, water is the only condensable constituent that is sufficiently abundant to create the kind of vigorous convection that would lead to lightning," he said.

Saturn's water clouds are buried deep; water first condenses about 200 kilometers (120 miles) down from the visible cloud tops. Internal heat triggers convection of the atmosphere, bringing the water up about 70 kilometers (44 miles). At that altitude, it turns to ice. Lightning on Earth seems to occur at the level where liquid water begins to freeze. Particles of ice and liquid water collide, causing a separation of charge. Modelers expect lightning on Saturn to begin about 100 kilometers (62 miles) down from the dark clouds seen in visible light.

The location and limit of Saturn's thunderstorm activity present a mystery that is only deepening as summer comes to the northern hemisphere. New clouds are exploding in the north, at exactly the same distance from the equator.

The poles of Saturn display other wondrous features. Locked directly over the south pole, a whirlpool gazes from concentric cloud bands like a vast eye. The storm's cliff-like rim rises 40 to 64 kilometers (25 to 40 miles) high, reminiscent of a terrestrial hurricane's eye. In the north, a colossal hexagon drapes over territory that has the diameter of two Earths. The puzzling stream of air is stable and long-

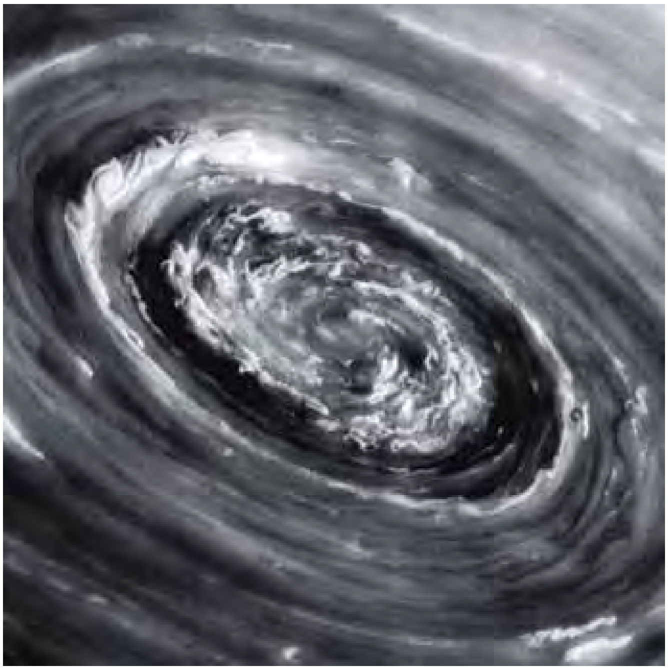
ABOVE Cassini *captured this approximately true-color view of the huge storm roiling in Saturn's northern latitudes on February 25, 2011.*

Illustration: Michael Carroll; Saturn image: NASA/JPL/SSI/color composite by Ian Regan lived, as seen in *Voyager* spacecraft images in the 1980s. The hexagon's cause is not well understood, making it one of the great planetary mysteries today.

IT'S RAININ' ALL OVER THE WORLD(S)

Along with wind comes precipitation. The rainfall in the outer solar system is truly alien. In this realm of bitter darkness and numbing cold, storms large enough to swallow the entire Earth rage for years. Earthly gases turn to liquid or freeze into ice. Snows of crystals of ammonia and methane drift from electrified clouds, melting into rainfall as they descend into the warmer depths.

The remarkable colors of Uranus and Neptune result from methane. Methane absorbs red light, leaving the bluer parts of the spectrum to reflect back at the observer. A ruddy haze shifts the color of Uranus toward the green. Uranus retains a subtle version of the same belts and zones exhibited by its gas giant siblings, but its weather is subtler than that of Jupiter or Saturn. Why? The answer lies within the hearts of these outer worlds. Jupiter, Saturn, and Neptune all put out more energy than they receive from solar heating. This internal heat drives their weather from within. Uranus is far colder compared to its surroundings. Temperatures on Uranus and Neptune are nearly equal at –323 degrees Fahrenheit (–197 degrees Celsius), even though Neptune receives only about 44 percent of the solar energy that Uranus does. Uranus' temperature appears to be in equilibrium with the incoming solar energy, leading to an atmosphere that is less mixed from interior to surface.



BELOW *Saturn's rings and serene, golden beauty make it the jewel of the night sky. Up close, however, spacecraft document a world of swirling storms. On November 27, 2012,* Cassini *imaged Saturn's summer north pole from a distance of 361,000 kilometers (224,000 miles). This feature sits at the center of the north pole's gigantic hexagon. A link to an animation is at* **bit.ly/tpr1305**.

Image: NASA/JPL/SSI/Emily Lakdawalla

Voyager was able to image only Uranus' southern hemisphere because the north was in darkness. (Unlike other planets, Uranus spins nearly on its side.) As Uranus has moved along its 84-year orbit, day has finally dawned in the north, and Uranus has shown some dramatic changes. Planetary scientist and Society Vice President Heidi Hammel has studied both Uranus and Neptune using two powerful instruments: the Hubble Space Telescope and the Keck 10-meter telescope atop Hawaii's Mauna Kea. Hammel has found features at Uranus that resemble the diversity of Neptune's meteorology. "We saw clouds popping up all over Uranus," she said. "The Hubble and Keck telescope images showed all sorts of transient rapid cloud activity." At Uranus, methane clouds boil into the sky, where jet streams pull them into thousand-mile banners. Hammel calls these storms "tadpoles" because of their form as seen from above.

It appears that the weather on the green giant is becoming more similar to that on Neptune. Dark storms—similar to Jupiter's Great Red Spot—last for roughly five years on Neptune. The duration of those on Uranus is unknown because of constraints on observing time. The Hubble Space Telescope and the Keck 10-meter are the only two facilities in the world with enough spatial resolution to detect these features, and access to them is limited. Hammel's team was able to use Hubble for a scant six hours a year, and time on the Keck was scarcely twice that. Despite

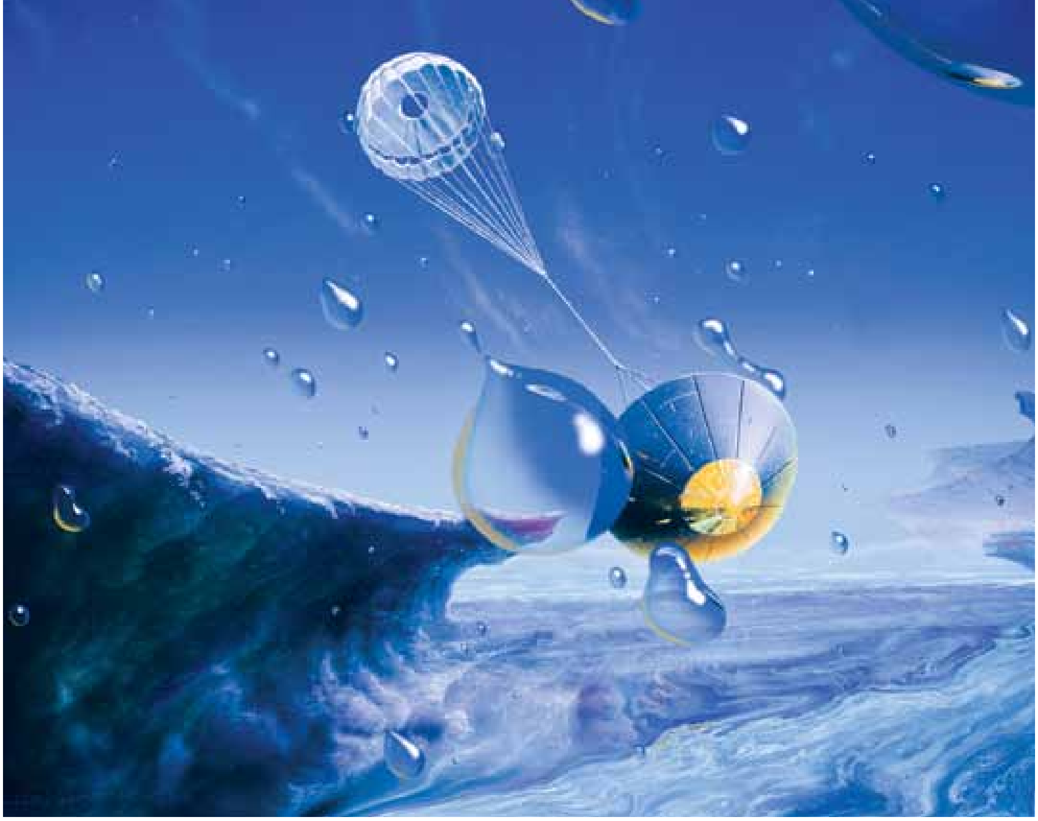


Illustration: Michael Carroll

LEFT *Uranus and Neptune have 20 times the amount of methane in their atmospheres as Jupiter and Saturn. Unlike water rain on Earth, however, methane condenses rapidly and can quickly grow into raindrops the size of a beach ball. Here, methane super drops accompany an atmospheric probe as it descends toward Neptune's lower cloud deck.*

these limitations, Hammel could tell that one dark spot was a comparatively long-lived storm. She charted its movements for many months, possibly as long as a year. The storm resembled a similar dark spot on Neptune spied by *Voyager* two decades earlier.

Both planets have fewer clouds than predicted by models. In any atmosphere, a battle rages between upwelling air currents that keep particles afloat and the force of gravity pulling particles down. For clouds to form, particles must stay airborne long enough to assemble into a group large enough to become visible. Small particles act as cloud seeds, attracting liquid to form droplets. If the particles are few and far between, larger droplets will condense, falling more rapidly and forming fewer clouds.

Kevin Baines of NASA's Jet Propulsion Laboratory suggests another concept for the missing clouds. "When methane condenses, it may condense so rapidly, and there's so much of it, that in just a few seconds to a minute you go from a little droplet that grows to the size of a beach ball, and the beach ball falls," he said. In this scenario, Baines suggests that giant methane raindrops would fall from the air too quickly to form clouds.

"Uranus seems bland compared to the stunning disk of Neptune. Neptune's clouds are intrinsically blue," says Heidi Hammel. "There is some kind of coloring agent in the atmosphere that gives it the more bluish color compared to Uranus." What that agent is remains a mystery. In Neptune's clear upper atmosphere, at a pressure of about 100 millibars (one tenth that of Earth's surface pressure), temperatures hover at about -360 degrees Fahrenheit (-218 degrees Celsius). Temperatures rise with depth. At a pressure comparable to Earth at sea level, temperatures reach -334 degrees Fahrenheit (-203 degrees Celsius). Beneath this level, the air is warm enough for methane to exist as a liquid or vapor. Methane cools and condenses into bright clouds, upwelling high into the stratosphere. Some storms traverse 50 to 100 kilometers (30 to 60 miles) of altitude.

Rain in a more familiar form falls on Saturn's largest moon, Titan. Within its orange fog, clouds boil into the upper troposphere. As they condense, rain falls to blanket the rolling hills below. Flash floods pour through dry riverbeds, rolling stones toward

Frequent Planetary Society contributor **MICHAEL CARROLL** *paints, speaks, and writes about the wonders of space. This article is adapted from his recent book* Drifting on Alien Winds: Exploring the Skies and Weather of Other Worlds. *His next book,* Alien Seas, *will be published at the end of this year.*

ABOVE *Cryovolcanic geysers break through a surface layer of nitrogen ice on Triton, Neptune's largest moon. When nitrogen is irradiated by sunlight, it turns a dark brown, similar to the color of the plumes and of drifts of dark material on the moon's surface.*

Illustration: Michael Carroll

the lowlands. Titan's showers, however, are not water showers. Rather, they consist of cryogenic liquid methane. The *Cassini* spacecraft has observed active rainstorms moving across Titan's equatorial regions. Extensive methane lakes spread across the northern hemisphere, one of which is the size of the Earth's Black Sea. Another huge lake in the south, Ontario Lacus, resembles its terrestrial namesake in both outline and size. *Cassini* is slated to study these phenomena in more detail, but scientists would like to get down into those lakes. In 2010, a team proposed the first planetary "boat," called the Titan Mare Explorer, or TiME. TiME was passed up in NASA's latest mission selections in favor of the Mars *InSight* lander, but similar missions may explore Saturn's foggy planet-moon in the future. These missions might use probes that bob across its lakes, or airplanes or blimps that fly through its dense air.

A HAZY SHADE OF WINTER

Snow falls in many forms and in many places in our solar system. Both the *Phoenix* lander and *Mars Reconnaissance Orbiter* have detected snowfall on Mars. Far from bringing winter holiday cheer, this snow consists of a chilling mix of water and frozen carbon dioxide. On our other next-door neighbor, Venus, snows or frosts of metals may condense on the highlands.

Radar images of Venus show a strange pattern of brightening on high ground, beginning at about 3.5 kilometers (2.2 miles) above the planetary "sea level." In radar, bright reflections usually mean a rough surface, but something else is going on here. The brightening drapes everything from rugged mountains to high plateaus. A variety of metals could explain the radar returns. At Venus' drastic pressures, specific metals called halides and chalcogenides may exist as vapor. On Venus, as on Earth, temperatures drop with increasing altitude. Low-lying plains on Venus register a blistering 873 degrees Fahrenheit (467 degrees Celsius), whereas the bright, higher elevations cool down to a lovely 728 degrees Fahrenheit (387 degrees Celsius). Volatile metals may vaporize in the lowlands and migrate gradually to higher terrain, condensing again as they cool.

Such a haze of metallic vapor could explain a mysterious set of spacecraft failures at Venus, at what is called the 12.5-kilometer anomaly. In 1978, four *Pioneer* Venus atmosphere probes sampled the Venusian environment. At an altitude of about 12 kilometers (7.5 miles), a power spike surged through all four probes, though they were thousands of miles apart, some in daylight and one in darkness of night. The surge was accompanied by bizarre readings of temperature and pressure. Many of the instruments failed completely. The Soviet probes *Venera 11*, *12*, *13*, and *14* all experienced similar power spikes at about the same altitude, and the *VEGA 1* Venus lander may have prematurely started its science package because of the same phenomenon. It attempted to drill and analyze rocks some 18 kilometers (11 miles) above the surface! There are other explanations for the 12.5-kilometer anomaly (including electronics failure resulting from heat), but metallic frost would certainly add to the alien nature of Venusian meteorology.

WEIRDER WEATHER

Perhaps the most exotic weather of all visits Neptune's largest moon, Triton. Initially, *Voyager 2*'s images of Triton baffled researchers. Its alien, weathered surface spread before *Voyager*'s cameras as a tortured combat zone of hollows and clefts. Its rarified atmosphere had one ten-thousandth the pressure of Earth's (15 microbars).

Triton's meager atmosphere consists mostly of nitrogen. Because of its low gravity, the outer fringes of its air waft to an altitude of 800 kilometers (500 miles). Brownish hazes settle among nitrogen geysers that rise 8 kilometers (5 miles). Winds, clouds, hazes, and even air pressure are driven by the freezing and thawing of Triton's polar caps, which leave behind those strange landscapes. As winter arrives at one of the poles, Triton's nitrogen migrates there, freezing to the surface. The entire atmosphere collapses twice a year, when it's winter on one pole or the other. The strange moon has "weather" only during the spring and fall because it has an active atmosphere only during those seasons. Many scientists believe that the *New Horizons* spacecraft will find a similar process ruling the skies of Pluto when the robot arrives there in 2015. If the other planets are any indicator, Pluto holds many meteorological surprises in store for us.

SOCIETY TRAVEL

Join Us for an Eclipse Safari!

October 23–November 6, 2013

Watch a total solar eclipse—and gorillas and chimpanzees!
These experiences await you in the mountain paradise of Uganda.

Join fellow Society Members and tour leader David Bygott, a British naturalist and photographer who has lived for decades in East Africa, on an unforgettable exploration of the country's finest national parks, gorilla reserves, and chimpanzee sanctuaries.

Allow yourself to be dazzled by the total solar eclipse as it illuminates the sky above Uganda's beautiful Murchison Falls National Park on November 3, 2013.

It's the expedition of a lifetime—a Planetary Society safari to Uganda, the "Pearl of Africa." Sign up now for your next great adventure!

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Free Online College Introductory Astronomy Class

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If you answered yes to any of these questions, you are in luck. Go online for Dr. Bruce Betts' ***Physics 195: Introduction to Planetary Science and Astronomy*** class at California State University, Dominguez Hills. You can watch live, with options to ask questions, on Wednesdays through May 8, 2013 at 3:00 p.m. Pacific Time. You can also watch the video archive any time. Find out how, as well as where to find the syllabus, class outline, assignments, and even tests (if you want to take them recreationally) at **planetary.org/bettsclass**.

BRUCE BETTS *is director of projects for The Planetary Society.*

One Alpha Centauri Planet...

And Probably More to Come

RIGHT *Debra Fischer and Julien Spronck on the mount for the 1.5-meter telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile, where they are searching for planets around Alpha Centauri.*

USING MORE THAN four years' worth of data, astronomers using the High Accuracy Radial velocity Planet Searcher (HARPS) spectrograph on the 3.6-meter telescope at ESO's (European Southern Observatory's) La Silla Observatory in Chile reported, in October, the discovery of a planet with mass slightly larger than that of Earth, orbiting the star Alpha Centauri B. This is the first discovery of a planet in our closest neighbor system of stars, and it is the least massive exoplanet ever discovered around a star resembling our sun.

The planet would be crispy, toasty hot (not a technical term!), at least on the side facing its parent star, because it orbits only 6 million kilometers (3.7 million miles) from that star, in a 3.2-day orbit. For comparison, the closest point to our Sun in Mercury's elliptical orbit is 46 million kilometers (29 million miles), and Mercury has an 88-day orbit.

The Alpha Centauri system, a little more than four light-years away, consists of three stars labeled A, B, and C, going from brightest to dimmest. The two brightest are roughly Sun-like, whereas the third, also known as Proxima Centauri, because it is the closest to Earth, is a red dwarf much farther out in the system. The newly discovered planet orbits around Alpha Centauri B (also known as AlphaCenB, or aCenB), which is somewhat smaller and less bright than the Sun.

The Planetary Society is supporting another Alpha Centauri exoplanet search, led by Debra Fischer at Yale University (see *The Planetary Report*, March Equinox 2012). Debra shared the following thoughts with me. "There is not a more exciting result for an individual star, even with the long line of spectacular results from the last two decades. The indication that our nearest neighbor has rocky planets is incredible. Furthermore, statistical results from the NASA *Kepler* mission suggest that where there is one, there are usually several rocky planets. This leaves open the possibility of a terrestrial planet in the habitable zone—in fact, I think this strengthens the speculative possibility of a habitable world in the AlphaCen system." Read more on the discovery and Debra's thoughts at **bit.ly/tpr1304**.

Thanks in part to crucial support from Planetary Society Members for telescope nights for Debra's team (neither NASA nor the National Science Foundation will pay for the telescope rental), they were able to obtain many weeks of data from the Alpha Centauri system in 2012. They use the CHIRON spectrograph on the 1.5-meter CTIO (Cerro Tololo Inter-American Observatory) telescope in Chile. The clever fiber-optic "scrambler" system that improves the precision of their system was developed based on the Member-supported FINDS (Fiberoptic Improved Next-generation Doppler Search) Exo-Earths project. Debra's team's clever system allows the sci-

Thanks! Planetary Society Members have helped make these and other exoplanet search programs possible. Thank you.

Photo: Zachary Kaplan

entists to get radial velocity precision comparable to that obtained by the larger telescope used by HARPS. Those radial velocity measurements of the stars' "wobble" are what we use to infer the presence of planets.

The system will be even more capable starting in April 2013, after the team installs a newly constructed tip-tilt mirror system. With it, team members will be able to make rapid pointing adjustments that will keep the telescope pointed more exactly at the one star under study in that observation, at the same time eliminating stray light contamination from other stars, which is critical in studying a multi-star system.

Planetary Society Members are helping out again to get the needed telescope nights in 2013. To donate, go to **exoplanets.planetary.org**. You can listen to a *Planetary Radio* interview with Debra Fischer at **bit.ly/tpr1303**. To learn more about how exoplanet searches are done, watch my lecture on the subject at **bit.ly/tpr1302**.

WHAT'S UP? *by Bruce Betts*

IN THE SKY

Jupiter is bright in the west after sunset, getting lower as the weeks pass. Venus comes up low in the west in May, getting higher over time. On May 10, Jupiter and Venus are within one degree of each other, very low on the horizon. Mercury is low in the west after sunset in June, getting highest in mid-June. Yellowish Saturn is rising in the east in the late evening, getting earlier over time. Comet C/2011 L4 Pan-STARRS may be visible to the naked eye in the west after sunset from mid-March through April in the Northern Hemisphere. There will be an annular solar eclipse on May 10, visible from parts of Australia and the South Pacific, with a partial eclipse visible more broadly in those areas. The Eta Aquarids, an above-average meteor shower, peaks May 4/5.

RANDOM SPACE FACT

On average, an object about 45 meters in diameter, the size of asteroid 2012 DA14 (which flew by Earth on February 15), impacts the Earth about every 1,200 years, and an object about 15 meters in diameter, the size of the Chelyabinsk Russian asteroid/meteor (which impacted on February 15), impacts about every 100 years. These are averages. The next such occurrences could be tomorrow, or thousands of years from now.

TRIVIA CONTEST

Our September Equinox contest winner is John M. Myers from Imperial, California. Congratulations! **THE QUESTION WAS**: What is the name of the suspension arrangement used with the six-wheel setup on all rovers that have gone to Mars? **THE ANSWER**: Rocker-Bogie.

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

After what regular polygon is a huge north polar cloud pattern on Saturn named?

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 May 1, 2013. The winner will be chosen by a random drawing from among all the correct entries received.

For a weekly dose of "What's Up?" complete with humor, a weekly trivia contest, and a range of significant space and science fiction guests, listen to *Planetary Radio* at *planetary.org/radio.*

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Image: NASA

Do You Enjoy a Challenge?

Planetary Society CEO Bill Nye, the Board of Directors, and the M.R. & Evelyn Hudson Foundation invite you to become an Investor in The Planetary Society Carl Sagan Fund for the Future.

The Carl Sagan Fund for the Future will increase the Society's stability and flexibility, enabling us to seize opportunities when new projects arise, advocate more extensively, and reach more people worldwide.

Thirty-three years ago, Carl Sagan, Bruce Murray, and Louis Friedman started The Planetary Society with a call for Members. They called out to people who were invested in shaping the future of space exploration.

This investment, made by Members like you and me, has paid off.

Today, the Society's tens of thousands of Members celebrate exciting discoveries, daring new technologies, and stunning successes in shaping space policy.

Let's build on this success. Let's renew our investment in the future.

The Hudson Foundation, at the request of Planetary Society Charter and Board Member Wally Hooser, is jump-starting this renewed investment in the Carl Sagan Fund for the Future with a challenge grant of up to $100,000.

The Foundation's challenge, to you and me and our fellow Members, is to help build this Fund. Your gift, large or small or somewhere in between, makes a difference. Its members want every one of you to make a gift–by the end of this year.

In return, the Hudson Foundation will match your gifts to the Carl Sagan Fund for the Future until the $100,000 goal of its challenge grant is met.

Every Member counts. Your participation is crucial.

Please renew your investment in the future.

Thank you.

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