THE PLANETARY SOCIETY

THE PLANETARY REPORT

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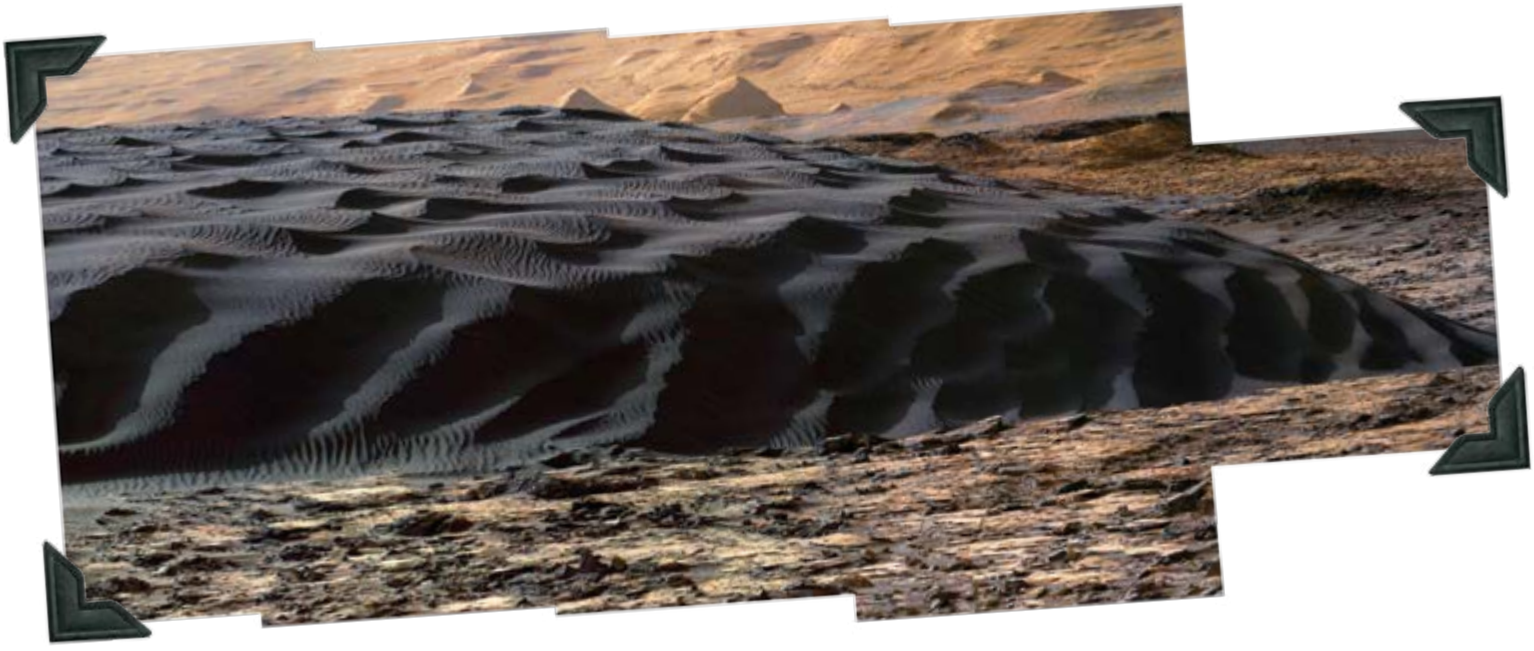
ILLUMINATING CERES

***DAWN* SHEDS NEW LIGHT ON AN ENIGMATIC WORLD**

BREAKTHROUGH STARSHOT ✲ *LIGHTSAIL 2* TEST ✲ MEMBERSHIP UPGRADES

EMILY STEWART LAKDAWALLA
blogs at planetary.org/blog.



Black Sands of Mars

ON SOL 1192 (December 13, 2015), *Curiosity* approached the side of Namib, a massive barchan sand dune. Namib belongs to a field of currently active dark basaltic sand dunes that form a long barrier between the rover and the tantalizing rocks of Mount Sharp. This view, processed by Elisabetta Bonora and Marco Faccin, features wind-carved yardangs (crests or ridges) of Mount Sharp in the background. After taking this set of photos, *Curiosity* went on to sample sand from the dune, and it is now working its way through a gap in the dune field on the way to the mountain.

–Emily Stewart Lakdawalla

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Image: NASA/JPL/MSSS/Elisabetta Bonora and Marco Faccin

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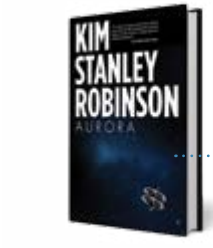

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ON THE COVER: Ceres—the largest body between Mars and Jupiter—once defied categorization regarding its true nature. Is it a star, a planet, an asteroid, or a comet? Although scientists would eventually settle on "dwarf planet," *Dawn*'s arrival will help us begin to understand Ceres. This enhanced-color close-up of Haulani crater shows smooth material and a central ridge on its floor, as well as evidence of landslides from its rim. The rays of bluish ejecta surrounding the crater indicate freshly exposed material. Haulani is 34 kilometers (21 miles) in diameter. *Dawn* captured this image from 1,470 kilometers (915 miles) above the surface. *Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/Emily Lakdawalla*

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Future Forward

Society Policy and Technology Efforts Lead the Way

AMONG THE MANY THINGS that have always fascinated me about the Society, and about my job especially, is to sit in a lecture hall, a conference room, or a restaurant with a group of people who talk about going to Mars—I mean for real. These are the scientists, engineers, and scholars who work on the real costs and schedules for sending spacecraft and people to our nearby planetary neighbor.

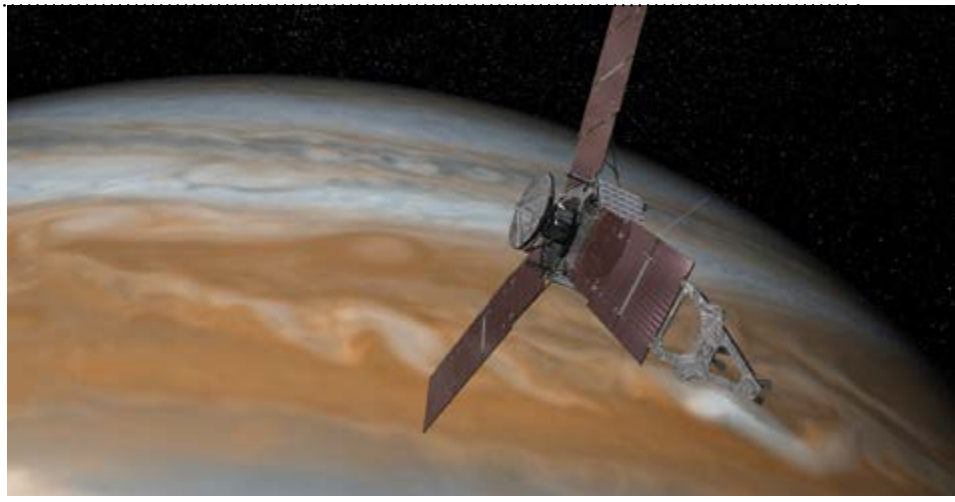
From the start, the Society has supported the robotic exploration of the solar system. Our complex robots enable us to know about Earth's neighbors and to compare our world to all the others out there. I have yet to *not* be astonished at how far away even our closest planetary neighbors are. As space explorers, we do not have the means to send humans to distant worlds; at least, not yet. Instead, we send our best robots, such as rovers to Mars or a sample-capturing system to asteroid Bennu. By the time you are reading this, *Juno* will have arrived at Jupiter to study its core and weather. You can follow *Juno*'s progress at **planetary.org**.

LEADING THE WAY IN WASHINGTON

Recently, several members of the staff and I went to Washington, D.C. For a full day, we met with people from Congress. We showed them the value of planetary science and exploration. We expounded upon the remarkable discoveries that no doubt await us on Mars and Europa. The discovery of life out there would affect the way everyone on Earth feels about our place in space. We explained the big idea: send robotic spacecraft first, then humans can follow. That evening, the Society held a gathering of members and supporters at the Mott House, only a block from the Capitol. We celebrated getting the budget for Planetary Science to its highest level in decades. Overall we are more effective than ever, thanks to your strong support and the good work of our policy analysts.

Presuming that our robotic spacecraft can accomplish the reconnaissance we will need to support such a mission, there are many people in the Mars exploration community who very much want to send astronauts to the surface of Mars. So the next day, a few of us attended the Humans to Mars Summit at George Washington University. There were several presentations and panels of experts on human spaceflight and Mars. Some, such as Buzz Aldrin, were very ambitious, suggesting that we need an enormous increase in the U.S. federal budget to enable NASA to produce the vehicles and deep-space habitats that will be required. Others suggested that costs can be managed best with a coordinated international consortium of space agencies and contractors. Fundamentally, everyone there wanted to send people to Mars. Everyone there agreed that sooner is better than later in this regard.

And we're continuing the conversation, bringing more groups in, with more credible possibilities. Our *Humans Orbiting Mars* report (published last year) inspired some of the best minds at Lockheed Martin. This year the Lockheed Martin team presented a scheme to put humans in orbit around Mars in 2028. It would be three Earth–Mars orbital opportunities sooner than the JPL study team's plan (which we featured at our workshop). But—here's the inspirational aspect of the presentation—we are like-minded, and we are reaching a consensus. The Mars exploration community is starting to home in on a feasible, executable exploration architecture. People are agreeing with and seeing the wisdom in orbiting Mars before attempting to land the many tons of equipment needed to support astronauts on its surface. We can



evaluate hardware, astronauts, vehicles, and methods to avoid contaminating the place, without trying to do it all in one trip. Thanks to you, The Planetary Society is leading the way.

LIGHTSAIL 2's PROGRESS

Speaking of leading, the following week, several of us attended the Day In The Life (DITL) test of our *LightSail 2* spacecraft at California Polytechnic University in San Luis Obispo. When those booms reeled out, and those sails deployed on the big white table, my heart leapt. If you followed along with last year's *LightSail 1*, you may remember that there were a great many snags. Last year, so many little things went wrong that the all-important deployment part of the DITL test of *LightSail 1* had to be delayed.

But this year, everything worked almost perfectly. I say almost because, after everything had gone so well in the morning, and the sails deployed in splendid fashion, the engineers clicking away on their keyboards realized that they could not get the motor to turn off. The little Swiss watch of a gear drive was pushing hard, the sails were fully out, but the spacecraft couldn't communicate with us. We had to partially disassemble the deployment table and shut the system off by hand. After an hour or so of thinking over the problem, the team realized that the motor itself gives off enough electromagnetic interference that it prevents the antenna from catching the signal from the ground antenna. The team settled in, talked it over, and found the solution to this and other subtle problems detected as result of testing. So, by the time our little spacecraft with the great big sail is due to be integrated into SpaceX's Falcon Heavy launch vehicle (a.k.a. Huge Rocket), I'm confident that we will be very ready. I'm excited about the next flight of *LightSail* and delighted with the strength of our design and operations team.

SAMPLES OF BENNU

While we were in Washington working to advance the exploration of Mars and Europa, the *OSIRIS-REx* spacecraft (that's the *Origins Spectral Interpretation Resource Identification Security Regolith Explorer*) was on its way to Cape Canaveral. We've been part of this mission since its inception. It will visit asteroid Bennu (which Society members helped to name) and bring back samples of what must be a bit of the ancient solar system.

For me, exploring an asteroid and bringing back a sample of its surface is part of the bigger idea: someday we will have to be ready to defend Earth from an impact, a catastrophic moment when a chunk of solar system material comes hurtling our way. Because of their remoteness and their size, most potential impactors are hard to find. Rendezvousing with Bennu will be a technical achievement that will help us learn just what we may need to do to nudge one of these things out of Earth's orbital path through space. It's one more example of the space science the Society has advocated for since our beginnings over 35 years ago.

All through this, we have made the world aware of what we're up to. When you're in love, you want to tell the world. And, so we do. The Society is growing in influence and spreading planetary knowledge. Together we are changing the world.

Bill Nye

ABOVE Juno *will allow us to peer underneath Jupiter's dense atmosphere for the first time. While* Juno*'s primary goal is to answer questions about the gas giant's formation and evolution, it will also enhance our understanding of the origins of our solar system.*

Image: NASA/JPL-Caltech

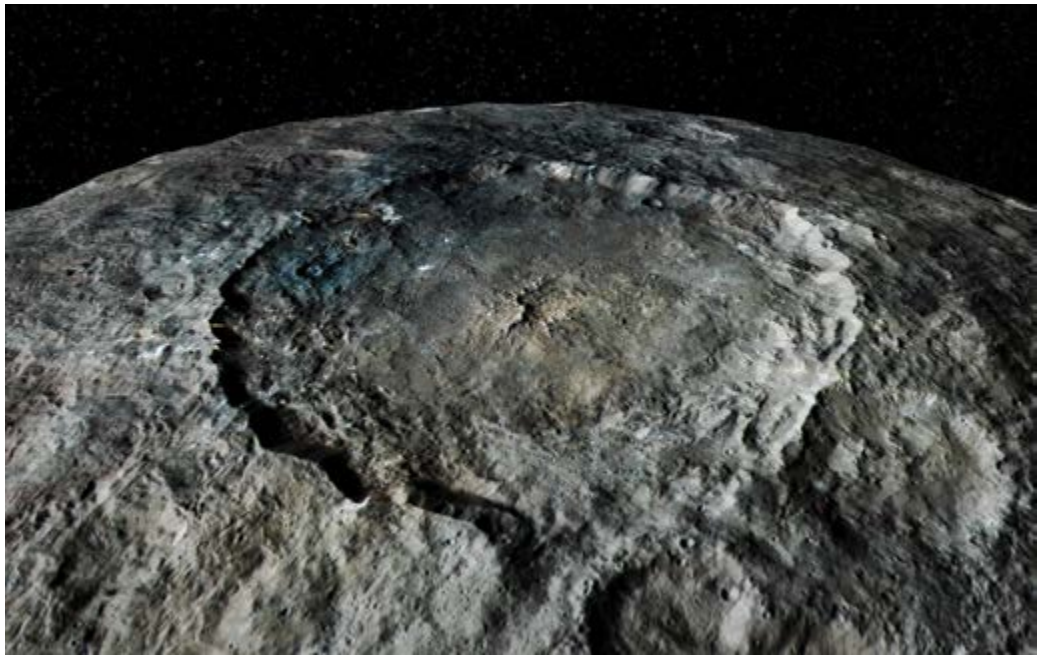
SIMONE MARCHI *is a Senior Research Scientist at the Southwest Research Institute in Boulder, Colorado.*

Unveiling Ceres

Dawn Solves Old Mysteries and Reveals New Ones

ASTRONOMERS IN THE LATE 18th century speculated about the existence of a missing planet presumably located between the orbits of Mars and Jupiter. The main argument in support of such a claim, first formulated by Johannes Kepler in 1596, was based on the observation that the distances between planets are spaced at regular intervals following a simple analytical expression known as the Titius-Bode law. Assuming the distance between the Sun and Earth is equal to 10, the distance of a planet from the Sun is represented by 4, 4+3, 4+6, 4+12, 4+48, 4+96, respectively, for Mercury, Venus, Earth, Mars, Jupiter, and Saturn. Notably, the progression skips 4+24, which corresponds to the distance between Mars and Jupiter. Eventually, the missing planet was serendipitously discovered by astronomer and Catholic priest Giuseppe Piazzi from the Royal Observatory of Palermo, Sicily, on January 1, 1801.

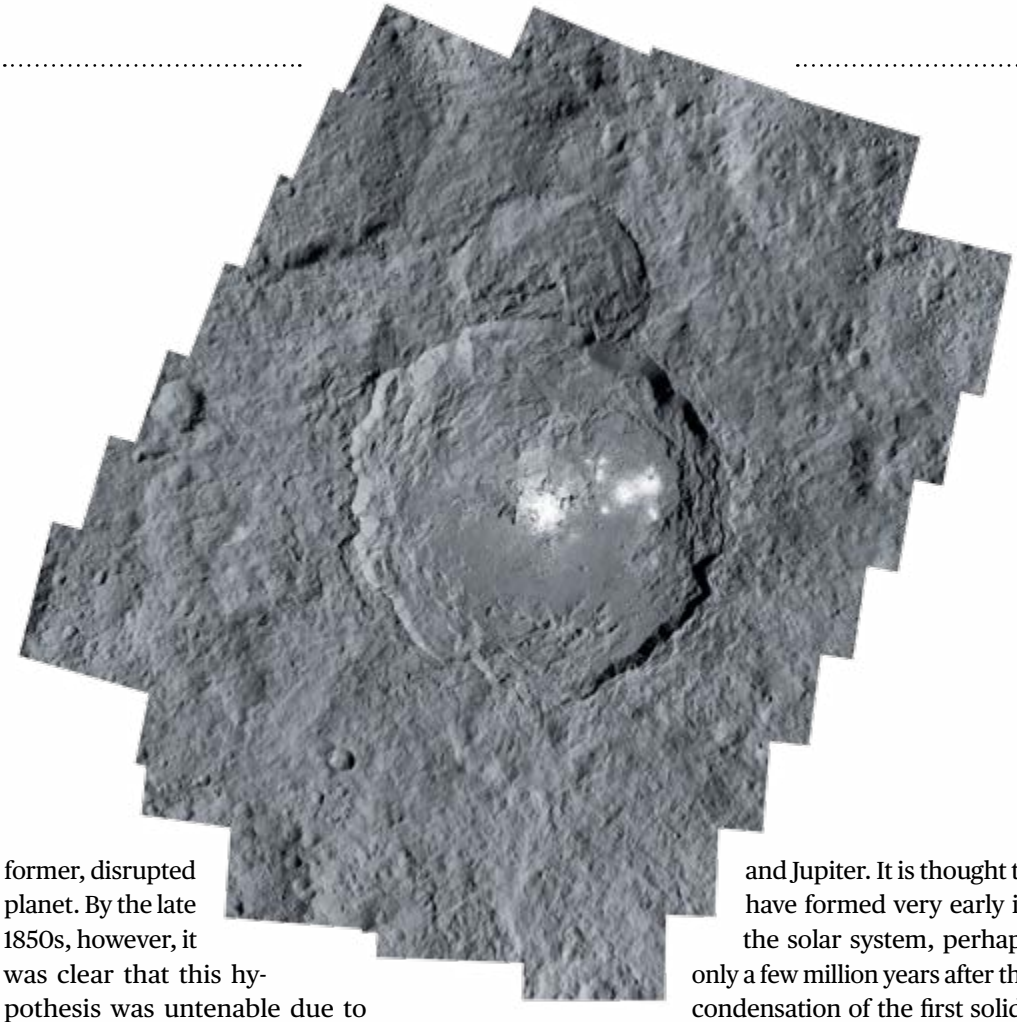
What is most striking about this discovery is that at first the new object, later named Ceres, was mistaken for an unknown star, and then a comet. Soon after Piazzi's first observations, Ceres was lost for several months. When it was eventually reobserved—thanks to a truly international search involving astronomers in France, Germany, the United Kingdom, and Italy—it was officially called a planet. This classification did not last for long, however, and in 1802 William Herschel proposed calling Ceres and the newly discovered Pallas, "asteroids," or "star-like" objects. Still, the idea that a planet should be found in this region of space was so deeply rooted that it led Wilhelm Olbers (the German physician and astronomer who discovered Pallas) to propose that Ceres and its then-known siblings could be fragments of a



RIGHT *Efforts to determine the true nature and origins of this small world between Mars and Jupiter have kept scientists busy since Ceres was first discovered more than 200 years ago. Ceres' Dantu crater has features that hint of a tectonic past for the dwarf planet's surface. Linear structures spread out over Dantu's floor and, outside Dantu's rim, these structures continue in the form of scarps and ridges. Dantu is 78 kilometers (about 47 miles) across.* Dawn *captured this image from an altitude of 385 kilometers (about 240 miles).*

OPPOSITE PAGE *Ceres' now famous bright spots, which scientists believe to be salts, reside on the floor of Occator crater. About 92 kilometers (57 miles) wide and about 3 kilometers (2 miles) deep, Occator is also among Ceres' youngest features.*

Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



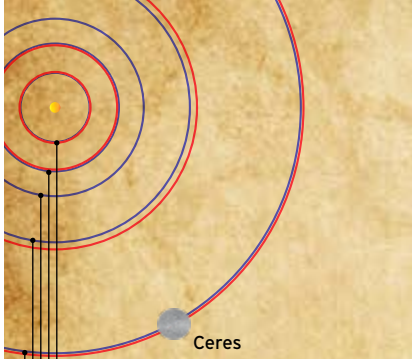
former, disrupted planet. By the late 1850s, however, it was clear that this hypothesis was untenable due to their widely scattered orbits. This led the way for these objects to be recognized as small, independent bodies.

WHY CERES IS IMPORTANT

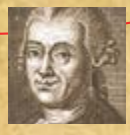
Ceres' importance to modern astronomers and planetary scientists is perhaps best explained by the intense debate about its true nature. Ceres is the only astronomical object to have been classified a comet, a planet, an asteroid, and in more recent times by the International Astronomical Union, a dwarf planet. This difficulty in its categorization reflects the characteristics of a transition object between the inner and outer solar system. Ceres is too large to be a simple asteroid, yet too small to be a regular planet such as Earth or Mars. Its almost-circular orbit rules out its being a comet, yet its presumed icy composition is reminiscent of the cold, outer solar system where comets originate.

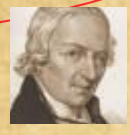
Regardless of its true nature, with an average diameter of 939 kilometers (583 miles) Ceres is by far the largest object between Mars and Jupiter. It is thought to have formed very early in the solar system, perhaps only a few million years after the condensation of the first solids from the primordial proto solar nebula. Furthermore, current theories of solar system formation suggest asteroids–and Ceres–are leftover debris from the formation of the planets, thus they can give clues to the solar system's early history. To put things into perspective, Ceres formed well before the Earth was fully accreted, and before the Moon was formed.

These and other aspects make Ceres a suitable target for *Dawn*, a dedicated reconnaissance space mission. Launched in 2007 under NASA's Discovery program, *Dawn* has been in orbit around Ceres for about one year, executing a complex orbital dance from a starting altitude of 14,000 kilometers (8,700 miles) above its surface to a mere 385 kilometers (about 240 miles) in the final orbit. These orbits have been precisely engineered to achieve primary scientific objectives such as global mapping and compositional investigation of Ceres' surface, along with the characterization of its internal structure by measuring the gravity field.



BODY	PREDICTION	ACTUAL
Mercury	(0+4)/10=0.4	0.39
Venus	(3+4)/10=0.7	0.72
Earth	(6+4)/10=1.0	1.0
Mars	(12+4)/10=1.6	1.52
Ceres	(24+4)/10=2.8	2.77
Jupiter	(48+4)/10=5.2	5.2
Saturn	(96+4)/10=10.0	9.54
Uranus	(192+4)/10=19.6	19.18

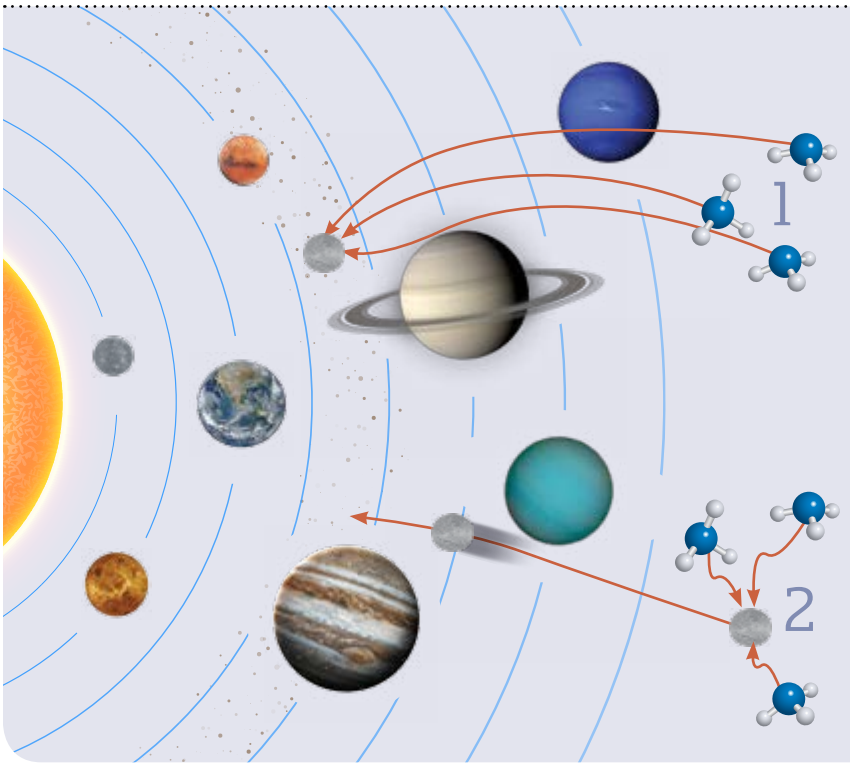




The Titius-Bode Law

The Titius-Bode law is an empirical rule giving the approximate distances of planets from the Sun. It was first announced in 1766 by the German astronomer Johann Daniel Titius but was popularized a few years later by his countryman Johann Elert Bode. Although the justification for the mathematical relationship is not fully understood, scientists are analyzing data to see if the Titius-Bode law might predict placement of planets in newly discovered extrasolar multiplanet systems.

Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



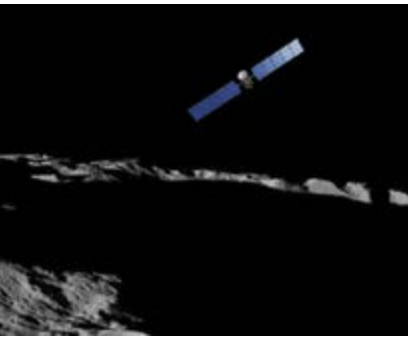
Where did the ammoniated clays on Ceres come from?

SCENARIO ONE

Ceres could have formed in situ, between Mars and Jupiter, and accreted within the first few million years a thick coating of outer solar system pebbles (full of NH3 and N-rich ices) that were drifting toward the inner solar system.

SCENARIO TWO

Ceres, as well as myriad so-called Kuiper Belt objects, completely formed in the outer solar system and then got knocked out of its original position during the migration of the giant planets and pushed into its current orbit.



ABOVE Dawn, *the first spacecraft to orbit a dwarf planet, arrived at Ceres on March 6, 2015. The spacecraft orbits closer to Ceres' surface than the International Space Station's average altitude above Earth.*

CERES' FUZZY ORIGIN

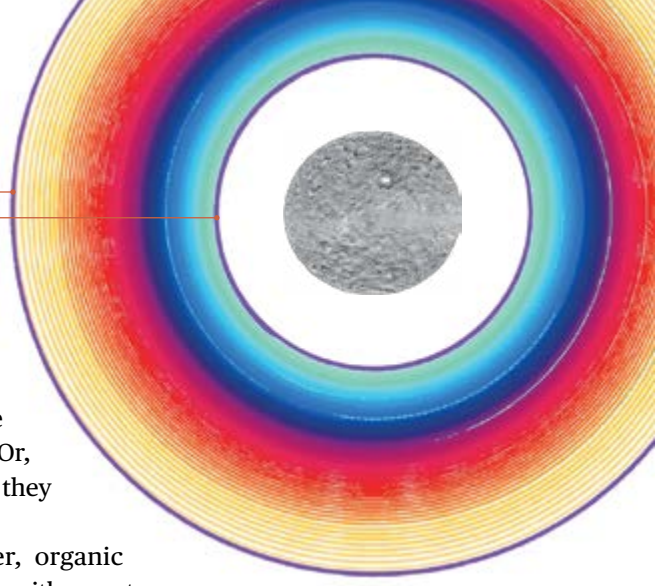
What is Ceres made of? What does it look like at close range? *Dawn* has provided answers to these fundamental questions, but it has also raised new, unexpected ones.

Before *Dawn*'s arrival at Ceres we had only a cursory picture of its surface and shape. The powerful Hubble Space Telescope had resolved its silhouette, giving just enough hints of surface features to raise our interest and desire to know more. Another space facility, the Herschel Space Observatory, gathered data that suggest the presence of water vapor in proximity of Ceres. Its average surface is pitch black, almost as dark as charcoal, perhaps an indication of enrichment in organic compounds. Other minerals such as clays were proposed to exist on the surface, based on data gathered over three decades by ground-based telescopes.

One of the first achievements by *Dawn* is its discoveries about Ceres' surface composition. When the spectrometer on board the spacecraft observed the surface, the acquired data returned a clear, unambiguous signature of the presence of ammoniated clays. Common terrestrial clays may contain alkali cations (positively charged ions) such as potassium (K^+). However, clays found on Ceres contain the cation ammonium ($NH4^+$), which has likely replaced potassium or other alkalis. Ammoniated clays, although easy to make on terrestrial conditions, are uncommon in meteorites, which are considered to originate from asteroids. Furthermore, ammoniated clays appear to be ubiquitously present on the surface of Ceres, implying they were the likely result of widespread processes. It thus became clear that Ceres had experienced a peculiar formation and/or evolution unlike other asteroids and meteorites.

What are the implications of this observation for Ceres' origin? The few laboratory experiments available on ammoniated clays in primitive meteorites indicated that ammonium likely originated from ammonia (NH3). Thus, either ammonia was available in the make-up of Ceres, or ammonia was a byproduct of an internal evolution of nitrogen-rich compounds. From a cosmogonic point of view, it

SIMONE MARCHI*'s research focuses on the formation of terrestrial planets and the Moon, the geology of asteroids and terrestrial planets, the spectroscopy and dynamics of minor bodies, and on meteorites. Aside from* Dawn*, he also works on Europe's* Rosetta*,* BepiColombo*, and* JUICE *missions.*



remains unclear whether compounds that condensed between Mars and Jupiter could bear enough nitrogen to drive the right chemistry that would explain the widespread presence of ammoniated clays on Ceres.

On the other hand, ammonia- and nitrogen-rich ices are expected to have condensed in the colder outer solar system beyond 5 to 10 astronomical units, as witnessed on Pluto-Charon and comets. This naturally raises the question whether outer solar system materials were accreted by Ceres.

From a dynamical standpoint, this is indeed possible in two broad scenarios. In one scenario, Ceres could have formed in situ, between Mars and Jupiter, and within the first few million years accreted a thick coating of outer solar system pebbles that were drifting toward the inner solar system. In a second scenario, Ceres, as well as countless so-called Kuiper Belt objects, completely formed in the outer solar system and then got knocked out of its original position during the migration of the giant planets and pushed into its current orbit. Either way, the early accretion of ammonia-rich and/or nitrogen-rich ices would have made them available during the initial stages of Ceres' internal evolution. Radiogenic heating would have readily produced liquid water, resulting in the production of ammoniated clays.

CLUES AND OTHER MYSTERIES

Clues to the origin of Ceres are not the only important discoveries by *Dawn*. For instance, a number of intriguing and mysterious surface features have been detected, including a 4-kilometer (2.5-mile)-tall isolated mountain named Ahuna Mons. There are also localized, geologically recent bright splotches, the most notable of which are within the floor of the prominent Occator crater. There are also the odd, subdued morphology of the largest recognizable impact feature, the 280 kilometer (174 mile) Kerwan crater, and the astounding lack of larger impact craters. The latter, according to current theoretical models, should be present in a significant number, yet they are apparently not visible. Were they obliterated by widespread resurfacing, perhaps associated with the early internal evolution? Or, contrary to the odds, did they not form?

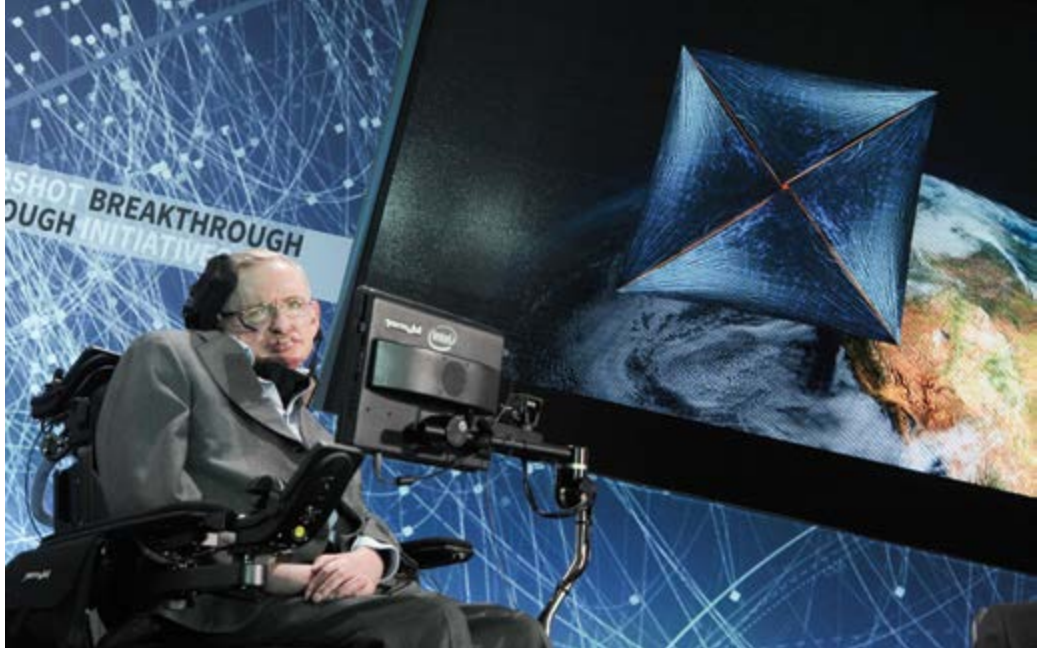
The presence of water, organic matter, and clays, together with a past evolution that possibly resulted in widespread liquid water, has important astrobiological implications. For instance, if a subsurface ocean was ever present on Ceres for a protracted time span, were the conditions met for early biological life to spawn?

Data returned by *Dawn* over the next months will help elucidate these mysteries. To put it in Piazzi's own words, "We shall wait for the observations to speak to us, for Ceres itself to speak to us." With its debated nature, Ceres still poses new, unexpected challenges. It appears to be a key transition object, both dynamically and compositionally. Surely, the astronomers involved in the discovery of Ceres more than 200 years ago would be delighted to know what a treasure chest it turned out to be for planetary sciences.

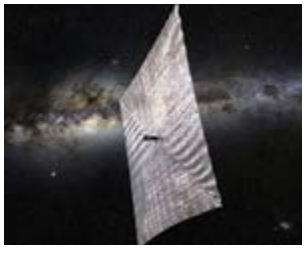
ABOVE *In its gradual descent toward Ceres' surface,* Dawn *completed 160 revolutions around the dwarf planet as it followed a tight spiral from high altitude mapping orbit (HAMO) to low altitude mapping orbit (LAMO). HAMO took place at an altitude of 1,470 kilometers (913 miles), while LAMO is operating at 385 kilometers.*

LEFT *Ahuna Mons is Ceres' tallest mountain. Geologists are uncertain as to why it rises so sharply out of an otherwise unremarkable area. On its steepest side, Ahuna Mons rises almost 4 kilometers (2.5 miles) above the surface. The large crater next to Ahuna Mons is about 17 kilometers (10.5 miles) in diameter.*

Graphic: NASA/JPL-Caltech; Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



TOP *Stephen Hawking took part in the April 12 press conference announcing Breakthrough Starshot, a proposed mission to send a flock of mini-solar sails to Alpha Centauri in about 20 years. Hawking is on the board for the Starshot project, a brainchild of Russian billionaire physicist Yuri Milner.*



ABOVE *In 2017, The Planetary Society's* LightSail 2 *will launch to Earth orbit aboard a SpaceX Falcon Heavy.*

Pathway to the Stars

Our Solar Sails Paved the Way for Breakthrough Starshot

HIGH ABOVE New York City, inside One World Trade Center, a group of scientists and entrepreneurs held a press conference on April 12, announcing a plan to send a fleet of miniature spacecraft to the stars.

The Breakthrough Initiatives group, led by billionaire Russian physicist Yuri Milner, launched a $100 million technology grant program. The program will fund studies to investigate whether a fleet of wafer-sized spacecraft equipped with reflective sails can be blasted with lasers, accelerated to 20 percent the speed of light, and sent to our stellar neighbor, Alpha Centauri, in a couple of decades. Tiny probes on the spacecraft would record data and images and relay them back to Earth.

Judging by the flood of resulting press coverage, the plan, formally known as Breakthrough Starshot, has captured the public's imagination. The effort has an advisory committee stacked with reputable scientists, and a board of directors that includes cosmologist Stephen Hawking and Facebook founder Mark Zuckerberg.

THE PLANETARY SOCIETY'S CONNECTION

Breakthrough Starshot is connected to The Planetary Society through its founders and efforts to advance solar sailing technology. Ann Druyan, a Starshot management and advisory committee member who co-wrote the original *Cosmos* documentary series with her late husband, Society cofounder Carl Sagan, described this connection just 20 minutes into the press conference.

"I remember in the 1970s, when [Sagan] first described to me this means of moving through the cosmos," she said. "I couldn't get over what a mythic achievement it seemed to me that it would be able to ride the light. What an immaculate way of traveling through the cosmos."

Sagan championed solar sailing with fellow Society cofounders Louis Friedman and Bruce Murray, who were working on the concept at NASA's Jet Propulsion laboratory in Pasadena, California. There, scientists and engineers hoped to build a kilometers-wide solar sail spacecraft to rendezvous with Halley's Comet when it flew past Earth in 1986. The plan never came to fruition, but the idea lived on in the form of *Cosmos 1*, the Society's privately funded solar sail that was ultimately doomed by a rocket failure in 2005.

AUDACIOUSLY TINY SAILS

"A few years after Carl died, I became involved

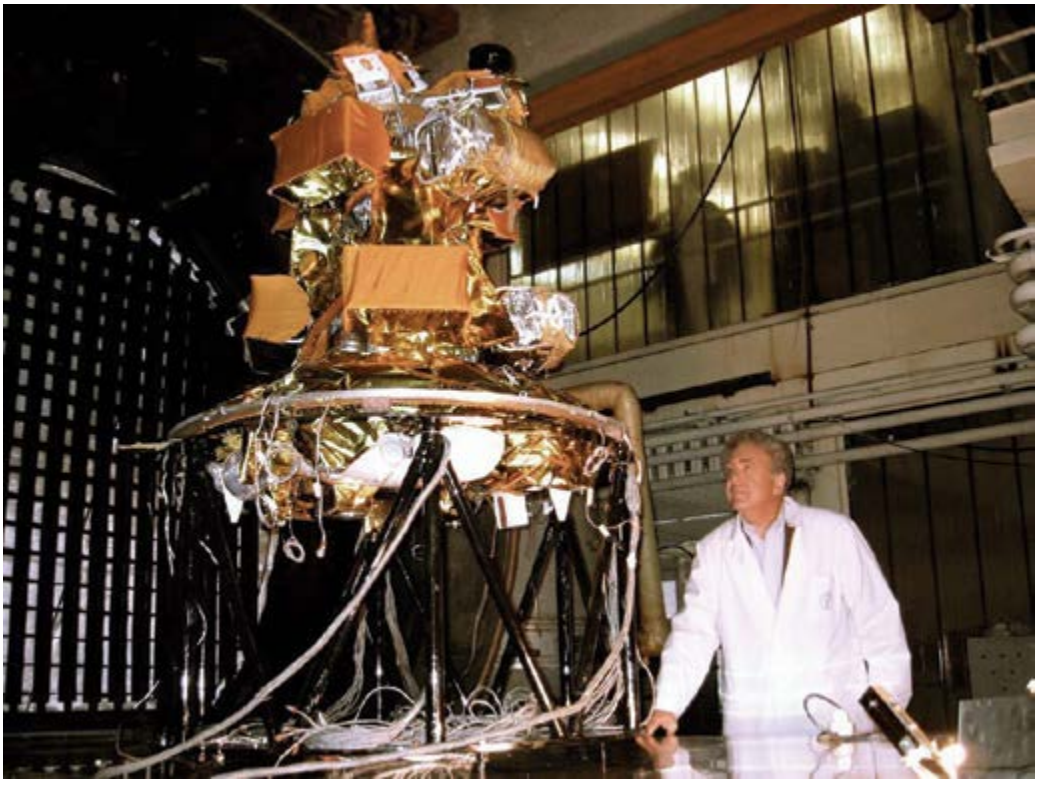
This story, by Planetary Society Digital Editor Jason Davis, appeared on April 22, 2016 at planet.ly/lightsailstarshot.

Photo: Dennis Van Tine, Sipa USA; Illustration: Josh Spradling/The Planetary Society

with The Planetary Society, working with Louis Friedman, who really wrote the textbook on solar sailing," Druyan said. "We were working on a proof-of-concept mission. But one thing we didn't think of was making the sail tiny—making the actual craft tiny. And I think that's the inspiring audacity of [Breakthrough Starshot]."

gram—a mass reduction by a factor of 5,000. And the sail would also need to be lighter and more reflective, possibly built from an exotic material like carbon nanotubes rather than Mylar.

Not surprisingly, Friedman, who led the Society's *Cosmos 1* project as well as *LightSail*'s initial development, is on the Starshot advisory committee. During a recent phone call he said that, while there is a large technology gap between *LightSail* and what Breakthrough Initiatives hopes to achieve, *LightSail* represents a key milestone in the effort to pair space sails with miniaturized technology.



LEFT *Planetary Society cofounder Louis Friedman looks over the Society's* Cosmos 1 *flight unit. Friedman is well known for his decades-long work on solar sailing and is the author of* Starsailing: Solar Sails and Interstellar Travel.

ABOVE *Russian space scientists and engineers stand below a single* Cosmos 1 *sail blade in the lab at Moscow's Lavochkin Association.*

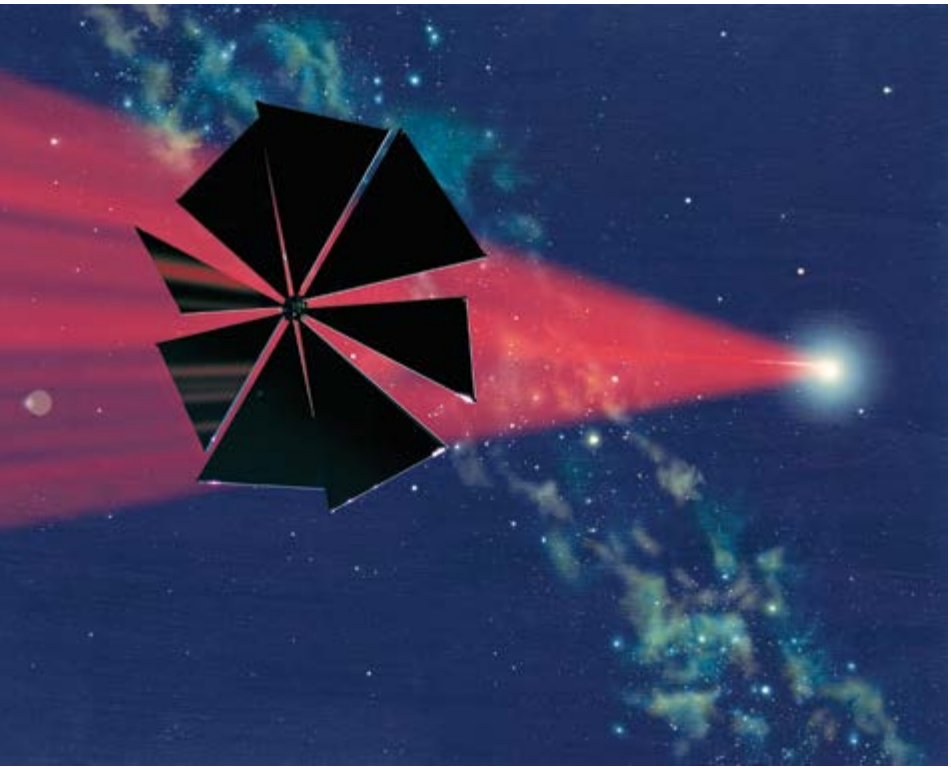
Cosmos 1 had a sail area of 600 square meters, whereas the Alpha Centauri-bound "nanocrafts," as Breakthrough calls them, would have sails with diameters of about 4 meters. Other solar sail spacecraft that have flown to date include Japan's *IKAROS* (196 square meters), NASA's *Nanosail-D* (9.3 square meters), and The Planetary Society's *LightSail 1* (32 square meters). If successful, *LightSail 2* (also 32 square meters) will be just the second solar sail spacecraft to demonstrate purposeful flight by light—*IKAROS*, thus far, is the first and only craft to do so.

Whereas *LightSail* weighs about 5 kilograms, the Starshot nanocrafts might weigh just a

"We went to a 3U CubeSat after working with spacecraft that weigh hundreds of kilograms," he said. "And we started working with these miniature sails. So *LightSail* is a motivator and the right direction. I'd definitely say it's a predecessor in terms of the technology and the research that's been used." Friedman's recent book, *Human Spaceflight: From Mars to the Stars*, describes the history of these projects.

Photos: Lavochkin Association/The Planetary Society

"The thing that makes solar sails so important is that they're the pathway to the stars … There's no other practical means of doing it."



ABOVE *In the early 2000s, The Planetary Society commissioned space artist Michael Carroll to illustrate the concept of star sailing. Here, a* Cosmos*-style solar sail glides through the Milky Way propelled by a laser from its home planet.*

BREAKTHROUGH'S CHALLENGES

During the *LightSail 1* mission, flight controllers faced a barrage of challenges, including software glitches, communication outages and a radio malfunction. *LightSail 2* is sure to present its own hurdles. But those difficulties pale in comparison to what must be overcome to actually make Breakthrough Starshot a reality.

The group's website lists 25 major engineering challenges that span every aspect of the project, including: How do you keep the spacecraft and sail in one piece under the searing energy of a high-power laser? What will enable the probes to communicate over such vast distances? Can they be steered within camera range of an extrasolar planet? And what about the political hurdles of constructing a James-Bond-villain-like array of ground lasers?

Right now, debating whether Breakthrough Starshot can solve every challenge and complete the project as envisioned may not be as important as asking the technical questions in the first place. "The fact that they're openly doing it, and inviting a worldwide community to work on it, is encouraging," Friedman said.

There are also intermediary missions that could help refine nanocraft solar sail technology while providing reconnaissance for an eventual mission to Alpha Centauri. Friedman likes the idea of sending a small telescope far enough from the Sun to use the Sun as a gravity lens, capturing otherwise impossibly high-resolution images of other star systems.

"You could use the solar gravity lens focus to image an exoplanet and get kilometer-scale imaging of a habitable world," he said. "One that you might want to target as a destination."

CubeSats like *LightSail*, which can hitch free rides to orbit and utilize off-the-shelf hardware, have drastically lowered the cost of entry-level space missions. Breakthrough Initiatives believes its sail nanocraft could be mass-produced at the cost of an iPhone. If that turns out to be the case, could fleets of the tiny explorers be sent all over the solar system, revolutionizing the field of planetary science?

It's possible. But for Breakthrough Initiatives and Friedman, the ultimate destination remains much farther away.

"I've always said, right from the very beginning: The thing that makes solar sails so important is that they're the pathway to the stars," Friedman said. "There's no other practical means of doing it."

Illustration: Michael Carroll ©The Planetary Society

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

Life, the Universe, and Everything

A Death Valley Conversation with Tyler Nordgren and Jill Tarter

DEATH VALLEY GETS *a bum rap. Ominous name notwithstanding, it is one of the most spectacular and inspiring spots on our pale blue dot, and you'll have a tough time finding better night skies between Los Angeles and Las Vegas. The National Park Service's decision to celebrate a "Celestial Centennial" there was genius. All of the national parks are celebrating the 100th birthday of the system this year, and each puts its own spin on the occasion.*

This past spring, I was invited to the park for a conversation with Jill Tarter and Tyler Nordgren. Jill has been my guest on Planetary Radio several times. No one who is so closely identified with the Search for Extraterrestrial Intelligence (SETI) speaks more articulately or with more passion than this scientist. Jill holds the Bernard M. Oliver Chair at the SETI Institute, and continues the search. She is also deeply involved in generating not just science literacy, but also the love of investigation and exploration.

Tyler Nordgren is a busy academic astronomer at the University of Redlands, teaching and working on mysteries like dark matter. But he's also a gifted artist and photographer. A loose but fruitful partnership with the Park Service resulted in Tyler's gorgeous book, Stars Above, Earth Below–A Guide to Astronomy in the National Parks, *as well as an ongoing series of posters that bring home a phrase Tyler coined: "Half the park is after dark."*

On April 9, the three of us talked for over an hour in the crowded Death Valley Visitors' Center auditorium. I learned, without surprise, that they had a separate yet shared genesis of wonder as children. It was this sense of awe that we devoted much of our lively discussion to, and we attempt to capture it below. I hope it will make you want to listen to our entire conversation in the April 26, 2016 Planetary Radio *episode at* planetary.org/radio.

Death Valley photo: Tyler Nordgren

MK Jill, how goes the search?

JT Well, the search goes on. We use the Allen Telescope Array every day. We just last week changed our modality of observation because

"President Barack Obama talked about how the wonders of astronomy inspire generations, and about this young boy in Brooklyn who wanted to learn about the stars. That boy was Carl Sagan, who would inspire the next generation. I was a child of that generation. I bought the *Cosmos* book with my allowance, read along each week, and I teach out of that book today. So the cycle of inspiration continues..."

of the results from the Kepler spacecraft that indicated essentially every star has a planet. We had been observing all the exoplanet systems that were known, but now we've started observing 20,000 red dwarf stars that are much closer to us. Many of them haven't been observed or planets haven't been found, but statistically we know they should be there. So we're looking at our closest neighbors.

BELOW *[l to r] Mat Kaplan, Jill Tarter, and Tyler Nordgren.*

MK Tyler, this is not precisely your field; you largely deal with that stuff that makes up most of the universe that none of us can see. Do you find that this topic of SETI and the possibility of life elsewhere generates the same sense of awe in you?

TN Oh, absolutely. As a kid I looked up at the sky and wondered what was out there, were there other civilizations around any of those stars looking back at me? We were having a class on this just last week, and the discussion in that room was about whether we should listen, should we broadcast, what it will be like if we ever hear from somebody else. That is what captures the passion and interest of generation after generation.

I had the great pleasure of going to the White House as part of the White House Astronomy Night. President Barack Obama came out and talked about how the wonders of astronomy inspire generations, and about this young boy in Brooklyn who wanted to learn about the stars. That boy was Carl Sagan, who would inspire the next generation. I was a child of that generation. I bought the *Cosmos* book with my allowance, read along each week, and I teach out of that book today. So the cycle of inspiration continues.

JT Like Tyler, when I was young–six or eight–I got to walk along the beaches of Florida's Manasota Key with my dad. There were such dark skies. I remember looking up and wondering whether, on a planet circling one of those stars, there was a young creature walking along an ocean with its parent looking back at me. So I have always felt that possibility.

Photo: The Planetary Society

MK Do you both feel fortunate to be living and working in the professions you're in?

JT Definitely. I just wish I were 50 years younger, because I want to see what happens in the next 50 years. It is going to be awesome.

MK Tyler, my colleague, Emily Lakdawalla, calls this the Golden Age of Exploration.

TN I agree. Just this last summer we finally got images of the surface of Pluto. Who could have imagined what a beautiful, crazy, confusing place that would turn out to be? It reminds me of back when we first started exploring other moons, like the moons of Jupiter. We thought they would look something like our own Moon, a grey, lifeless, cratered world. Then we got there and we saw that they were beautiful, amazing, and confounding. And now, there's Europa, where we're about to send another spacecraft. I, for one, and this is not backed up by any science, but I swear there's probably something swimming around. I'm going to go out on a limb and say that. Something beyond our wildest dreams will be found in this solar system, if not our lifetimes, then in the next generation.

MK So does that sense of awe still drive what you do, Jill?

JT Yes. Otherwise I wouldn't be able to get up out of bed the next day and go fight with someone over funding. That's the only bad part of this. But yes, I got hooked thinking about trying to answer questions by exploring rather than believing and I've stayed hooked. It's a privilege. Come on. To be a scientist, to have that be your path, the way you make a living, by posing questions and then trying to answer them, and, if you're lucky, coming up with an answer that no one else has yet figured out. It's sleuthing, it's puzzle solving, it's spectacular. More people should think about science as a career.

TN When I was in graduate school we'd take a break, go out for lunch, and as we were getting ready to go back to work we'd look around at one another and say, "Time to push back the frontiers of human knowledge," and we'd go back to work, and we would joke about it. But that's what we were doing. That's what we had the privilege and the opportunity to do, and who knows what discovery we might make that day, and if tomorrow is the day we discover life elsewhere, what a great day that will be.

WHAT'S UP? *by Bruce Betts*

IN THE SKY

Bright, reddish Mars, in the South in the evening sky, will fade over many weeks as Earth and Mars get farther apart. It will remain near yellowish Saturn and the red star Antares in Scorpius. Jupiter is bright in the West in evening. By late in August, it is joined by the even brighter Venus and the dimmer Mercury soon after sunset low in the West. The Perseid meteor shower peaks August 12–13, with increased activity several days before and after the peak. Particularly after the Moon sets around midnight, the Perseids should yield 60 to 80 meteors per hour visible from a dark site. On September 1, an annular solar eclipse will cross central Africa.

RANDOM SPACE FACT

When Pluto was last at its current point in its orbit around the Sun—in other words, one Pluto year ago (1768)—the United States didn't exist and the American Colonies belonged to Great Britain.

TRIVIA CONTEST

Our December Solstice contest winner is Stephen J. Tognoli of Hollywood, Florida. Congratulations! **THE QUESTION WAS:** What material forms the bulk of Mars' seasonal polar caps (the ones that grow in the winter and dissipate in the summer)? **THE ANSWER:** Carbon dioxide ice, also known as dry ice.

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

Within the Local Group of galaxies, what is the name of the one other galaxy that is similar in size to, or larger than, our own Milky Way Galaxy?

E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). By entering this contest, you are authorizing *The Planetary Report* to publish your name and hometown. Submissions must be received by August 1, 2016. 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*.

HAPPENING ON
PLANETARY RADIO
planetary.org/radio

SPACE POLICY EDITION

HUMAN SPACEFLIGHT AT THE END OF THE OBAMA ERA

The premiere of a new monthly "policy" segment, examining the latest NASA budget move by the House of Representatives, as well as Lockheed Martin's new "Mars Base Camp" proposal. planet.ly/spacepolicy

NEW!

CELEBRATING YURI'S NIGHT WITH SAMANTHA CRISTOFORETTI

We're partying under Space Shuttle Endeavour in the first of two shows featuring interviews from the worldwide celebration of space. *Star Trek*'s Robert Picardo will talk about his new video newsletter, the *Planetary Post*, and we'll visit with Samantha Cristoforetti, who returned last June from 200 days aboard the International Space Station. planet.ly/yurisnight

DISCOVERER OF THE FIRST EXTRASOLAR WORLD

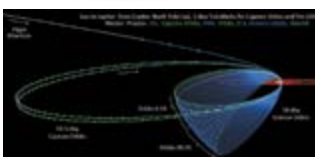
Michel Mayor and his team rocked the astronomy world with their 1995 announcement, but this modest man says it was a discovery whose time had come. planet.ly/extrasolar

INTERSTELLAR DREAMS

Famed science fiction author Kim Stanley Robinson is back with *Aurora*, a cautionary tale about just how difficult interstellar travel may be. planet.ly/kimstanley

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

ON *PLANETARY.ORG*



NOW AT JUPITER

WHAT TO EXPECT FROM JUNOCAM *Juno* doesn't need a camera, but it has one! What will we see? planet.ly/junocam

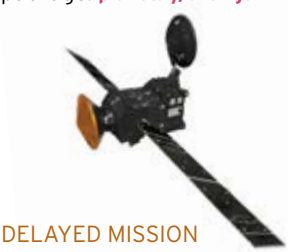
RED DRAGON AND PLANETARY EXPLORATION What impact might SpaceX's Dragon spacecraft have on planetary exploration? planet.ly/reddragon

LOCKHEED WANTS HUMANS ORBITING MARS Casey Dreier looks at the similarities between Lockheed Martin's plans and the ideas set forth in our *Humans Orbiting Mars* report. planet.ly/lockheed

INSIDE POLITICS

FINDING FUNDING IN WASHINGTON An astrophysics graduate student attends a workshop to learn about the federal budget and advisory process, and to develop science advocacy skills. planet.ly/funding

LUNAR FARSIDE *CHANG'E 4* LANDER The mission team is deciding the landing location, as well as the mission's instrument package. planet.ly/change4



DELAYED MISSION

***EXOMARS* DOMINO EFFECT** Anatoly Zak on how the postponement of ESA and Roskosmos' *ExoMars* rover might affect other missions. planet.ly/dominoeffect

OPPORTUNITY UPDATE

FIELD REPORT FROM MARS: SOL 4365 Larry Crumpler details significant concentrations of clay minerals in an outcrop and ridge, as well as some confusing readings. planet.ly/sol4365

BACK TO THE MOON

NEW LUNAR MOSAICS Jason Davis finds buried treasure in a computer-intensive process to extract data from more than 90,000 image frames digitized from NASA's *Surveyor* program. planet.ly/lunarmosaics

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

ABOVE *Planetary Society members had fun photographing the 2016 total solar eclipse from Indonesia.*

Experience an Eclipse!

CHILE ANNULAR ECLIPSE EXPEDITION
FEBRUARY 22–MARCH 4, 2017
With optional Easter Island extension March 4-7, 2017

SUN VALLEY IDAHO TOTAL SOLAR ECLIPSE
AUGUST 18-26, 2017
From Boise to Grand Teton and Yellowstone National Parks, you'll enjoy fossils, a raft trip, Peregrine falcons, a rodeo, and more! See the eclipse from a mountain top at Sun Valley!

GRAND TETONS TOTAL SOLAR ECLIPSE
AUGUST 15-23, 2017
Our other expedition for the eclipse of August 21, 2017 will include similar activities. We will witness the eclipse from atop Rendezvous Peak, overlooking the Tetons and Jackson Hole!

ALASKA AURORA BOREALIS
MARCH 2-8, 2017
Come see the Greatest Light Show on Earth as part of this utterly delightful Alaskan excursion!

IN SEARCH OF AMELIA EARHART
JUNE 21 - JULY 11, 2017
On the 80th anniversary of Amelia Earhart's Round the World flight, be a part of this expedition to search for Amelia's plane and artifacts. We will sail onboard the *Reef Endeavour* to remote Nikumaroro Island, 1,000 miles north of Fiji.

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

Planetary Society members photo by David Morrison; space advocates photo by Tushar Dayal

Amazing Outreach

WASHINGTON, D.C. is an important place for space exploration. Every United States-led mission has to pass through key decision-making processes, whether in the White House, Congress, or NASA headquarters.

Naturally, The Planetary Society's space policy staff spend a great deal of time in Washington, ensuring that our members' voices are heard. But we're focused not only on educating politicians; we want to engage everyone in the adventure of exploration. So in Washington–and so many other places around the world–we have an amazing team of volunteers getting the public excited about space.

This past February, the Washington volunteers rallied around the 2016 Legislative Blitz, which is organized in collaboration with the Space Exploration Alliance, a coalition of organizations devoted to space advocacy, policy, and industry. Planetary Society members and volunteers joined other space advocates to hold meetings in Congress, educating leaders about the importance of space exploration. Over the course of two days, 67 participants held a whopping 173 meetings, advocating for a future they believe possible. The Planetary Society will strive to continue to provide such opportunities so that members and volunteers can make real contributions to space advocacy.

As always, keep an eye out for volunteer opportunities in your area and around the world. Go to **planetary.org/volunteer** to learn more.

ABOVE *Planetary Society members and fellow space advocates train for their Legislative Blitz meetings in Congress.*

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

Partisan Peril

Spaceflight and the Risks of Presidential Leadership

ABOVE *On May 25, 1961, President John F. Kennedy announced, before a special joint session of Congress, the ambitious goal of landing an American on the Moon and returning him safely to Earth before the end of the decade. At the time of his speech, Kennedy's party enjoyed significant majorities in both houses of the U.S. Congress—majorities that would endure for decades. Modern presidents face a congress that can see significant shifts in political power every few years.*

AS THE UNITED STATES grinds ever closer to November's presidential elections, the question of the space program's future becomes ever more relevant. NASA is in the midst of a generational transition of its human spaceflight program, and there are a number of large science projects throughout the agency that will be years away from launch when the next administration takes office. The question of what to do—or what not to do—with these projects will fall to the next president, whose decisions will be shaped by the prominence of space within his or her governing agenda.

The president wields significant control over the space program by appointing NASA leadership, setting the nation's space policy, formally requesting new projects, and setting the initial terms of the annual funding debate through the official budget request to Congress.

But the president has a deeper relationship with NASA, one that traces its roots back to John F. Kennedy's challenge to land a man on the Moon and return him safely to Earth. The success of *Apollo* cemented Kennedy's legacy and defined the narrative behind the role of strong presidential leadership in space exploration. This narrative has grown only stronger in the intervening decades, as many presidential administrations have clearly lacked a strong commitment to space, leading to commensurate drops in funding and ambition for NASA. If only, so the argument goes, we had a strong U.S. president to commit the nation to a clear direction in space exploration and expend the political capital necessary to make it happen.

INDUCED POLITICAL OPPOSITION

There is a subtle risk associated with this idea, however, a risk that is a product of our modern political era: What if, by making space a major part of his or her political agenda, the president actually incites political opposition to space exploration where none was previously found? The idea of induced political opposition applies to many issues

Photo: NASA

beyond space, and the book *Beyond Ideology*, by the political scientist Frances Lee, provides a compelling argument for this effect and its increasing prevalence in U.S. politics over the past few decades.

This effect primarily rises from two conditions: that the U.S. has only two major political parties, and neither has been able to hold a sustainable majority since the 1990s.

The two-party system is a zero-sum game: one party wins when the other loses. And one party can win by making either a positive case to voters or by undermining the opposition party. Add to the mix the fact that both parties feel outright control of the Congress is within their grasp—again, a relatively recent phenomenon—and you have a strong incentive to form uniform voting blocks against signature legislation of either party. Consider the examples of uniform Republican resistance to stimulus funding proposed by President Obama in 2009, or the uniform Democratic opposition to social security reform proposed by President Bush in 2005.

THE POLITICS OF SPACE

The U.S. president is the most visible leader of a political party, and the president's agenda naturally becomes the focal point for the political opposition. Undermining the president's agenda is a highly visible way for the opposition party to prevent the president's party from making a successful case to voters in the next election, and it tends to attract the most ferocious resistance. Notably, this dynamic has little to do with the content of the proposed legislation. The fact that the president has proposed it hypercharges partisan resistance. In her book, Lee quantified this induced opposition for various types of issues and found that legislation relating to space, science, and technology incurs the greatest increase in partisan opposition when included in the president's agenda.

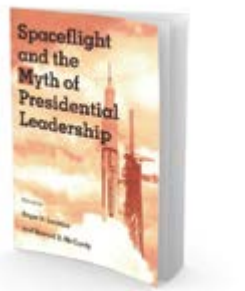
Despite this, presidents can still create significant change at NASA during their tenures. And I acknowledge that the space program benefits from a strong bipartisan coalition from legislators that have NASA centers and contractors in their districts. But for major initiatives that would disrupt the status quo, or new programs that would last decades—like sending humans to Mars—a strong enough consensus must be developed to sustain the program through multiple presidents from both parties. Ironically, by presenting a bold vision for NASA and explicitly tying it to their governing agenda, presidents in this era face the very real risk of undermining the very consensus needed to make their goal successful in the long run.

So perhaps the next president should resist the (possible) temptation to make a JFK-style speech about a grand vision in space. Instead, it might be wiser to follow a Theodore Roosevelt-style path and "speak softly" about the space program, closely work with space supporters in Congress, and wield a big stick via the annual budget request and national space policy. The politics of space don't have intrinsic ideology to guide or protect the issue from partisanship, and presidents (and space advocates) must think carefully about the risks of strong, visible leadership in this hyperpartisan era.

I'm curious about what you think. Do you want space to play a major role in the next president's agenda? Or would you prefer quiet support and a clear agenda in space? What is the right balance? Send your thoughts to election2016@planetary.org *today.*

FOR FURTHER READING:

Beyond Ideology
By Frances E. Lee
University Of Chicago Press, 2009



Spaceflight and the Myth of Presidential Leadership
Edited by Roger D. Launius and Howard E. McCurdy
University of Illinois Press, 1997

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

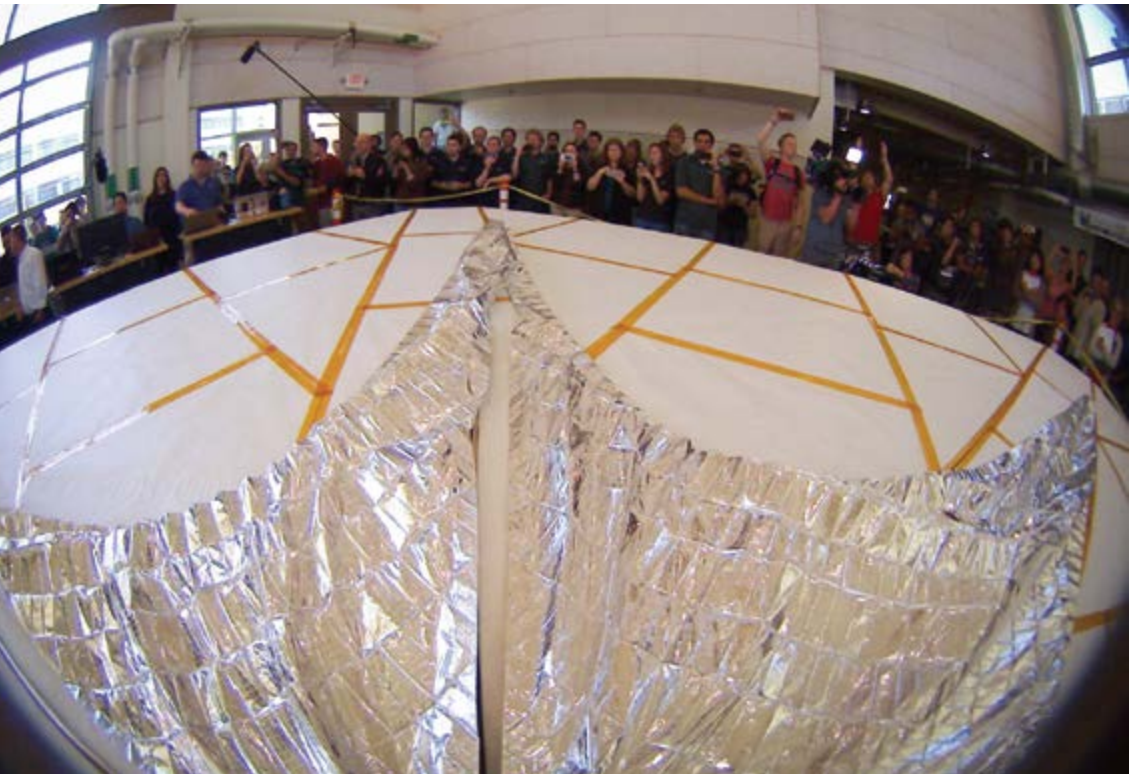
Update on *LightSail 2*

A Better and Smarter Project Moves Forward

WE JUST CELEBRATED the one-year anniversary of the *LightSail* test mission (*LightSail 1*), a roller-coaster ride of a mission that ended in success: demonstration of the operation of the loaf-of-bread-sized spacecraft, and deployment of our 32-square meter solar sail. We did all that thanks to the members and donors who made the mission possible.

LightSail 1 was a test mission with an orbit perigee (the low point in the orbit) of about 470 kilometers (290 miles) in altitude, and an apogee (the high point) of 780 kilometers (485 miles). Even in space, there is still enough atmosphere at altitudes below 600 kilometers (about 370 miles) that, once you deploy big sails on a small spacecraft, the atmospheric drag not only precludes testing of solar sailing, but it also brings the spacecraft to a fiery atmospheric burn-up within about a week after deployment. The mission did what it was supposed to do: demonstrate solar sail deployment and provide lessons learned. (Learn more about the *LightSail 1* mission in the June Solstice 2015 issue of *The Planetary Report*.)

After the end of *LightSail 1*, focus turned to *LightSail 2*, the follow-on mission that will attempt to demonstrate controlled solar sailing: orienting the spacecraft in such a way that slight pressure from sunlight will measurably change the spacecraft's orbit. This will be the first time this has been done with a small spacecraft, in this case a 3U CubeSat, and it will pave the way for future CubeSat missions, including missions in deep space. We are just finishing the final pre-launch testing of *LightSail 2*, so it is a good time to reflect on where we have come from and where we are going with the mission.



BELOW *On May 23, 2016 an excited crowd packed Cal Poly San Luis Obispo's Bonderson Engineering Center to watch* LightSail 2*'s Day In The Life test. The spacecraft's own -X axis camera photographed the sails as they deployed.*

Photos: Jason Davis/The Planetary Society

BETTER AND SMARTER

Based on lessons learned from *LightSail 1* and the required capabilities for the *LightSail 2* mission, we have made numerous modifications, additions, and upgrades to hardware and

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

software to improve the spacecraft's function and operability. *LightSail 2* looks like *LightSail 1*, but its hardware is more capable and its software is smarter.

A key new piece of hardware is included in *LightSail 2*: a momentum wheel, which is a wheel that can be spun up and slowed down to cause the required changes in the spacecraft's orientation. *LightSail 2* also needs to greatly expand the Attitude Determination and Control Subsystem (ADCS), the system that determines where you are and what your orientation is, and controls the changing of those things. Using the ADCS, we will demonstrate controlled solar sailing by spending half of every 90-minute orbit with the sail perpendicular to the sunlight, gathering momentum from light hitting the sails. Then, the spacecraft will rotate 90 degrees to "feather" the sail as the spacecraft heads back in the Sun's direction. It then rotates 90 degrees again and the process repeats, thus modifying the orbit. So a lot of effort has been going into modifying, refining, and improving the ADCS system.

TESTING–AND MORE TESTING

One key to successful spacecraft operations is testing, and lots of it. We performed many component-level tests, followed by system level-testing. This testing, as intended, uncovered various issues. Those issues were then fixed and more testing was done. As of this writing, we have just completed the critical Day In The Life test: a simulation of the key mission milestones, from first signal acquisition through solar panel deployment and sail deployment. We successfully deployed the sail at Cal Poly San Luis Obispo while commanding the spacecraft using the spacecraft radio and the Cal Poly ground station, just as it will be done when the spacecraft is in orbit. The test was successful, though some anomalies were found–the purpose of this testing–and are being corrected as I write.

Next up will be ADCS testing in a facility at Utah State University. It is sort of a Day In The Life Part 2, this time focusing on the ADCS system inside a Helmholtz cage, a device that allows simulation of an artificial magnetic field. Basic magnetometer calibration was carried out recently at UCLA. At Utah State, mission simulations will be run and various sensors, including magnetometers, gyros, and Sun sensors, will be tested and calibrated as needed, and the ADCS software will be tested as part of the process.

After ADCS testing, the spacecraft will return to Cal Poly San Luis Obispo for vibration and thermal testing and final functional testing, basically another partial Day In The Life test, as a final check to make sure all is well. Then, on a schedule currently planned to be in mid-July, *LightSail 2* will head to Georgia Tech for integration into their *Prox-1* spacecraft. On orbit, *LightSail 2* will deploy from *Prox-1*, which will then chase down *LightSail 2* and perform proximity operations near it. We hope *Prox-1* will also generate some stunning imaging to complement *LightSail 2*'s onboard cameras.

LightSail 2 will launch on the second launch of the new SpaceX Falcon Heavy rocket, as part of the U.S. Department of Defense Space Test Program-2 payload. The first Falcon Heavy launch has been delayed until late 2016, meaning *LightSail 2* will likely launch early in 2017. To keep up with developments in the next few months, and for details of what has been happening the last several months, see our dedicated LightSail website, **sail.planetary.org**, and check out the blogs by Jason Davis on **planetary.org**.

ABOVE *Because* LightSail 2*'s 32-square-meter solar sails are too large to fit inside a clean room, the spacecraft must be transported inside an electrostatic bag to a large high bay for sail deployment testing.*

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

We're Building a Movement!

New membership options create new opportunities

I LIKE TO SAY THAT, like the universe itself, The Planetary Society is expanding.

Our 35 years of hard work are paying off. Our programs have been propelled to new heights of success, as exemplified by our *LightSail 1* test flight, our effective grassroots advocacy efforts to get a mission to Europa on the books, and our expanding in-depth coverage of space exploration that includes new directions in human spaceflight and our future journey to Mars.

These successes have inspired expansion of our membership, too. Thanks to public interest in our programs, the number of Planetary Society members has increased to more than 50,000 as of this writing. As the Society builds momentum, our membership itself is becoming a movement!

ADVANCING SPACE EXPLORATION

Now Planetary Society members have a multitude of new ways to engage. In a world of increasing information options, members are connecting not only through *The Planetary Report* and *Planetary Radio*, but with new digital media such as our website and blogs, our social media on Facebook, Instagram and Twitter, our new *Planetary TV* channel, and our new eNewsletter, *The Planetary Post*. Our members have an insatiable desire to learn and discover with us and, in so doing, to become planetary explorers themselves.

Explorers are agents of change, leading humanity on a journey of discovery that starts at the edge of what's familiar, then expands to the horizon and, beyond that, the unknown. Curiosity is a deeply ingrained human characteristic, and our member-explorers are shining examples of it. Planetary Society members are at the leading edge of a new movement, as our CEO often exhorts us, to "change the world!" We are witnessing–and we are part of–the birth of a peoples' movement to advance the exploration of space.

UPGRADE YOUR MEMBERSHIP!

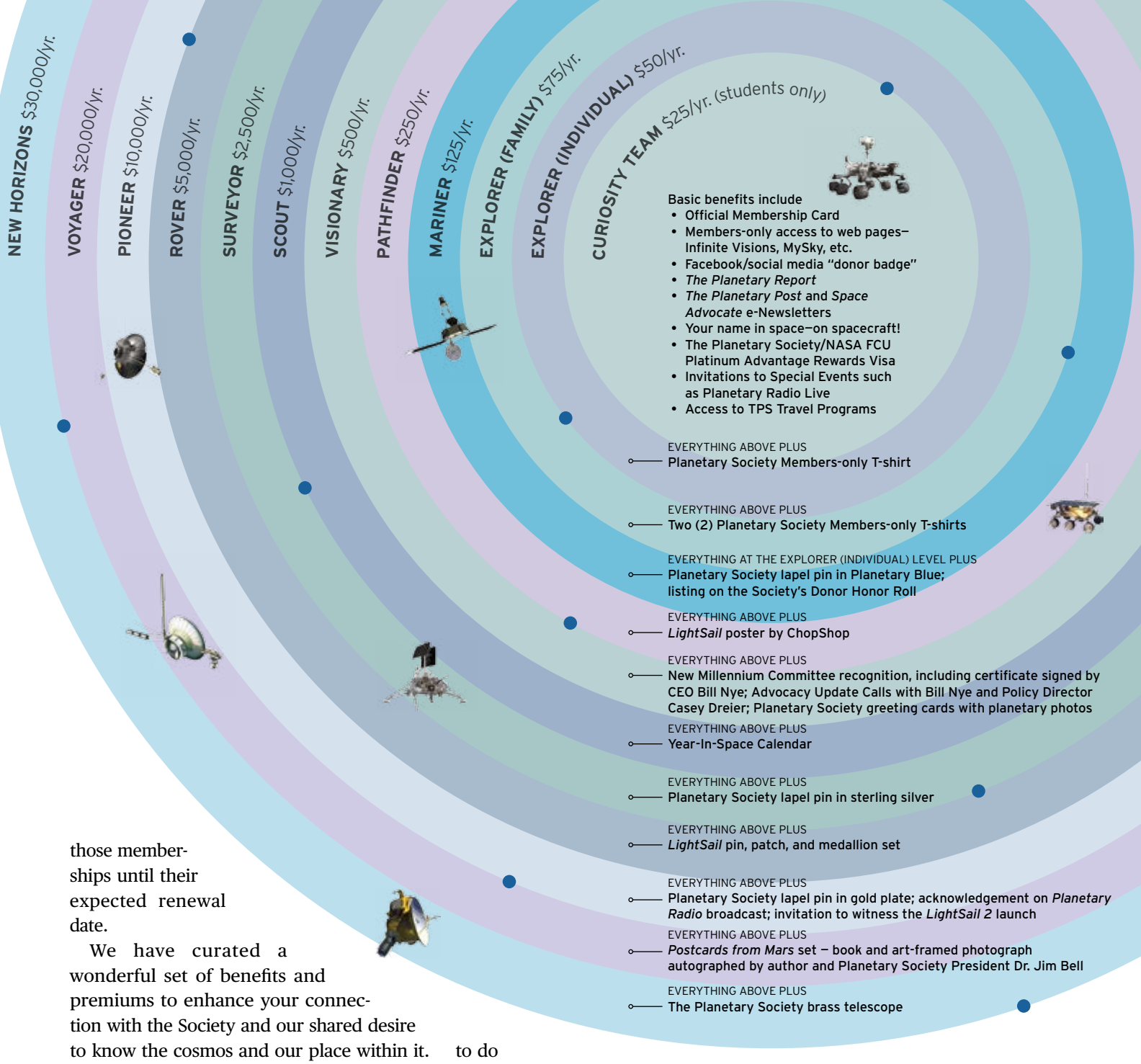
In this issue of *The Planetary Report*, The Planetary Society announces a renewed and expanded membership program that will help us continue to build momentum for this movement to explore the cosmos. The themes of our program are Exploration and Empowerment. Through your membership gift to The Planetary Society, you are getting so much more than a subscription to this magazine–you are helping to open up the universe to exploration–not only for you, but for everyone on Earth.

In this major update of our membership program, we have added new levels, features, and benefits designed to enhance our members' opportunities to connect with us and to their passion for exploring the cosmos. We are combining our three categories–Basic Membership, the Discovery Team, and the New Millennium Committee–into a single program that celebrates the explorer who lives inside all of us.

Yes, after many years, our membership rates are changing. Notably, we are streamlining our rates so that international members pay the same amount as our U.S. members, and we are also creating a Classic Membership category exclusively for our current U.S. members who love what they already have and simply want to stay the course.* (Classic Membership will not be available to our international members because our new rates already represent what we hope will be a welcome reduction for them.) While we are continuing special lower rates for students, seniors, and educators, we are also expanding increasingly popular monthly payment opportunities to almost every level. If you are a current Discovery Team member, we will continue your sustaining support at the new level that matches your current monthly payment. And for those who have multiyear memberships (typically 2- and 3-year memberships), we will honor

The New Millennium Committee Is Expanding, Too!

The New Millennium Committee will continue as our premier recognition opportunity for members who make gifts of $500 or more. In addition, we will now welcome to the committee all donors who make cumulative gifts of $500 or more in a 12-month period, whether to membership, our special projects, or all of the above!



those memberships until their expected renewal date.

We have curated a wonderful set of benefits and premiums to enhance your connection with the Society and our shared desire to know the cosmos and our place within it. The names of our new membership levels are inspired by the names of some of the great missions to explore our solar system–names such as *Curiosity*, *Explorer*, and *Sojourner*. And we have added benefits to each of these levels, including, by popular request, our Planetary Society logo pin (the same one Bill wears every day!). Oh, and did we mention the new T-shirt? Everyone who upgrades into the new program will get our new T-shirt, which is now available in both women's and men's styles.

Please check out the new membership levels and benefits in the chart above. You don't have to do anything right now to join the new program–we will send you information during your regular renewal month. But if you are as excited as we are about these new opportunities and you just can't wait to get that new T-shirt, you can also use the enclosed insert to renew early, or go online to our new membership web page at **planetary.org/membership**.

Now more than ever, we are your place in space!

–Richard Chute
Chief Development Officer

*Satisfied with your current membership and don't want to change it? Then continue to renew as usual during your anniversary month and select our Classic membership available only to current members and still just $37.00 (though you'll miss out on the new T-shirt and other great new benefits!).

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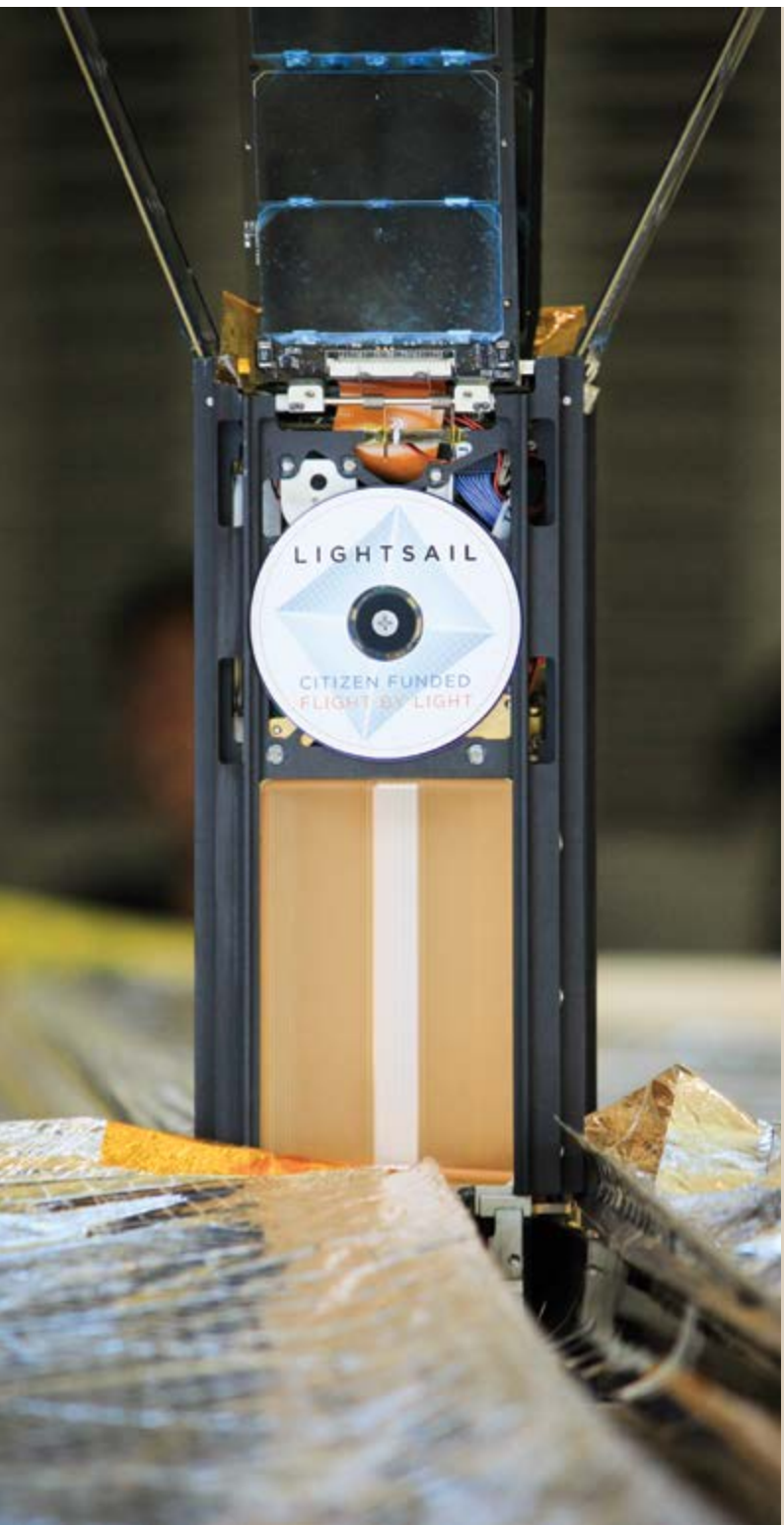

Citizen-Funded Flight by Light

It may look tiny, but the DVD mounted on *LightSail 2* is mighty!

The disc seen in the photo at left is from our recent Day In The Life (DITL) test. It bulges with the names of an astonishing number of supporters—some 46,000 combined Planetary Society members and Kickstarter backers in the United States and around the world who joined together to support the *LightSail™* project financially. Each supporter gave, on average, the relatively small sum of $60. But by banding together and concentrating our resources, we are demonstrating the power of the people to raise millions of dollars and to reach new heights in exploration without relying on big business or government. Accordingly, next year's flight of *LightSail* represents a key moment of truth in the democratization of space.

In *Cosmos*, Carl Sagan asserted that "Exploration is in our nature. We began as wanderers, and we are wanderers still. We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars." Our members and backers claim this heritage as their own. We are, indeed, explorers on a journey beyond the horizon.

Go, *LightSail*!

Onward,

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