

THE PLANETARY REPORT

SEPTEMBER
EQUINOX 2013

VOLUME 33, NUMBER 3

planetary.org

POLYGONS ON MARS

GIANT CLUES TO ANCIENT SEAS?



Bruce Murray

1931-2013

Dear Planetary Society Members:

It is with great sadness that I write to tell you that our co-founder, Bruce Murray, died on August 29, 2013.

We are saddened, to be sure. But as we look back on Bruce's life and leadership, we're also hopeful (even joyous) that the influence he made on planetary exploration, his students at the California Institute of Technology, the Jet Propulsion Laboratory, and The Planetary Society will live on to inspire a better future.

Bruce was my mentor, boss, colleague, and friend for more than half my life. It was a great privilege and a terrific experience to work with him.

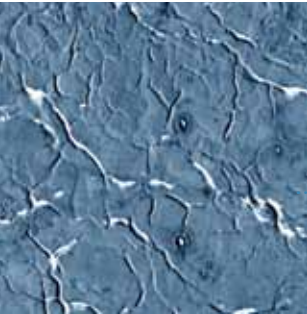
Like you, every one of us at The Planetary Society shares in this loss.

You can read more about Bruce in the obituary written by Charlene Anderson and me on our website at planetary.org/brucemurray. There, we've provided a way for you to share your own stories about Bruce or to offer a written tribute.

Together, we celebrate a great man.

A handwritten signature in blue ink, which appears to read "Louis D. Friedman". The signature is fluid and cursive.

Louis D. Friedman
Executive Director Emeritus



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Louis Friedman remembers our co-founder and friend.

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ON THE COVER: Although some scientists believe Mars’ giant polygons may be further evidence of ancient oceans on the Red Planet, their exact origin remains a mystery. These giant polygons—in the southern Utopia area of Mars’ northern lowlands—are surrounded by relatively straight troughs. This image, taken by the Context Camera (CTX) on *Mars Reconnaissance Orbiter*, is about 29 kilometers (18 miles) across, and most of the polygons shown are between 8 and 15 kilometers (5 and 9 miles) across. *Image: NASA/JPL/MSSS*

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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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YOUR PLACE IN SPACE



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

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1931-2013

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Thank You

Members Are the Reason for Our Success

THANK YOU FOR SUPPORTING OUR LONG-TERM FUNDING

Our reserve fund, the Carl Sagan Fund for the Future, is growing. Although I have served on our Board of Directors for several years, it wasn't until I became your CEO that I fully appreciated the need for long-term financial planning. Thanks to you, we have been able to reinvigorate our Carl Sagan Fund for the Future, which was established back in 1997. We are working hard to provide Members like you with a place where they can put money and be confident that it will be doing great good to advance humankind's exploration of space. A sufficiently funded reserve will allow the Society to operate without the continual concern that we might have to spend our savings for day to day expenses. This one effort would be enough to get someone in my position feeling pretty good. But there is so much more to be excited about. Read on.

THANK YOU FOR YOUR ADVOCACY

Through your efforts, the United States Congress is doing the right thing. As I write, the Senate has proposed increasing the NASA budget to over \$18 billion a year. This would be a wonderful turn of events. They made this bold proposal because apparently they have come to embrace the idea that investment in space is not only good for the dreams and deep curiosity of humankind; it's also exceptionally good for the economy in a not so subtle way. Investment in space leads to innovation, which in turn spurs invention, which in turn produces new business, which in turn creates new jobs for a new generation.

Meanwhile, the U.S. House of Representatives is haggling over its own version of the same legislation. But through all the proposals and counter proposals, every version of each bill has included more money for plan-

etary science. No matter what each faction has brought forth, the importance of planetary science has been acknowledged—thanks to you. We analyzed the NASA budget. We homed in on the number \$1.5 billion and hammered away on it. This is the amount of funding it will take to continue extraordinary exploration of extraordinary places in our solar system as outlined in the U.S. National Research Council's Decadal Survey. We are getting this job done—thanks to you.

ASTEROIDS ONLINE

I had the rewarding experience of being asked to explain the importance of asteroids to humankind on a very popular internet program called *ASAP Science*. It was the most viewed YouTube video in the world for a few days. You can watch it at bit.ly/stopanasteroid.

I was able to do this in large part because of the unique knowledge one gains in my position. As the manager of the world's largest space interest organization, every day one comes across information that most of us wouldn't know about. I communicate with the Earth's asteroid finders pretty often at meetings and by email. I lead the Society that is pursuing what looks to my engineering eye as the best way to nudge a deadly asteroid off course—our Laser Bees project. I have spent years on camera as a science educator. So, this video is a result of your support. Thanks for this, too.

TELEVISION SHOWS

This Fall, I was cast as a "star" on the television show *Dancing With The Stars*. (For our British readers, it's a very similar format to your *Strictly Come Dancing*.) Additionally, I will be joining the distinguished cast of *The Big Bang Theory* for an episode. Both shows are watched by millions.

Through appearances like these, I believe we can broaden awareness of the Society and thereby humankind's exploration of the cosmos through entertainment.

**THANKS FOR YOUR SUPPORT OF
PLANETARY SOCIETY KIDS**

I have been appointed to the NASA Advisory Council (the NAC). I will do my best to help NASA refocus its education and public outreach work to make it more effective and more broadly used. My appointment is a result of my being your CEO and a well-known informal science educator. It's a remarkable confluence.

I believe a person has to be engaged in science before or around the time he or she is 10 years old. I imagine most of you reading this have loved science from the time you were very young. Others among you, who may not have come to love space until later in life, almost certainly were exposed to the great value of being open-minded and thinking critically when you were a kid.

In the last issue of *The Planetary Report*, we asked you if we should keep running *Planetary Society Kids* as an insert in the magazine. Thank you for your feedback! We heard from many of you who value *Planetary Society Kids* and pass the inserts on to the young people in your lives. We also heard from some who find the insert a distracting addition to the magazine. So, we have decided to keep everybody happy by sending *Planetary Society Kids* to only our members who want to continue receiving it with *The Planetary Report*. Just email us at tps@planetary.org, or call us at (626) 793-5100 to let us know you want to continue to receive *Planetary Society Kids* in the future. If you do not wish to receive *Planetary Society Kids*, you don't need to do

anything—starting with our next issue, it will no longer be bound into the magazine. We will still have all of our *Planetary Society Kids* issues available in print as well as online. Also, I hope to expand our online education components in the coming months. Thanks for your feedback and your support.

With all this, we're growing. We're growing for the first time since 1996, when many of you responded with your support



We have received a match of \$100,000 from the M.R. and Evelyn Hudson Foundation. Your generous donations to the Society's **CARL SAGAN FUND FOR THE FUTURE** made this possible. Thank you!

We are excited to keep the momentum going. Each of your gifts is an investment in The Planetary Society and, in turn, the future of space exploration. If you have not given already, please join us in growing this reserve fund.

planetary.org/futurefund

Questions? Contact Andrea Carroll, Carl Sagan Fund for the Future liaison at andrea.carroll@planetary.org or (626) 793-5100, extension 214.

after our founder Carl Sagan died. It indicates that the Society is healthy. We're effective in bringing space down to Earth and helping people everywhere be part of the extraordinary, vital, and inspiring adventure that is space exploration. Thank you. Let's change the world. 🍀

Bill Nye



HAPPENING ON
PLANETARY RADIO
planetary.org/radio

ON THE ROAD

WATCHING THE LADEE LAUNCH IN PASADENA, CA

Brian Day (from the launch site in Virginia) and David Paige help us understand the significance of LADEE's mission. bit.ly/planetary-2013-09-09

THE 100-YEAR STARSHIP SYMPOSIUM

Only days after *Voyager 1* reached interstellar space, forward thinkers met in Houston, Texas to consider how humans can become a starfaring species. bit.ly/planetary-2013-09-23

THE ANCIENT SNOWS OF MARS

Kat Scanlon discusses evidence of rain or, more likely, snow that helped shape the surface of Mars billions of years ago. bit.ly/planetary-2013-08-05

CHARLES BOLDEN AND CHARLES ELACHI

We join the NASA Administrator and JPL Director for a visit to JPL. bit.ly/planetary-2013-08-19

MAVEN UPDATE

Principal Investigator Bruce Jakosky discusses the Mars Atmosphere and Volatile Evolution Mission (MAVEN) orbiter, which leaves for the Red Planet in November of 2013. bit.ly/planetary-2013-09-16

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



**EXPERIENCE
A TOTAL
LUNAR
ECLIPSE**



**EXPLORE WITH
THE PLANETARY SOCIETY
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Copper Canyon Eclipse

APRIL 10-17, 2014

Imagine watching a total lunar eclipse from Mexico's deepest and largest canyon system—Copper Canyon. Consider the dramatic volcanic scenery, bridges, tunnels, and villages you will experience from the famous Chihuahua al Pacifico train and the new Copper Canyon Tram, which descends thousands of feet to the floor of Barranca del Cobre. The canyon complex has a rich history, and the indigenous people who inhabit this unique place live much as they have for the past 400 years. The total lunar eclipse begins on the evening of April 14 (in Mexico) and will continue into the early hours of April 15.

**Join us on this exciting
adventure!**

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ON PLANETARY.ORG

MEDIA

MUSIC FROM THE MOON

Composing music through terrain cameras on Japan's *Kaguya*. bit.ly/planetary-moonbell



BLOG

A TRIBUTE TO VOYAGER

Steven J. Pyne looks back at the milestones of this historic mission. bit.ly/planetary-2013-09-25

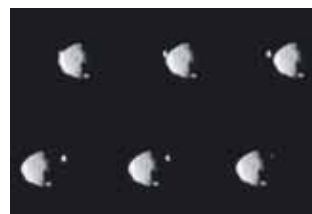
CURIOSITY

WHERE'S THE SCIENCE?

Emily Lakdawalla looks at the scientific achievements of *Curiosity*'s first year on Mars. bit.ly/planetary-2013-08-07

ONE YEAR ON MARS: MY FAVORITE MOMENTS FROM PLANETFEST 2012

Casey Dreier shares video highlights from Planetfest 2012, our "landing party" for *Curiosity*. bit.ly/planetary-2013-08-06



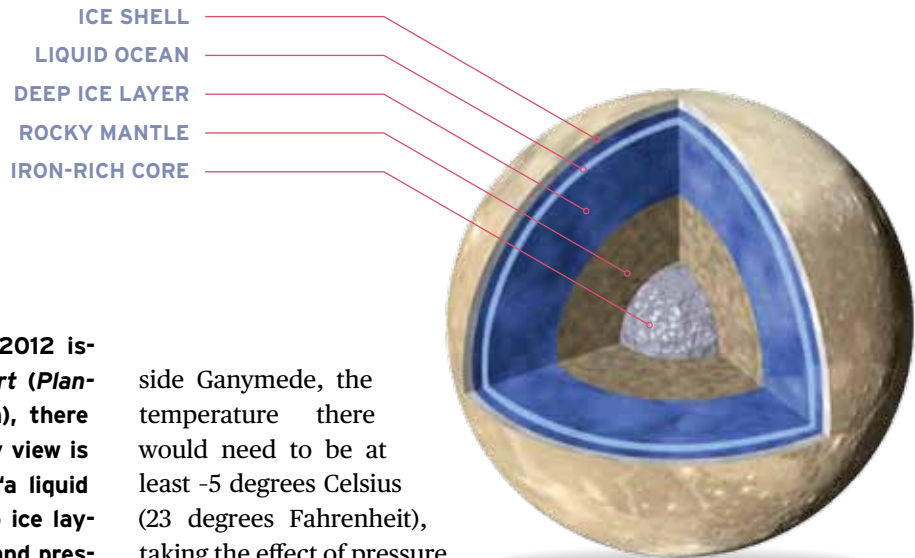
PHOBOS AND DEIMOS

Curiosity got a cool animation of Mars' moons moving through the sky. bit.ly/planetary-2013-08-16

GREAT EXPLANATIONS

GRAVITY ASSIST

David Shortt explains this essential—and sometimes confusing—procedure. bit.ly/planetary-2013-09-27



Q In the December Solstice 2012 issue of *The Planetary Report* (*Planetary Society Kids* section), there is a page on Ganymede. A cut-away view is shown, and the description says, “a liquid water ocean layer lies between two ice layers.” What profiles of temperature and pressure would lead to such a structure? Also, what observational data are there to support this idea for Ganymede?

—John Hartwell, Hillsborough, North Carolina

A This model of a deep, high-pressure layer and an outer, icy shell in Ganymede’s interior is supported by two sets of *Galileo* measurements. *Galileo*’s gravity measurements tell us that Ganymede is layered, with a core made up of iron and iron sulfide (like that inside Earth). This core is surrounded by a mantle of rock and then with a shell of water. Measurements obtained with the spacecraft’s magnetometer indicate that the water shell is partly liquid and forms a deep ocean. That layer was found because an ocean rich in salts interacting with the magnetic field of Jupiter creates a secondary magnetic field. Indeed, there are really only two methods to detect a deep ocean in an icy satellite without sending a lander to its surface: one is by measuring the deformation of the body in response to the tidal forcing exerted by its planet. The other one is through the detection of a magnetic field that periodically changes as the satellite travels across its planet’s magnetosphere.

For a layer of liquid water to exist in-

side Ganymede, the temperature there would need to be at least -5 degrees Celsius (23 degrees Fahrenheit), taking the effect of pressure into account. We believe the pressure at the base of Ganymede’s icy outer shell to be around 1,000 times that of Earth’s atmosphere, while the top of the high-pressure ice layer is equivalent to about 5,000 Earth atmospheres. Both of these values depend on temperatures in those locations. Water can exist in various forms as a result of pressure, temperature, and the composition of the ocean. In addition, various pressures cause ice molecules to arrange themselves differently. At various places in the solar system, we find low-pressure ices, many types of high-pressure ices, very low temperature ices, and so on.

This picture shows that at certain depths within Ganymede, water should be liquid, but at other depths it should become solid again. This sandwich-like structure of Ganymede’s shell is determined by the physical properties of its ices.

I don’t think we can obtain observational proof that the high-pressure layer exists, but we can infer that it is there, based on *Galileo*’s gravity data and the thermal structure inferred from the magnetometer observations. 🐼

—Julie C. Castillo-Rogez, Jet Propulsion Laboratory-California Institute of Technology

ABOVE *Galileo*’s gravity and magnetometer measurements of Ganymede indicate that this huge Jovian moon is layered, with an iron and iron sulfide core much like Earth’s. On top of that core sits a rocky mantle, topped by a thick layer of what may be warm, soft ice. A liquid water ocean lies between the deep ice layer and a thin, cold, rigid ice crust.



DOROTHY OEHLER is a Participating Scientist on the Mars Science Laboratory mission.

The Enigmatic Polygons of Mars

Are They Giant Clues to Past Oceans?

BELOW These giant polygons, dotted with bright mounds, are in Cydonia Colles, part of the southern Acidalia region of Mars' northern lowlands.

This image, taken by the Context Camera (CTX) on Mars Reconnaissance Orbiter, is about 11 kilometers (7 miles) across. The mounds themselves range in size between about 0.25 and 0.75 meters across.

EARLY TELESCOPES TOLD US FIRST of Mars' characteristic red color, then its canals. Flash forward hundreds of years, and various Martian orbiters, as well as the twin rovers *Spirit* and *Opportunity* and the more recent *Curiosity* rover, have revealed details of the Red Planet's surface, offering clues to the possibility of water and habitable settings for potential past life. What new facts and further mysteries will Mars give up? Perhaps they lie in its giant polygons.

MARTIAN GIANT POLYGONS AND A NEW ANALOG

Giant polygons have been recognized on the Martian surface since the 1970s from images taken by the *Mariner 9* and *Viking* orbiters. These features occur almost exclusively in the northern lowlands and are particularly abundant in Acidalia and Utopia Planitiae.

The giant polygons are kilometer-scale in size; most examples are 2 to 20 kilometers (about 1 to 12 miles) across. Their outlines are defined by troughs and their shapes can be rectangles, hexagons, or morphologies with curved boundaries. The large size of these polygons distinguishes them from the variety of smaller-scale Martian polygons, which are typically less than 250 meters across.

Similarly, on Earth, most polygonal terrains involve features that are only a few hundred meters across. Because of this, few terrestrial analogs (such as desiccation or ice-wedge polygons) have seemed a good fit for the giant polygons on Mars.

Without a good analog, the origin and significance of the giant polygons on Mars are still a mystery. There have been suggestions that their origins involve tectonism associated with uplift due to unloading of water or ice, compaction of fluid-rich sediments over irregular terrain, or convection of water through permafrost followed by desiccation, compaction, or thermal contraction.

However, recent research offers a new possibility of their origin—one that involves compaction of rapidly deposited, fine-grained sediments in subaqueous settings. This idea is based on results of three-dimensional (3-D) seismic data acquired by the petro-

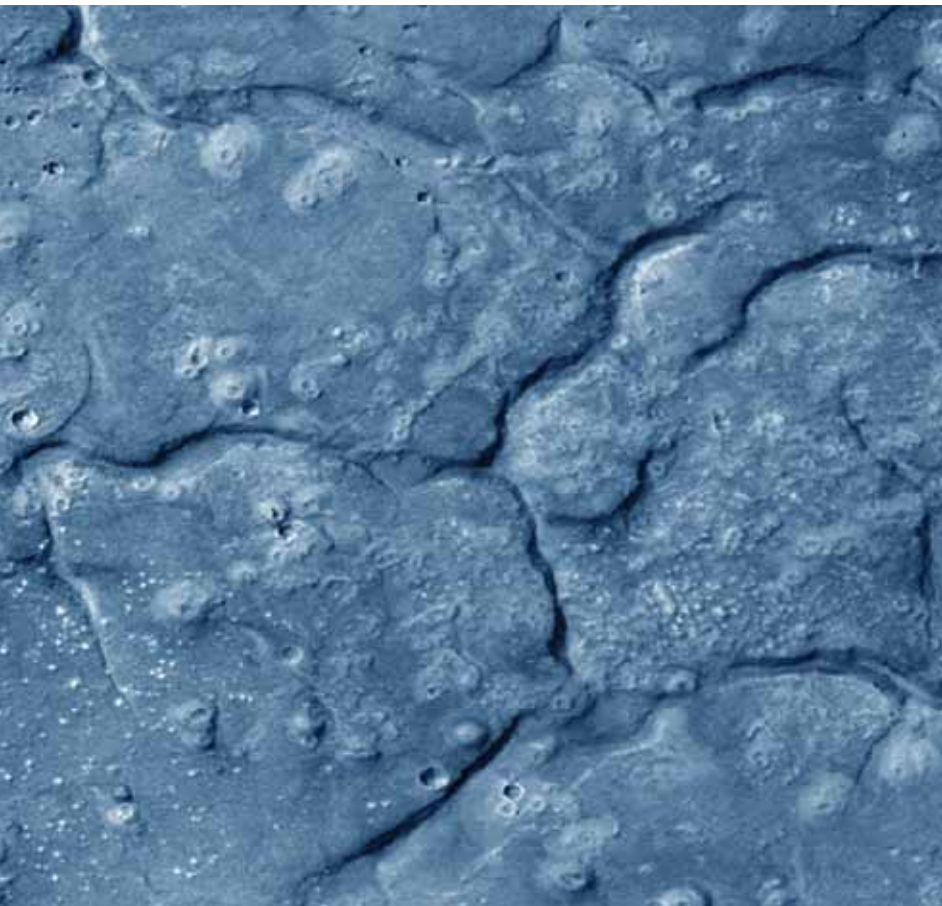


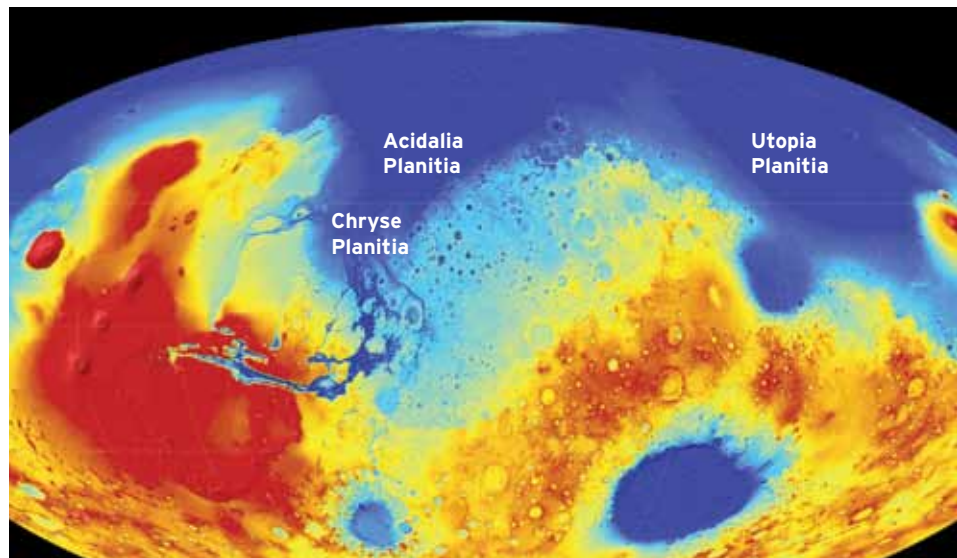
Image: NASA/JPL/MSSS

leum industry as part of their exploration in offshore basins. These 3-D datasets allow creation of detailed plan-view maps of the shallow subsurface, and it is these maps that have revealed numerous examples of kilometer-scale polygons in the uppermost kilometer of subsea basins. Until recently, these large-scale polygonal features were completely unknown, but there are more than 50 examples of marine basins that have terrestrial giant polygons.

TERRESTRIAL GIANT POLYGONS

The subsea polygons range from about 0.5 to 4 kilometers (about 0.3 to 2.5 miles) across and are bounded by faults. They occur from the sediment surface to depths of about 700 meters. They can have basin-wide extent (some occur over areas larger than a million square kilometers), and many of them have fluid expulsion features such as mud volcanoes or depressions on the sea floor called pockmarks, which result from subaqueous gas release.

Common to all the basins with these features is an accumulation of rapidly deposited, fine-grained sediments in a subaqueous depocenter. (A depocenter is typically the point of deepest and thickest deposits in a sedimentary basin.) Of particular note, all the basins that have these large-scale polygons are located in settings that lack strong horizontal stresses. These settings are called passive margins. Many relatively wide continental shelves are passive margins and are sites



where thick sections of sedimentary rock accumulate. There are various theories for how the terrestrial giant polygons are formed, but at a minimum, we know that they involve three-dimensional contraction and dewatering due to sediment loading.

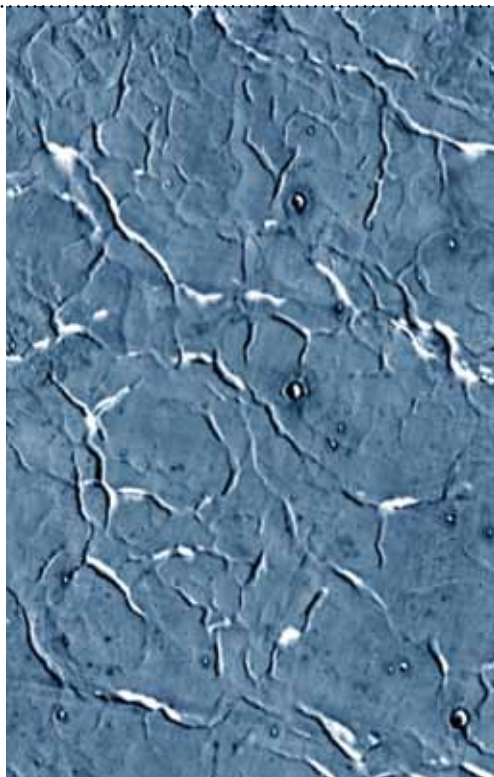
These large-scale polygons are thought to be formed by the following sequence of events: During initial stages of burial, sediment porosity and permeability decrease due to initial compaction. Polygonal faulting begins as linear furrows that develop near the sediment-water interface, apparently in response to mono-directional volume contraction. With burial of about 21 meters, sediment contraction becomes radial, and a hexagonal pattern of furrows develops. With

ABOVE This map, created from elevation data returned by the Mars Orbiter Laser Altimeter (MOLA) on Mars Global Surveyor, shows the dichotomy between Mars' northern lowlands (where most of its putative ancient oceans would have been) and its southern highlands. Blue denotes low elevations and red depicts high. Acidalia and Utopia Planitiae contain extensive giant polygon development.

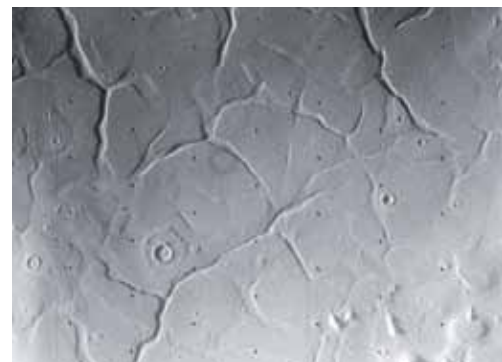
DOROTHY OEHLER is a Research Scientist in the Astromaterials Research and Exploration Science Directorate at Johnson Space Center and a Participating Scientist on the Mars Science Laboratory team.

Map: NASA/JPL/MSSS/Dorothy Oehler

UPPER LEFT *These giant polygons in southern Utopia are between 4 and 20 kilometers (about 2.5 and 12 miles) across. This view is a mosaic of daytime infrared images captured by the Thermal Emission Imaging System (THEMIS) on NASA's Mars Odyssey orbiter.*



UPPER RIGHT *On Earth, recent 3-D seismic data of offshore basins gathered by the petroleum industry show intriguing analogs to Mars' giant polygons, suggesting that the Martian features may have been formed in subaqueous basins. This map view illustrates large-scale polygons in the strata below the ocean's surface off the coast of Norway. This image spans about 6 kilometers (4 miles) and most of the polygons range between 0.5 and 1.5 kilometers (0.3 and 1 mile) across.*



LOWER LEFT *Mud volcanoes—frequently associated with fluid expulsion—often appear with terrestrial polygons. These cold “mud pots” were photographed in northern California. The one at right is about 10 centimeters (4 inches) high and 18 centimeters (7 inches) wide. Similar features, such as the bright mounds in the image on page 8, occur with some of the giant polygons on Mars.*

LOWER RIGHT *Scientists got their first glimpses at Mars' giant polygons in images taken by Mariner 9 and Viking. The polygons in this Viking 1 Orbiter image are about 5 to 10 kilometers (3 to 6 miles) across. In this view, taken on July 25, 1976, north is at 11:00.*

greater burial, sediment strength due to compaction increases to the point where it can form and maintain faults, and the polygonal furrows develop into polygonal faults. With burial beyond 300 meters, polygonal faulting becomes more closely spaced, and large polygons are divided into smaller, second-order polygons. This process continues until about 700 meters of burial, where compaction by sediment shrinkage is completed, and the fault frequency has reached its maximum.

COMPARISON OF MARTIAN AND TERRESTRIAL GIANT POLYGONS

The similarities between the Martian giant polygons and those in terrestrial offshore basins are intriguing. The kilometer-scale

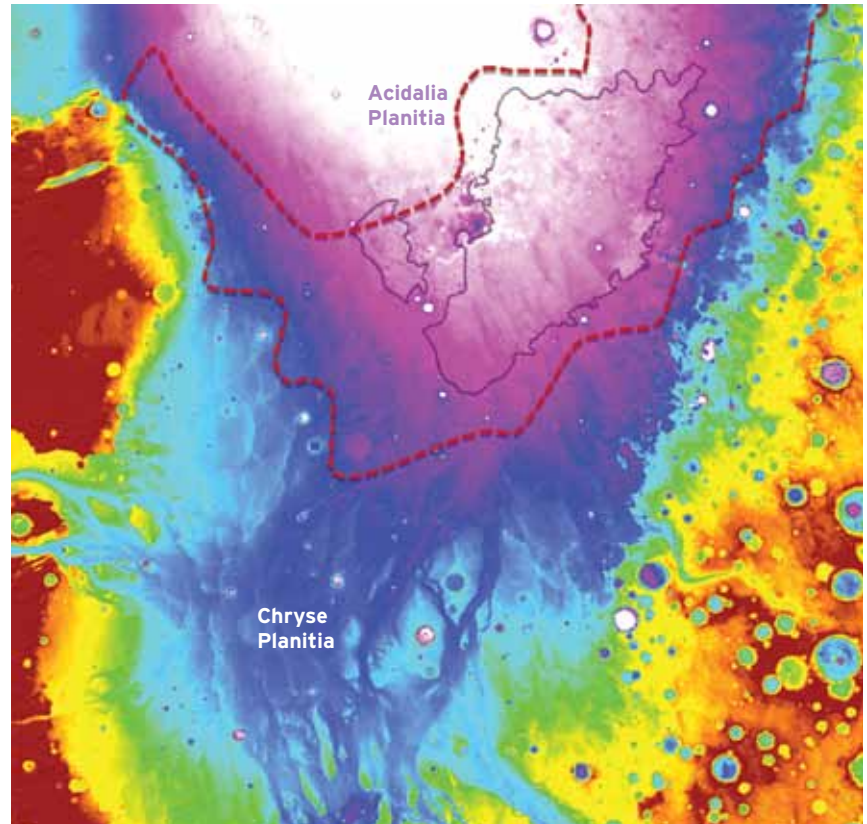
size of each stands out from other potential types of polygonal landforms. While the terrestrial offshore polygons appear to have a smaller size range (0.5 to 4 kilometers, or 0.4 to 2.5 miles) compared to the size of most of the Martian examples (2 to 20 kilometers, or 1.2 to 12 miles), this discrepancy may be only apparent. Some of the newer image data from the Context (CTX) and High Resolution Imaging Science Experiment (HiRISE) cameras on NASA's *Mars Reconnaissance Orbiter* (with resolutions of 6 meters and 25 centimeters, or about 20 feet and 10 inches per pixel, respectively) show that many of the Martian giant polygons are actually composed of smaller, second-order polygons that are approximately 2.5 to 5 kilometers

(1.5 to 3 miles) across. Other HiRISE images show subtle polygons, about 1 kilometer across, that were never observed in the older datasets. In addition, the sizes of terrestrial polygons scale inversely with burial depth and grain size. The larger features occur in areas with least burial and/or smallest grain size, and may be most comparable to the Martian giant polygons.

Importantly, the geologic contexts of terrestrial and Martian giant polygons are similar. The Earth features form in passive margins. On Mars, the general lack of plate tectonics would have resulted in many basinal settings similar to passive margins in that they also would lack strong horizontal stresses.

In addition, both the Earth and Martian giant polygons appear to involve settings where fine-grained sediment accumulated rapidly. The terrestrial features occur exclusively in fine-grained sediments, and rapid deposition has been implicated in several occurrences. On Mars, work suggests that catastrophic outflow floods would have resulted in massive amounts of rapidly deposited sediment in northern Chryse and southern Acidalia, and recent research has suggested that the most distal and therefore the most fine-grained sediments deposited by those floods would accumulate in southern Acidalia Planitia—a region coincident with the giant polygons.

Finally, there is the common association of the terrestrial giant polygons with features related to fluid expulsion, such as mud volcanoes and pockmarks. On Mars, there may be features analogous to mud volcanoes in some of the areas of giant polygons, as masses of bright, circular mounds in southern Acidalia have most recently been compared to mud volcanoes. Mud volcanoes are sedimentary diapirs that rise through the subsurface in a slurry of fluid and fine-grained sediment, as a result of overpressure in rapidly compacting basins. In Acidalia, approximately 40,000 of these mud volcano-like mounds have been estimated to occur and their distribution



overlaps that of the giant polygons. While the distribution of the mounds is broader than that mapped for the giant polygons (from older *Viking* data), both sets of features are centered in southern Acidalia, and both are restricted to areas predicted to have accumulations of fine-grained sediment.

Utopia is different in that many fewer mounds have been noted there, and some of them may be pingos (diapiric mounds of ice). Nevertheless, while both mud volcanoes and large-scale polygons on Earth require fine-grained sediments and compaction of thick accumulations of sediments, they have different formation requirements for each set of features. Accordingly, mud volcanoes and giant polygons are not necessarily coincident. They may overlap in some areas, but in others they can be adjacent to one another or each may occur in isolation. This may explain the differences between the features of Acidalia and Utopia.

ABOVE Based on MOLA data, this map of Mars' Chryse and Acidalia regions indicates elevations above -1,600 meters in red-browns and elevations below -4,900 meters in pinkish purples. The red dashed line shows the extent of recently mapped mud volcano-like mounds. The thin black line in Acidalia shows the area where giant polygons were mapped by other authors previously using older *Viking* data. Newer CTX and HiRISE data reveal giant polygons beyond the originally mapped area.



To learn more, visit
bit.ly/dzoehler
and
bit.ly/planetary-2010-08-04

ON THE WEB

IMPLICATIONS FOR AN OCEAN

The fundamental question of whether an ocean ever existed on Mars remains controversial. Many researchers have proposed that major bodies of water once existed on Mars in the northern plains. This interpretation is drawn from landforms suggestive of ancient shorelines, and the distribution of valley networks (presumed to be ancient rivers) in the highlands that are consistent with, and may even require, a major source of water in the northern lowlands. More recently, a network of channels just north of the dichotomy that separates the northern and southern plains has been re-interpreted as a delta that flowed into standing water. In addition, data obtained with the radar sounder (MARSIS) on the European Space Agency's *Mars Express* have been interpreted to suggest that massive, subsurface ground ice "interior to previously proposed shorelines" may be the relic of an ancient northern ocean. The comparison of Martian giant polygons to terrestrial subsea features is supportive of these ideas.

CONTINUING CONTROVERSY

But more work needs to be done. Some question the interpretation of landforms as shorelines and others who have modeled Mars' ancient climate wonder if the planet was ever warm enough to support a major body of liquid water for any length of time. Work continues on climate models, and research scientists who have studied potential shorelines are refining their work with the higher resolution orbital image data that are now available. Maps are being constructed to look for evidence of equipotential surfaces (potential indicators of ancient sea levels) in the possible shoreline features. In addition, crustal deformations due to sediment accumulation or the weight of volcanics introduced in the Tharsis region (southwest of Chryse Planitia) are being considered to assess deviations from horizontality in potential shoreline features. The newer,

higher resolution data are also being used to fine-tune our understanding of the spatial occurrences of the giant polygons and mounds. Initial results suggest that densely occurring mounds as well as giant polygons in Acidalia and in Utopia all occur below elevations of -4000 to -4100 meters. This range is close to previously proposed levels suggested to be ancient shorelines and possible equipotential lines. Accordingly, work is continuing to determine whether the distributions of giant polygons and mounds may reflect past water levels.

WHAT IF...

The possibility that Mars once hosted a major ocean is of great importance, not only to understanding the climate history of the Red Planet, but also to our evaluation of habitable regions on Mars. If the northern plains were the site of a major body of water, then habitats there may have supported life for relatively long periods. And when conditions deteriorated as the climate became colder and drier, and the atmosphere thinned, allowing more destructive radiation to reach the planet, potential life that had thrived on the surface could have moved into the protection of the subsurface. There, evolving lifestyles could have allowed life to persist within sediment pores, as occurs in the vast communities of endolithic organisms known to inhabit Earth's subsurface. These would be the areas marked by the giant polygons.

Moreover, if the analogy to the subsea polygons on Earth is correct, then the giant polygons on Mars not only would represent sites of long-lasting liquid water, but they also would imply locales of fine-grained sediment accumulation and burial—both of which would enhance preservation of potential geochemical fossils. Thus, in the search for potential evidence of past life on the Mars, the giant polygons in the northern plains may point the way to prime areas for future exploration. 🐾



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

Forging a New Consensus

Building Bipartisan Support for Planetary Exploration



IN THE PAST FEW MONTHS, five bills that impact NASA's future were introduced in Congress. All of them—every single one—increase funding to NASA's planetary exploration program. This happened to no other program within the space agency.

Remember, the White House requested a mere \$1.2 billion for planetary exploration next year—the smallest budget for the program in more than a decade—while laddling on additional responsibilities. This budget precludes any mission to Europa, drastically cuts technology and scientific research, and slashes the number of small solar system missions, like the now-defunct Titan boat concept [see *The Planetary Report*, March Equinox 2013, “An Ode to Discovery”].

But thanks to your thousands upon thousands of emails and phone calls combined with our aggressive, focused advocacy efforts, we're building a new consensus in Washington that planetary exploration is one of NASA's highest priorities. This crosses party lines, bringing together Republicans like Lamar Smith and John Culberson from Texas and Democrats Adam Schiff and Dianne Feinstein from California to form a bipartisan agreement in an otherwise divided political environment.

While the consensus is in the right direction, Congress still hasn't agreed on the funding level we recommend: \$1.5 billion per year. Only with this number can we get to Europa and start a Mars sample return in the next ten years, rejuvenate our research, generate plutonium-238, and send a fleet of

small missions to explore the solar system. But we're making progress thanks to you and your continued support.

Beyond the new consensus on planetary science, there is little agreement on fiscal priorities. The Republican-controlled House proposed \$16.6 billion for NASA in 2014, which, when adjusted for inflation, would be the agency's smallest budget in nearly 30 years. The Democratic Senate took a different track, increasing NASA's top-line to \$18 billion. Both bills moved forward on party-line votes—an unusually partisan situation for NASA.

The separate authorization bills, which set spending limits and overall agency priorities but do not actually fund the agency, also face partisan discord in the House and Senate. The Senate authorizes a healthy amount of money for NASA while the House imposes sequestration-level spending caps. The House forbids NASA's asteroid retrieval initiative while the Senate allows it. And so on.

Very few people expect these disagreements, which stretch far beyond the U.S. space program, to be resolved in time for the new fiscal year beginning in October. We will likely see another “continuing resolution” that will continue funding at previous levels until next year's spending can be agreed upon.

The discord is deep, but we can take pride that planetary exploration is an area that unites people across Washington and across the world. It's another reason that we value it so highly, and why it's worth fighting for. 🚀



ABOVE Bill Nye speaks to U.S. House of Representatives Science Committee Chairman Lamar Smith (R-TX) during the Society's Capitol Hill staff education and outreach event in May 2013.

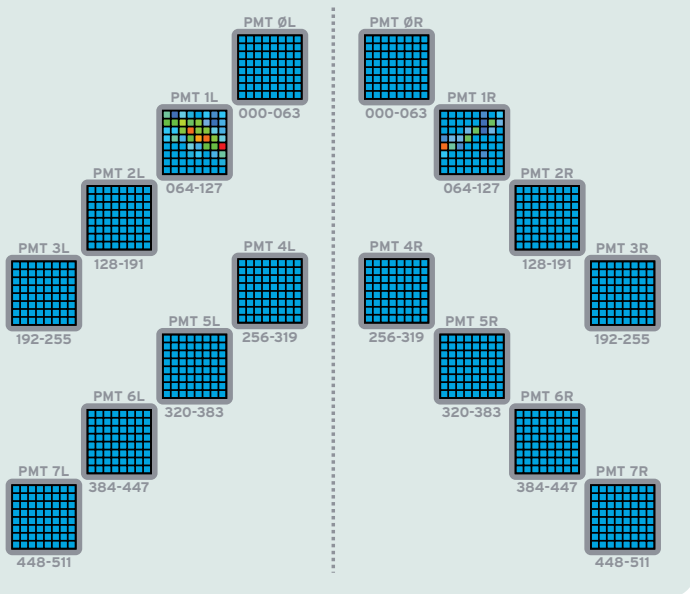


BRUCE BETTS is
director of projects for
The Planetary Society.

Upgrades to the Search

SETI and Exoplanet Telescope Searches Improved

RIGHT The new AdvCam system with its motherboard (front) and daughterboards sticking out in back.



ABOVE This is a false-color representation of pixels getting triggered within the AdvCam system at varying intensities during a Cherenkov radiation event, created with actual data from an event. Each square is a photomultiplier tube (PMT). The sky images are split and sent to two identical sets of PMTs, and only signals that appear on both sets—left and right—are considered “coincident pulses.”

IMPROVED HUNT FOR E.T.
The Planetary Society Optical Search for Extraterrestrial Intelligence (OSETI) Telescope was successfully

upgraded and tested, and it is now fully operational, looking for alien signals. The OSETI telescope is operated in Cambridge, Massachusetts by Harvard University Professor Paul Horowitz and his research group. It is the only optical all-sky SETI survey, scanning the skies every clear night, looking for laser pulses from distant extraterrestrials (none have been found yet, but wouldn't it be a rather big discovery if they were).

Horowitz's graduate student,

Curtis Mead, completed his PhD thesis, “A Configurable Terasample-Per-Second Imaging System for Optical SETI,” based on his development of the new OSETI telescope electronics system. Mead reported, “The Advanced All-Sky Optical SETI camera (AdvCam) is complete and has been operational since August 2012. It has completely exceeded my expectations and works better than I could have hoped.”

AdvCam, designed by Mead and funded in part by Planetary Society Members, significantly improved the telescope's already impressive back-end electronics. The electronics analyze terabytes (trillions of bytes) of information every second. When there is a possible “pulse event” that could be an extraterrestrial signal (ET), or something more mundane, AdvCam can record every pixel in two 512 pixel arrays for a period before and after the pulse. Its predecessor could only record a much smaller sampling of pixels over a shorter time frame.

Why is this upgrade so exciting? It allows the rapid distinguishing and removal of non-ET signals; specifi-

cally, Cherenkov radiation and airplane strobe lights. The Cherenkov radiation was particularly a problem. It is caused by cosmic ray particles hitting the atmosphere and creating a brief blue glow.

AdvCam also has extended the wavelength range being studied into the near-infrared, which is nice since we don't know where ET will broadcast. The more wavelengths we watch, the more chance we will have of detecting the “needle in a haystack” signal.

Mead reported: “The first observations with the Advanced All-Sky Camera were performed on September 11, 2012. As of March 31, 2013, 174.4 hours of observations had been completed, covering 3,602 square degrees. Within these 174 hours, 318 coincidence events were recorded; 18 of which are identified as Cherenkov light from cosmic ray-induced extensive air showers, about 30 are traced to aircraft, and the rest are single-pixel, low-amplitude pulses caused by detector artifacts.”

In other words, no ET, but the system is working as planned, so we will be better able to find ET signals if they

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



are there. AdvCam is doing its job: scanning the skies, analyzing the data, collecting the interesting stuff, and enabling the rapid sorting out of non-ET causes of “pulse events.” Find more information, including more details on the system from Curtis Mead, in my recent blog at bit.ly/opticalseti. ET, we’ve got our eyes on you!

IMPROVED HUNT FOR ALPHA CENTAURI EXOPLANETS

In another telescope hunt in another hemisphere, Planetary Society Members supported the hunt for exoplanets by renting telescope observing nights for Debra Fischer from Yale University and her group so they may continue to observe the Alpha Centauri system with an upgraded system. They are employing a FINDS (Fiberoptic Improved Next-generation Doppler Search for) Exo-Earths system that also was developed because of support provided by Planetary Society Members.

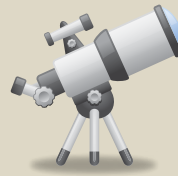
Alpha Centauri, the system of stars closest to the Earth, consists of two Sun-like stars (Alpha Cen A and B), as well as the

much smaller Proxima Centauri, which is far from the other two. Here is a summary update from Fischer about the main upgrade to the system and the initiation of observations using the new system:

“We designed, constructed and installed (in April 2013) a critical tip/tilt guiding system at the 1.5-m telescope [at the Cerro Tololo Inter-American Observatory in Chile] where the CHIRON spectrometer is located. This system was needed because the two stars (Alpha Cen A and B) are only about 6 arcseconds apart now and the guiding that we had with the aging telescope control system on the 1.5-meter was not fast enough. For single stars, this just meant that we lost light during brief intervals when the star was not centered on the input fiber, but for Alpha Cen, poor guiding introduced contamination from the companion star.”

They began their upgraded, improved hunt in May, thanks to you! You can find more information about their search and progress updates in my blog at bit.ly/exoplanethunt. 🐾

WHAT'S UP? by Bruce Betts



IN THE SKY

Comet ISON (C/2012 S1): Will it be the comet of the century or a dud? We don't know, but it probably will be somewhere in between, unless it is ripped apart by the Sun in late November. If it survives, the best visibility will probably be in December. See bright Venus low in the post-sunset west. Jupiter rises in the evening east. Mars is in the pre-dawn east. Saturn starts to rise in the pre-dawn east in November, getting higher with time. Mercury joins Saturn during November. Mercury and Saturn are only 0.4 degrees apart on Nov. 26, but tough to see low on the horizon. There is a hybrid solar eclipse (total in some areas, annular in others) on November 3 across the Atlantic and central Africa. Partial eclipse will be visible from eastern North America, northern South America, southern Europe, the Middle East and Africa. The usually excellent Geminid meteor shower peaks December 13/14, but a full Moon will make viewing tougher than usual.



RANDOM SPACE FACT

The appearance of Halley's Comet in 1066 was recorded in the Bayeux Tapestry that depicts the Norman conquest of England.



TRIVIA CONTEST

Our March Equinox contest winner is Antonio Sacin from St. Louis Park, Minnesota. Congratulations! **THE QUESTION WAS:** After what regular polygon is a huge north polar cloud pattern on Saturn named? **THE ANSWER:** A hexagon. The sides of the hexagon are about 13,800 kilometers (8,600 miles) long, which is longer than Earth's diameter.

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

Which astronaut on a Mercury mission became the first to do a manual (as opposed to an automated) re-entry?

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 December 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.

Thank you, Members, for your feedback on our recent issues of *The Planetary Report*!

MARCH EQUINOX

I've been a member since the 1980s and I wanted to let you know that the March Equinox 2013 issue of *The Planetary Report* was one of the better ones I've seen come down the pike. I thought the Europa article, the discussion of missions by Casey Dreier, and the article about solar system weather were excellent. I noticed that the latter two were written by people other than astrophysicists, and it showed: The text was extremely readable and insightful, and I thought Alyssa Rhoden and Robert Pappalardo discussed Europa in a very readable fashion.

It was a joy to read. Keep up the good work!

—Michael George, Burlington, Vermont

Thank you for the fine March Equinox 2013 issue of *The Planetary Report*. The magazine is always good, but this particular issue was extra special. In particular, I would like to thank you for the article by Michael Carroll. Somehow, I have missed his work until now, but I intend to rectify this. I have just purchased—and am now reading—Mr. Carroll's fine book, *Drifting on Alien Winds*.

I know that I speak not only for myself but many other Society members when I say thank you for the high quality of every issue of *The Planetary Report*.

—James S. Veldman, Shorewood, Illinois

JUNE SOLSTICE

As an "old" member of The Planetary Society, I'm impressed again and again by your fine articles on planets and the solar system. This was especially true for the fabulous article, "Rewriting the Books," by Linda Spilker (June Solstice 2013).

—Hans-Kaspar Wipf, Zurich, Switzerland

THE "MASCON EFFECT"

Regarding your Factino on lunar mascons in the June Solstice 2013 issue of *The Planetary*

Report: Lunar mascons were first discovered during Lunar Orbiter mission operations in 1966. They caused us to miss some of our intended photo sites by 30 to 40 kilometers. We reported this effect in the American Institute of Aeronautics and Astronautics paper, "Lunar Orbiter Mission Design," in 1968. Later, Bill Sjogren of JPL correlated the effect with proximity to the lunar craters, and proposed the "mascon effect." [This effect] was still a problem for the Apollo flights.

It would have been interesting if you had included this bit of history in your recent article in *The Planetary Report*.

—Norm Crabill, Newport News, Virginia

ERRATUM

On page 19 of the June Solstice 2013 issue someone matched 20 degrees Fahrenheit with -17 degrees Celsius.

Actually, 20 degrees Fahrenheit is -6.7 degrees Celsius.

—Frank Weigert, Wilmington, Delaware

Please send your letters to Members' Dialogue, The Planetary Society, 85 South Grand Avenue, Pasadena, CA 91105, or e-mail: tps.des@planetary.org. 📧

The Planetary Society reserves the right to edit letters for length and readability.

GOODBYE TO AN OLD FRIEND

The staff of The Planetary Report is sorry to announce that Andrew James (A. J.) Sobczak, our copy editor of 10 years, died on August 10, 2013 at his home in Santa Barbara. Always the professional, A. J.'s attention to detail and his dedication to polishing the content of this magazine were unflagging. Moreover, he was a really nice guy and always a pleasure to work with!

Our condolences go out to his family and friends.

—Donna Stevens, Senior Editor



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STAY CONNECTED



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



Power From the Isotopes

The United States is trying to generate plutonium fuel for the first time in nearly 25 years. But will it succeed?

WHEN *CURIOSITY* ROARED INTO space in 2011, it carried with it a material so potent that the President of the United States had to approve the launch. This material, plutonium-238 (Pu-238), is used to generate power from a process of radioactive decay, and though it has been essential to nearly 30 missions in NASA's history, its future is in doubt. The United States hasn't generated Pu-238 since 1988. Existing supplies are nearly exhausted.

But after years of effort by hundreds of individuals throughout the government, the United States is on the cusp of producing Pu-238 again. It's a complex,

expansive program requiring intricate coordination among multiple federal agencies, Congress, and the White House. It nearly did not survive its early political and budgetary battles. And though challenges lie ahead, NASA has quietly achieved its most important policy victory in decades.

PLUTONIUM-238

Secure facilities within Los Alamos National Laboratory, in Los Alamos, New Mexico, store the country's remaining supply of Pu-238. Exact amounts are not made public, but it's likely less than 30 kilograms (66 lbs.). These final, precious kilograms can only

support a dwindling number of missions. NASA now faces a shortage so crippling that vast areas of our solar system will become inaccessible unless more plutonium is created soon.

Solar energy dramatically decreases the farther one gets from the Sun—every doubling of distance decreases the amount of received energy by a factor of four (the inverse square law). Spacecraft that travel far from the Sun need larger and larger solar panels in order to generate the same amount of electricity, but mass constraints and other engineering problems limit the maximum size of solar panels a spacecraft can use.

ABOVE On January 19, 2006, an Atlas V rocket blasted off from Cape Canaveral, launching the New Horizons spacecraft on its journey to Pluto. New Horizons depends on 11 kilograms (24.25 pounds) of plutonium-238 (Pu-238) fuel to provide power during its long mission.

This mostly restricts solar panels to missions within the asteroid belt. Anything venturing deeper into space or exploring shadowed areas or dusty conditions cannot depend on the Sun for electricity. Pu-238 is the only practical power source on such missions.

Plutonium-238 is an unstable isotope that naturally decays to uranium-234 by kicking out an α -particle (essentially a helium nucleus) that then smashes into its surroundings, creating heat that is converted into electricity via Radioisotope Thermoelectric Generators (RTGs). These are the boxy, finned elements seen on spacecraft like *Voyager* and the rump of *Curiosity*, variants of which NASA has used for over 50 years.

This isotope is not found in nature. Its short, 87.7-year half-life guarantees that any natural deposits will decay away over geologic time scales. To maintain a steady supply, Pu-238 must be created, and it must be created constantly.

Jim Green understands this problem all too well. As director of NASA's Planetary Science Division, he is responsible for missions to destinations within the solar system. He is one of the key figures driving the plutonium restart effort at NASA.

"If we decide that the solar system is only a tiny fraction of the size that it really is, then we won't need Pu-238," said

Green. "A lot of people think of plutonium as something for the outer planets and yet you cannot do a mission without plutonium if you want to get a sample from the backside of Mercury, if you want to crawl into a permanently shadowed crater, or if you want to land on the north or south pole of Mars and do an ice core and pull it out and look at it. Plutonium-238 is an infrastructure capability."

In addition to providing energy, small pellets of Pu-238 can be used as heating elements on missions that otherwise use solar power. The passive heat provided by Pu-238 decay frees up precious amps for scientific instruments rather than inefficient electric heaters.

Two of NASA's most successful spacecraft, the *Spirit* and *Opportunity* Mars rovers, used numerous Plutonium-238 heating pellets. Without them, the rovers "wouldn't have lasted maybe even the 90 days," said Green, referring to the rovers' initial prime mission length. *Opportunity* is nearing its tenth year of operations on Mars; *Spirit* lasted for over six.

"Plutonium is essential for almost anything we do," he added.

HISTORY OF THE CRISIS

For the first half of the space age, creating Pu-238 wasn't a problem. Cold War concerns drove production of nuclear weapons in the

U.S., supporting a massive infrastructure devoted to their construction and maintenance. Pu-238 was generated in large quantities by piggy-backing on processes used to create its weapons-grade cousin, plutonium-239, in the reactors of the Savannah River National Laboratory in South Carolina.

But in 1988, numerous safety issues forced the Department of Energy (DOE) to shut down the aging Savannah River reactors. Plans to restart the reactors were scrapped in 1992 after cost estimates for repairs climbed into the billions and the need for nuclear weapons declined in the wake of arms-reduction treaties and the collapse of the Soviet Union. As the world celebrated the end of the Cold War, the U.S. lost its capacity to generate the fuel needed to explore space.

It was clear that the U.S. would eventually run out of Pu-238 after the Savannah River reactors shut down. But existing stockpiles would meet NASA's needs for the next few decades and, lacking an immediate crisis, the political will to rebuild domestic production capability was nonexistent. Nevertheless, the DOE initiated a program to purchase Russian plutonium in the early 1990s to augment remaining supplies.

As the years progressed, five missions launched with Pu-238, each one dipping

BELOW A fuel pellet of plutonium dioxide ($^{238}\text{PuO}_2$) glows red from the heat generated by its own radioactive decay—about 1,350 degrees Celsius (2,462 degrees Fahrenheit). Plutonium dioxide is a ceramic compound specially formulated to resist turning to powder upon impact (it is deadly if inhaled), to be fire-resistant, and to have low solubility in water. These fuel pellets are encased in protective layers of iridium and graphite, which are then inserted into a Radioisotope Thermoelectric Generator (RTG) as a heat source.

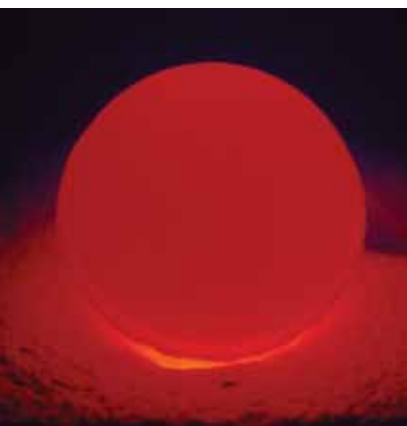
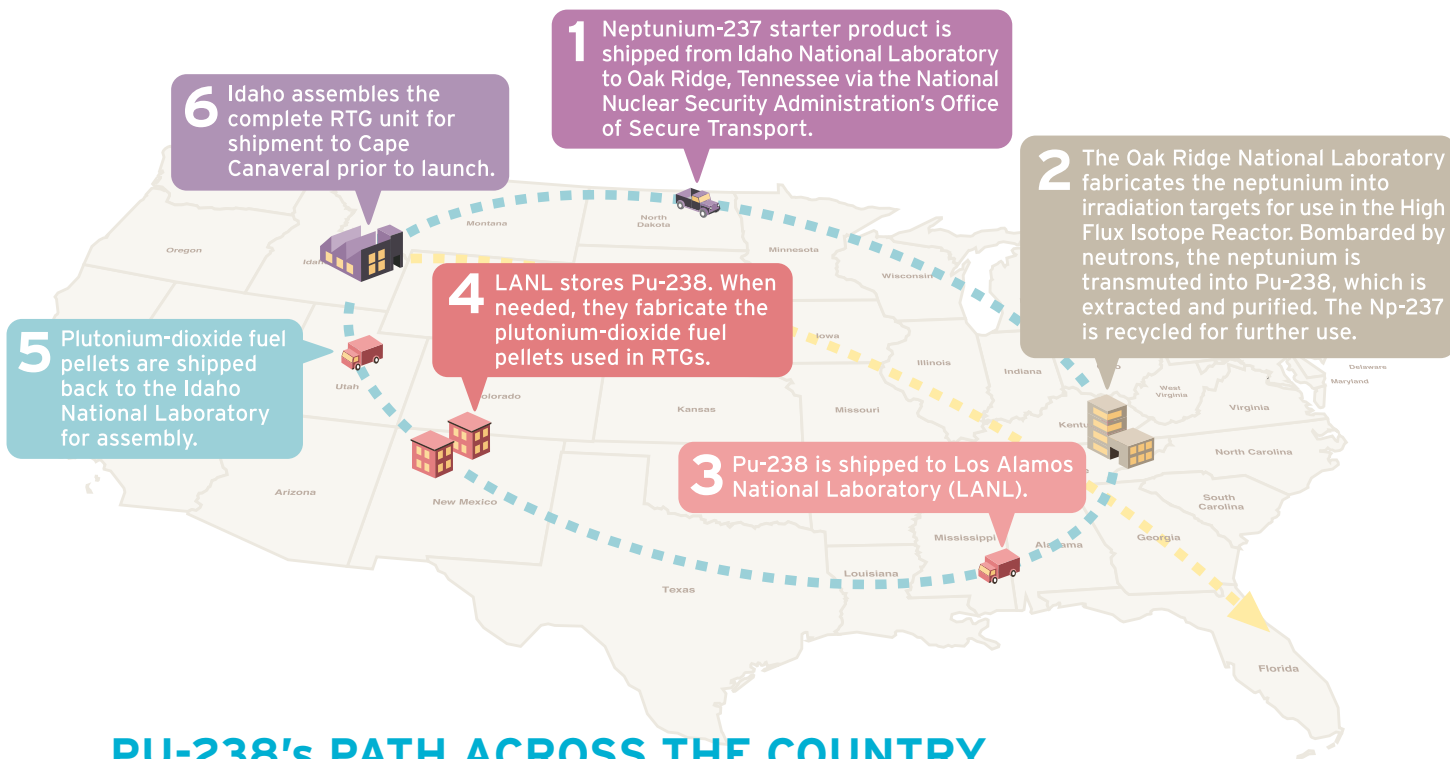


Photo: U.S. Department of Energy/Science Source



PU-238'S PATH ACROSS THE COUNTRY

into the diminishing supply. Radioactive decay relentlessly chipped away at what remained.

The plutonium problem was becoming difficult to ignore by the early 2000s. In an effort to stretch supplies, NASA initiated a technology program to improve the efficiency of RTGs and reduce the amount of Pu-238 needed in each mission. It created the Advanced Stirling Radioisotope Generator (ASRG), which is four times as efficient as existing technology, and in its final development.

Relying on ASRGs only delays the inevitable—plutonium will still run out. Faced with an impending crisis, Green was forced to act.

“When I became director

of the Planetary Science Division, we had no hope of being able to restart the generation of Pu-238—we were in a real fix,” said Green. “We embarked on a long-term program to convince our management here and [within the White House] that we wanted to move forward with restarting plutonium production.”

According to Green, the outcome was far from certain: “We went from absolutely nothing to starting a process where we had a chance—a chance!—of being able to get it going.”

GETTING TO RESTART

Restarting plutonium production is an unusually complex dance among various federal

agencies, administration departments, and Congress.

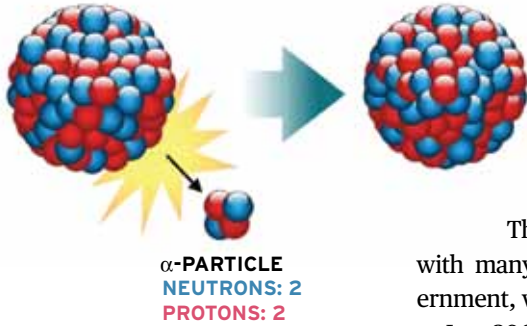
Because the DOE has sole authority to manage the nation's stockpile of radioactive material, NASA must work with the agency to create a production plan. The multiple offices within the White House that supervise science policy must agree to this plan. Because creating plutonium costs money, formal budget requests must be submitted on behalf of both NASA and the DOE. These budgets are governed by different subcommittees in Congress, and each subcommittee in both the Senate and the House has to agree to the plan and fund it accordingly.

The challenge of creating widespread agreement in so

ABOVE *The Department of Energy (DOE) depends on three national laboratories to create, store, and assemble radioisotope power sources for NASA. This graphic traces the circular journey of the neptunium-237 starter product to the complete Radioisotope Thermoelectric Generator (RTG) containing plutonium-238 fuel.*

Pu-238
NEUTRONS: 144
PROTONS: 94

U-234
NEUTRONS: 142
PROTONS: 92



ABOVE Plutonium-238 is an unstable isotope and decays via the emission of an alpha-particle to become Uranium-234. The collisions of these alpha-particles with their surroundings creates the heat used by RTGs to generate electricity.

many areas was daunting, to say the least.

The solution lay, as with many problems in government, with a report.

In 2009, the National Research Council released *Radioisotope Power Systems: An Imperative for Maintaining U.S. Leadership in Space Exploration*, which officially stated the dire situation facing the country and urgently advised resumption of Pu-238 production. The report contained no middling conclusions or gray areas.

“I’d like to think that the report was one of the tipping points,” said Ralph McNutt, a research scientist at the Applied Physics Laboratory at Johns Hopkins University and co-chair of the panel that authored the report. “The concern was to make certain that 25 years from then, if the program had ended up disappearing, nobody could say, ‘Why didn’t anyone say something?’”

In 2009, the DOE formally requested permission to restart Pu-238 production. Following historical precedent, they would pay for the restart process, estimated to cost around \$100 million over five years—a miniscule fraction of the agency’s \$30 billion annual budget.

NASA, the DOE, and the White House had all agreed on a restart plan. Space ad-

vocates breathed a sigh of relief. All that remained was for Congress to approve the funding.

POLITICS

To handle the daunting task of budget oversight, each house of Congress maintains twelve subcommittees responsible for allocating funds to the federal government. The Department of Energy and NASA each belong to different subcommittees.

Congressional committees are composed of elected representatives, but day-to-day operations depend on professional staff members who serve the committee. Because the staff are responsible for writing the actual bills and related reports, they can wield immense power—especially on issues that don’t catch the eye of elected representatives.

So in 2009, when the DOE first requested money for Pu-238 production, it was the subcommittees responsible for the DOE that shot it down, declaring that the program was “poorly defined” and “lacking an overall mission justification.”

Supporters of space exploration were stunned. “The Energy and Water subcommittee decided that [Pu-238 production] was not part of the DOE’s core mission and that NASA should pay for all of it,” said Alex Saltman,

who served as legislative director for Representative Adam Schiff (D-CA) at the time. Schiff sits on the House subcommittee responsible for NASA’s budget and is a strong supporter of the plutonium-238 restart project.

The DOE and NASA went back to the drawing board. The following year, the White House submitted a budget with each agency paying half the cost of the program.

Despite heavy lobbying by The Planetary Society and other scientific interest organizations, the Energy and Water subcommittee staff again rejected funding for the restart, having decided that “plutonium-238 is not needed for any DOE or National Nuclear Security Administration missions, including national security applications. As NASA will be the only user of plutonium-238, the Committee believes NASA should pay for the entire service.”

Alex Saltman dismisses that argument. “The biggest counterexample to the idea that the DOE should stick to its core issues is that the National Nuclear Security Administration—which is an enormous part of the DOE—is entirely aimed at defense needs. The DOE is used to being a service agency when it comes to the Department of Defense, but not used to it when it comes to NASA.”

“It’s frustrating, but you’re working in Congress, so the whole thing is frustrating,” said Saltman.

Two years had been lost to the energy subcommittees. In the interim, Russia had reneged on its previous

agreement to sell Pu-238 to the United States, deepening the supply crisis. NASA decided to pay for everything. They had no choice. The Energy and Water subcommittee had won the high-stakes game. In 2010, Congress granted NASA authorization to pay the DOE to create Pu-238. In 2012, it finally provided NASA with the funding to do so.

NASA’s Jim Green is prag-

matic: “If we pay [the DOE] for their role, you know, that’s the cost of doing business sometimes. To me that was the lesser of the bigger problem, which was getting it restarted, which had been forbidden by law.

RESTART

In July of 2012, just outside of Knoxville, Tennessee, a small amount of neptunium-237 was gently lowered into a chamber of the High Flux Isotope Reactor at the Oak Ridge National Laboratory. Bombarded by high-energy neutrons, some of the neptunium transmuted into Pu-238

for the first time in 25 years.

Only a very small amount of Pu-238 was created last year—far less than what’s needed to power a spacecraft. But this was by design. Creating radioactive materials must be approached cautiously and with great respect for health, safety, and environmental impact. Though the theoretical process for creating Pu-238 is well understood, it has never before been attempted in modern facilities. The DOE must determine the best way forward, and NASA is paying them to do so.

It’s frustratingly slow going, and without an influx of cash, full production won’t happen until 2019, at which point the DOE will generate about 1.5 kilograms (3.3 lbs.) of processed plutonium per year.

“The project is currently in its technology demonstration phase, which involves demonstrating and optimizing pieces of the process before scaling up to the full production rate,” explains Ryan Bechtel, the Power Systems Safety Manager in the DOE’s Office of Nuclear Energy. “The funds received by the project have been sufficient to support excellent progress so far.”

Ralph McNutt, co-author of the official plutonium report, finds the current progress acceptable: “The gradient is in the right direction. From what I’ve seen everybody is doing their

LEFT Flight technicians examine the Curiosity rover’s Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), which contains 4.8 kilograms (10.6 pounds) of Pu-238 fuel. For safety purposes, the MMRTG was not inserted into Curiosity until just prior to launch, when the rover was securely ensconced in its launch vehicle.



Pu-238 PELLETT
(actual size)



damnedest in the system to try and make this work. Everybody realizes that this is important for the country [U.S.] and that it's important that we all work together to manage to pull this off."

By the end of 2013, the DOE will provide NASA with a clear set of requirements to sustain production of Pu-238. If all goes well, the full program will be implemented in 2015.

THE FUTURE

The ultimate success of the plutonium restart project depends on two factors: the steady production of Pu-238, and the availability of the Advanced Stirling Radioisotope Generator.

Without the efficiency gains promised by the ASRG, the DOE will not produce plutonium at a sufficient rate to meet NASA's needs. Older, less efficient RTG technology would limit NASA to one, maybe two missions per decade.

The ASRG, like nearly all programs within NASA, faces a shrinking budget. A planned test to simulate a long-duration mission with the ASRG was recently canceled, though NASA claims it's still on track to deliver two flight-ready units by 2016. Additional budget cuts could delay the program, preventing ASRG use in missions into

the 2020s due to the long planning horizons required for spacecraft.

Dwindling funds have reduced NASA's immediate needs for plutonium powered spacecraft. The only mission in active development that depends on Pu-238 is the Mars rover planned for 2020. Smaller missions may be selected in the coming years, but these wouldn't launch until the late 2010s or early 2020s.

The difficulties that lie ahead should not belie the great success of the plutonium restart program. It was a triumph of will, but of no one individual's will. Hundreds of dedicated people fought for years to ensure the continued existence of a particular radioactive isotope in the United States. This is not common.

It was also a victory for the battered planetary exploration program at NASA, which has suffered repeated funding cuts and canceled missions in recent years. But when funding improves, the plutonium fuel will be there, ready to enable the most compelling and exciting missions we can dream of.

You can help ensure that the Pu-238 and ASRG programs continue. Visit planetary.org/SOS to become an Advocate for Planetary Exploration. 🐾



ABOVE Technicians stand above the High-Flux Isotope Reactor at the Oak Ridge National Laboratory in Tennessee. The Department of Energy is currently refining the process that would use this reactor to create Pu-238 for the first time since the late 1980s. Full production is expected to begin in 2015.



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Photo: Oak Ridge National Laboratory



EMILY STEWART LAKDAWALLA
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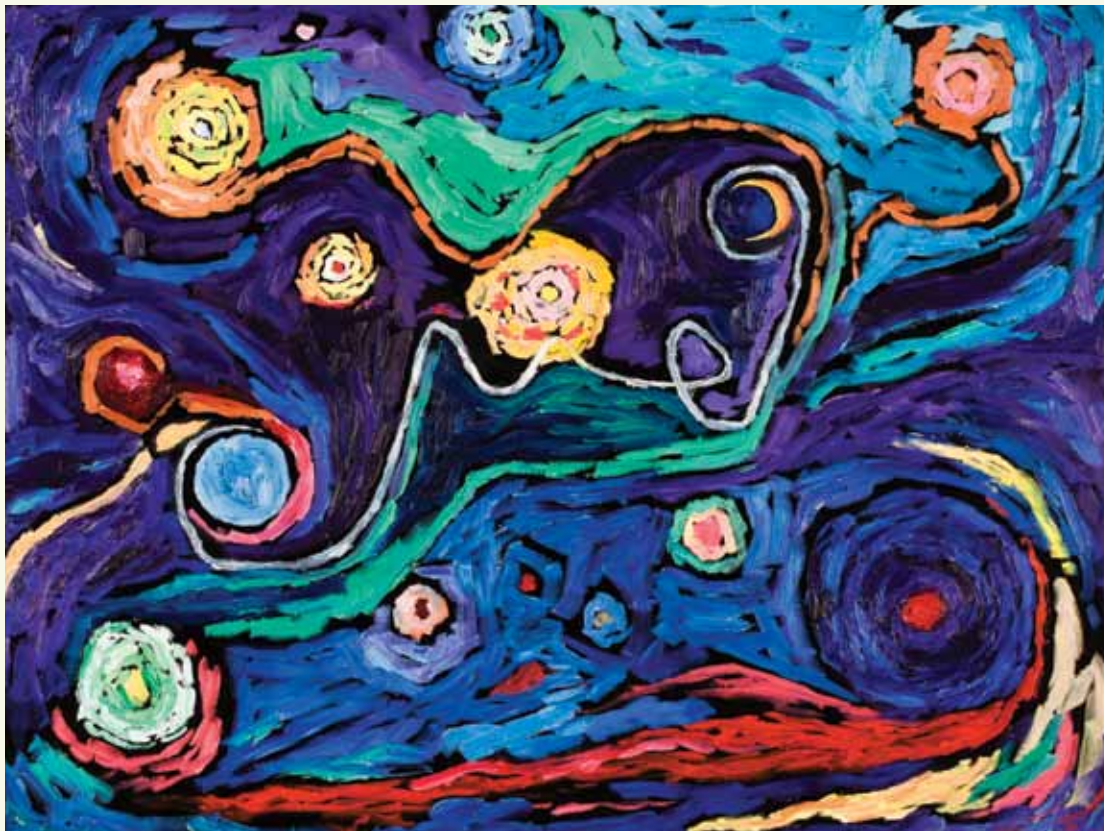
Europa in Beautiful Color

THIS IS THE ONLY high-resolution color observation of Europa captured by *Voyager 2*—and it’s still one of our better views of this mysterious moon. Here, Björn Jónsson has combined data taken through *Voyager*’s Narrow-Angle Camera’s orange, blue, and violet filters to simulate a view our human eyes would see. The fresh, mostly uncratered ice is stained pink by unknown contaminants, possibly a combination of salts dredged up from Europa’s subsurface ocean and sulfur that originated in Io’s volcanoes. The colors in this image are subtler than is typical for published images of Europa, which are usually enhanced to bring out contrast among the moon’s surface features. 🐦

—Emily Stewart Lakdawalla

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Ed Belbruno [below], whose *Cosmic Orbit* is featured here, devised the course that took Japan's *Hiten* spacecraft to the Moon in 1991 using a never-before-tried trajectory based on his application of chaos theory to spaceflight. His concept was published for the first time in *The Planetary Report* (May/June 1992). A mathematician and scientist, Belbruno is also an artist whose oils have been exhibited internationally. He is the focus of an upcoming documentary, *Painting the Way to the Moon*.



The Planetary Society is a remarkable group of people—Members, supporters, and, as CEO Bill Nye is fond of saying, “people who just haven’t found us yet.”

People, like you and me, who want to know more about our cosmic neighborhood, about the mysteries of our world and others, and about the possibility of life beyond

Earth. People who are part of real space missions. People who are shaping our future in space.

Thank you!

Consider introducing a family member, colleague, or friend to The Planetary Society. You might make a gift in their honor. Or give them a gift membership. Or simply share this magazine, or point them to our

website. Share this story of artist and scientist Ed Belbruno; share the stories told in these pages and online; share your own story as a Member of our Planetary Society community.

You'll find many ways to share at planetary.org.

Andrea Carroll
Chief Development Officer

Would you like a copy of Ed Belbruno's article, "Through the Fuzzy Boundary: A New Route to the Moon?" E-mail me at andrea.carroll@planetary.org or call me at (626) 793-5100, extension 214.