# THE PLANETARY REPORT

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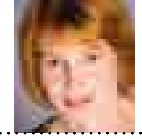
## BEYOND WATER

*CURIOSITY* AND DETERMINING A LOCATION FOR THE NEXT MARS LANDING

*PLANETARY RADIO* AWARD ✱ DOUBLE SUNS DISCOVERED ✱ VESTA: A SPACE-SCIENCE REVELATION



EMILY STEWART LAKDAWALLA
*blogs at* planetary.org/blog.

# Endeavour's Peaks Within Reach

## Finally rolling into the crater

**FOR THREE YEARS,** Endeavour crater has been a distant goal for the *Opportunity* rover, its peaked rim forming a dim line of mountains on the rover's horizon. In the summer of 2011, *Opportunity* finally reached that horizon, rolling onto Cape York, a low part of the crater's rim. On sol 2678 (August 6, 2011), from its vantage point near Cape York, *Opportunity* gazed southward to capture this picture postcard of the western rim of Endeavour, using the color panoramic camera. The three peaks are called (from left to right) Cape Dromedary, Cape Byron, and Cape Tribulation; the monikers come from places named by James Cook in his exploratory voyage as captain of the ship *Endeavour*. Below is a wider view of *Opportunity*'s surroundings, shot on the same day with the navigation camera.

–*Emily Stewart Lakdawalla*

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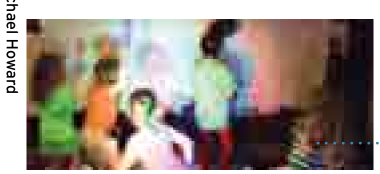
Pancam image: NASA/JPL/Cornell/Damien Bouic

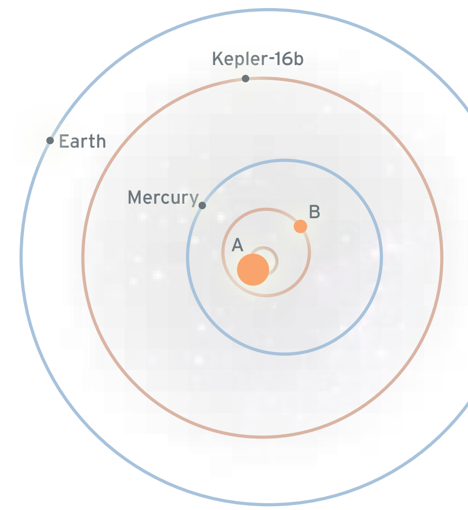
Navcam image: NASA/JPL/Michael Howard












**ON THE COVER:** The High Resolution Science Experiment on *Mars Reconnaissance Orbiter* has detected mysterious features that may be our first evidence of liquid water on Mars. This view, a combination of orbital imagery and 3-D modeling, shows a slope as it would look from a helicopter inside Newton crater. "The best explanation for these observations so far is the flow of briny water," said Alfred McEwen of the University of Arizona. The study of craters, such as Newton and the much-anticipated Gale, brings us ever closer to knowing if life ever graced the Red Planet. For more information on this discovery, go to HTTP://BIT.LY/TPS0610. *Photo: NASA/JPL*

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**BILL NYE** *is executive director of the Planetary Society.*

# We Are All Modern Explorers

## Why do we reach for the stars?

**I RETURNED TO MY ALMA MATER**, Cornell University, this summer because I made a donation: a big clock–three meters across and one meter thick. The school installed it on the front of a building seven stories high named Rhodes Hall, in honor of retired university president Frank Rhodes. The reason I worked on designing and funding the clock over the last 13 years is the same reason I chose to come and work for you: I want everyone in the world to know and appreciate our place in space and to seek life on other worlds.

For a modern space explorer like you or me, a clock is a remarkable thing. We need clocks to navigate here on Earth and through the vastness of interplanetary space. Precise timekeeping makes our modern world go around. Science historians often argue that the reckoning of time has changed our world more than has the invention of the wheel.

If you've ever compared your watch or mobile phone clock with the time shown on a sundial, you'll find that they seldom agree. The inclination of the Earth with respect to the main plane of the solar system conspires with the slight ellipticity of Earth's orbit to make your clock's noon occur at a different time from the Sun's daily culmination–its maximum height above the horizon, what we call *solar noon*. This fact alone may prompt us to ponder the remarkable chain of astronomical discoveries and the bold confidence of our ancestors who chose to risk years-long sea voyages without the aid of precise instruments. We might also ponder the astonishing accuracy of our watches, clocks, and calendars, which now is commonplace but once was almost imponderable.

So it is that on the new clock on Rhodes Hall, solar noon is indicated by a Sun-shaped symbol below the number 12. It's lit from behind by light transmitted through a shiny duct from a Fresnel lens dome on the building's roof. A controller designed by Cornell engineering students opens up a few minutes before solar noon and remains open for a few minutes after. I hope that passersby, students, faculty, and visitors alike will take a few moments from time to time (pun intended) to ponder just how we came to know the Earth's motion around the Sun and why the reckoning of time has changed the world.

Solar clock: Bill Nye

This project gave me a great appreciation for astronomical discoveries, to be sure, and it also gave me a deep appreciation for those who donate money to causes and projects they believe in–people like you. Thank you for your support of the Planetary Society.

### JUPITER: FOR THE SAKE OF ITS MAGNETIC SECRETS

Our Earth is home, but we are very much aware of other planetary places. I attended the launch of the *Juno* mission, which is on its way to Jupiter. (We can predict the time of arrival to within a fraction of a second, even though that event will not occur for five years.) *Juno* will seek to understand the strong magnetic fields, the gravitation, and the wild weather we observe on Jupiter.

I was at Cape Canaveral with 150 people who had traveled to the "Tweetup" tent from all over the world. They, like you and I, just want to be part of the adventure of space exploration. It was a glorious launch on a glorious day. The Atlas V rocket shot up from the pad, its flame longer than the rocket itself. It left a halo of ice crystals at an altitude that is difficult to estimate from the ground; the water vapor in the rocket exhaust created its own high-altitude annular cirrus cloud. Most of us have experienced nothing remotely like it, and in five years, we'll have images from Jupiter like none that anyone has ever seen.

Images: Juno liftoff: NASA; Bill at the Capitol: Mat Kaplan

Meanwhile, the *Dawn* spacecraft made its way to Vesta, so we had a Vesta Fiesta. People attended events hosted around the world to celebrate the up-close look at this asteroid that, in the nineteenth century, was considered worthy of planet status. It's big, round, and rocky. The images show that one impact made a crater just about as big as the whole of Vesta. What a violent place the early solar system was.

Closer to home, the two *GRAIL* (*Gravity Recovery And Interior Laboratory*) spacecraft are headed to the Moon to learn more about its past and thereby find out more about how we all got here.

We are in an exciting time in space exploration. We may be entering the golden age of knowing our planetary neighbors. Here's hoping we maintain our efforts.

### ADVOCATING FOR PLANETARY EXPLORATION AND DISCOVERY

The remarkable nature of astronomy and space exploration is common knowledge to all who read *The Planetary Report*, but occasionally it seems that these great discoveries are undervalued by our leaders, especially here in the United States. If we let the world's largest space agency cease exploring, where does that leave us?

With that in mind, we went to work to implore U.S. leaders to support NASA in its primary mission of space exploration. You were all part of it. Our members–living in the United States and in other nations–sent us more than 20,000 signed petitions, some by postal mail, others by e-mail. We took these petitions to the U.S. Capitol building and saw to it that everyone's voice was recorded by members of the House of Representatives, the Senate, and the administration.

You are part of this adventure. Together, our voice is amplified. Together, we can shape the future. Thank you for your efforts to ensure the future of science, technology, and space exploration.

Space exploration brings out the best in us. It reminds us that our species is capable of great things and that we can be optimistic about the future. At the Planetary Society, we will continue to expand our services for our supporters and work to help people everywhere know and appreciate our place in space.

Bill Nye

**LEFT** *For a few minutes on every sunny day, solar noon lights up Bill Nye's Rhodes Hall Clock at Cornell University.*

**MIDDLE** *The Atlas V rocket launching* Juno *on its mission to Jupiter executed a picture-perfect liftoff on August 5, 2011.*

**RIGHT** *Bill Nye holds a box of signed petitions supporting space exploration. On September 9, 2011, Bill hand-delivered more than 20,000 of these petitions–from Planetary Society members and supporters worldwide–to Congress and the White House.*

**MAT KAPLAN** *is producer of the* Planetary Radio *show.*

# *Planetary Radio* Wins Parsec Award

## Making Great Radio Reaps Benefits

**ABOVE** *A beaming Mat Kaplan holds* Planetary Radio*'s Parsec Award on September 3rd, 2011 in Atlanta. The Parsec Award recognizes excellence in science fiction and fantasy podcasts.* Planetary Radio *won for the "Best Fact Behind the Fiction."*

**SOMEWHERE OUT THERE IS A VERY HAPPY** listener who took his or her affection for *Planetary Radio* to the next level. The result was an e-mail message I received a few months ago saying that an anonymous fan of our weekly podcast and radio show had nominated *Planetary Radio* (*PlanRad*, as we like to call it) for a Parsec Award. Parsecs, when they're not measuring the distance to nebulas and galaxies, are awards bestowed upon science fiction and fantasy podcasts and are handed to the lucky winners as part of Atlanta's enormous Dragon*Con fan event.

*Planetary Radio* was nominated in the "Best Fact Behind the Fiction" category. We learned we had been selected as a finalist a few weeks later. With the encouragement of my Planetary Society colleagues, I made an airline reservation and crossed my fingers.

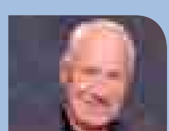
On Friday, September 2, I arrived in Atlanta, just as a late summer heat wave fell over the city (good thing the major hotels hosting the Con were connected by sky bridges!). What a sight all around me. The crowds! The costumes! The Filk singers! The costumes! The parade! Did I mention the costumes?

The Parsec ceremony began late Saturday afternoon. It won't make Oscar look over his shoulder, but it was great fun. Past winners presented the awards and brought their own talents to the podium. MCs Christiana Ellis and George Hrab were terrific. I admit to being much more anxious than I'd expected; after all, the competition was stiff. When Paul and Storm, a music comedy duo, harmonized the category nominees, opened the envelope, and sang out "*Planetary Radio*," I was ecstatic! I didn't even know if I was expected to make a speech. I was, so I asked if that listener who nominated us was in the audience. "If you're here, raise your hand!" No reaction. I paused. "The beer will be on me." Hundreds of hands shot skyward.

So now the Planetary Society has a new memento for its crowded shelves, and I get to thank my *PlanRad* colleagues–Bruce Betts, Emily Lakdawalla, and Bill Nye–and everyone else at Society headquarters who makes the show possible. Most of all, I thank all of you who have allowed us to share our love of space exploration on the radio and on your favorite digital device for nearly nine years. It's a big universe, and there are a few more tales to tell. Stay tuned. *–Mat Kaplan*

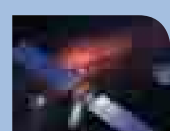
**If you've missed *Planetary Radio* lately, here are some recent highlights:**

***Opportunity* Reaches Endeavour**

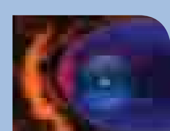


***Apollo 15* Astronaut Al Worden**

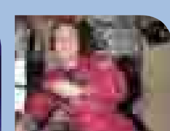
**Flying with Your Telescope to the Edge of Space**



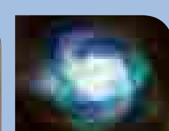
**Visiting Vesta Fiesta, with Pablo Gutierrez-Marques of the *Dawn* Mission**



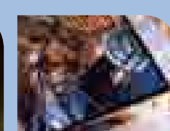
**Two Clouded Mysteries: Jupiter and the *Pioneer* Anomaly**



**Staying in Shape in Space, with Astronaut Clay Anderson**



**Become an Ice Hunter, with Pamela Gay**



**An Optical SETI Update from Paul Horowitz**

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

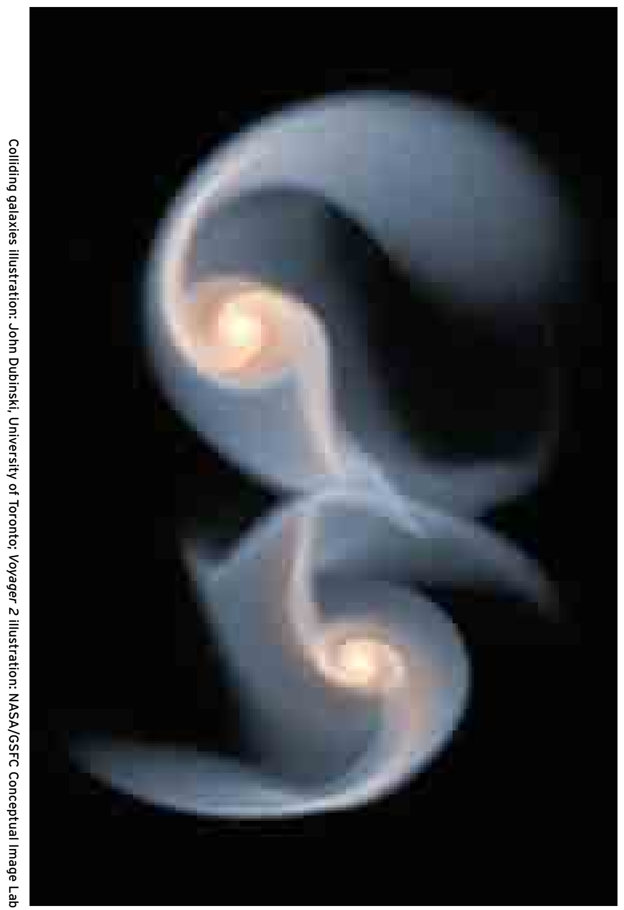




**Q How long does it take for the Milky Way to make one complete revolution? Is it possible that Earth, being near the outer edge of our galaxy, could also be affected by another galaxy close by?** *–Ron Purcell, Sherman Oaks, California*

**A** Our galaxy is a collection of hundreds of billions of stars, star clusters, gas, and dust, and thus does not rotate as a solid body. To determine how long it takes stars in the Milky Way's disk to make a complete revolution, or orbit, around the galaxy's center, astronomers measure the rotation speeds and distances of the stars. Objects near the center take less time to orbit than do those farther out. At the distance of the Sun (about 25,000 light-years from the center), the orbital period is between 200 and 250 million years. (The last time Earth was in the same place in its orbit, dinosaurs roamed its surface!) This corresponds to a rotation speed of about 250 kilometers (155 miles) per second, or about 900,000 kilometers (560,000 miles) per hour. This website from the Royal Astronomical Society of Canada's Calgary group provides more detail: HTTP://BIT.LY/TPS0602.

To answer your second question, Earth certainly could be affected by nearby galaxies. In fact, the Milky Way and the Andromeda galaxy are falling together under gravity at a speed of 100 to 150 kilometers (about 60 to 90 miles) per second. In three to four billion years, we expect that the two galaxies will merge to form a new galaxy (see illustration at left). The stars in the two galaxies will likely pass right by each other–it's the stickiness of their gas and dust that will lead to the merger. We don't know how Earth and our solar system will be affected by this collision: we could be unaffected, or we could be ejected into interstellar space. *–Terry Bridges, Queens University, Canada*

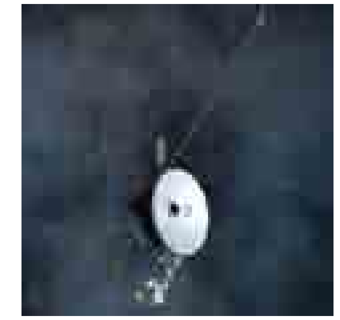


Colliding galaxies illustration: John Dubinski, University of Toronto; Voyager 2 illustration: NASA/GSFC Conceptual Image Lab

**Q Is there a "*Pioneer* Anomaly" effect, or mysterious slowing down, that is measured in the *Voyager* spacecraft? If not, why?** *–Paul Grimm, Littleton, Colorado*

**A** The *Pioneers* are spin-stabilized spacecraft. The *Voyagers* are three-axis stabilized craft that fire thrusters to maintain their orientation in space or to slew around and point their instruments. Those thruster firings would introduce uncertainties in the tracking data that would overwhelm any effect as small as that occurring with *Pioneer*.

This difference in the way the spacecraft are stabilized actually is one of the reasons the *Pioneer* data are so important and unique. Most current spacecraft are three-axis stabilized, not spin stabilized. *–Bruce Betts, Director of Projects*



**ABOVE** Voyager 2 *is speeding away from our solar system at 15 kilometers per second (34,000 miles per hour). The anomalous deceleration affecting the* Pioneers *cannot be observed on the* Voyagers.

**LEFT** *In three to four billion years, the Milky Way and Andromeda galaxies likely will collide. This illustration shows the galaxies in the positions they will hold a few hundred million years after closest approach, with the smaller Milky Way at bottom. Eventually, the two galaxies will merge and transform into a single elliptical galaxy. For more information, and to see an animation of this collision, go to* HTTP://BIT.LY/TPS0601.

**BELOW** *This Lunar Reconnaissance Orbiter Camera (LROC) image, taken in 2009, is a close-up view of a possible skylight in a lava tube in an ancient volcanic region of the Moon called the Marius Hills. This feature was first imaged, from a higher altitude, by Japan's* SELENE/Kaguya *Terrain Camera in 2008.*

Image: NASA/GSFC/ASU

### A SPECIFIC GOAL

Our Planetary Society is Earth's leader for space advocacy, and I enjoy the way your contributors make science understandable to me and to the general public. I have been a member from the beginning.

Charlene Anderson's article in the June 2011 issue faults our political leaders for lack of a specific space exploration goal, either human or robotic. I agree but want to make several points about the issue.

"Do you want to see human explorers walk on other worlds?" she asks us. "Do I see some sort of Planetary Society advocacy for humans in space?" I ask myself. The Planetary Society was founded by Jet Propulsion Laboratory director Bruce Murray, popular scientist Carl Sagan, and former JPL employee Louis Friedman to stop the leakage of funds from the robotic space exploration program to what was then called the "manned" spaceflight program.

Perhaps the Planetary Society will take a fresh look at human space exploration. Anderson's article implies that robotic exploration depends on human exploration. I agree. As the *Mercury* astronauts explained to the German rocket scientists, "No Buck Rogers, no bucks."

The publication in the same issue of Jacques Blamont's article, "Planetary Cave Dwelling: A Strategy for Exploration," adds a bit of hope that the Planetary Society is loosening up a bit. Before we start living in caves on Mars, we need to learn how to create our safe havens–on the Moon. Both Japan and the United States have photographed a pit crater on the lunar surface (at left), which is likely a lava tube exposed when its roof collapsed. What's in those caves on either side of the hole? Though challenging, robotic exploration would pave the way, then people would do the rest. We must learn how to grow our own food, recycle our water and our waste, and solve all the other problems of ultra-primitive camping. Rescue, if things go wrong, is only three days away. As for exciting and inspiring images, establishing a foothold on the Moon promises visual excitement equal to watching the Pilgrims establish Plymouth Colony.

I suggest that the Planetary Society renew itself and advocate the goal of the United States, and perhaps other nations, of returning to the Moon to explore the nature of these lunar caves and the possibilities of dwelling in them. If the president does not articulate a goal, it means that someone else must. The Planetary Society is uniquely structured to lead the space advocacy community by unifying the many divergent ideas and focusing on one specific goal.

*–Grant Hovey, La Habra, California*

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# Chasing Earth

**SCIENTISTS HAVE DISCOVERED THE FIRST** known "Trojan" asteroid sharing Earth's orbit around the Sun. They found asteroid 2010 TK7 using NASA's Wide-field Infrared Survey Explorer (WISE) telescope, which scanned the entire sky in infrared light from January 2010 to February 2011.

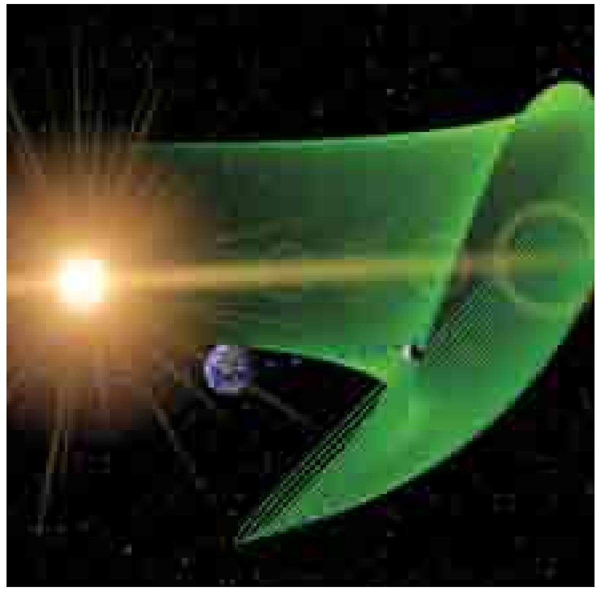
Trojan asteroids share a planet's orbit near a stable point. Because they constantly lead or follow a planet in its orbit, they can never collide with it. Mars, Jupiter, Neptune, and two of Saturn's moons also have Trojans.

"These asteroids dwell mostly in the daylight, making them very hard to see," said Martin Connors of Athabasca University in Canada, lead author of a paper on the discovery in the July 28 issue of the journal *Nature*. "But we finally found one, because the object has an unusual orbit that takes it farther away from the Sun than what is typical for Trojans. WISE was a game-changer, giving us a point of view difficult to have at Earth's surface."

Follow-up observations with the Canada-France-Hawaii Telescope on Hawaii's Mauna Kea confirmed 2010 TK7 as an Earth Trojan.

*–from NASA/JPL*

Images: WISE: NASA/JPL-Caltech/UCLA; Kepler: NASA/Ames/JPL-Caltech



**LEFT** *The extreme orbit of Earth's recently confirmed Trojan asteroid 2010 TK7 is shown here in green. The blue dots represent Earth's orbit. To watch an animation of 2010 TK7's wild orbit, go to* HTTP://1.USA.GOV/TPS0604.

# Double Suns?

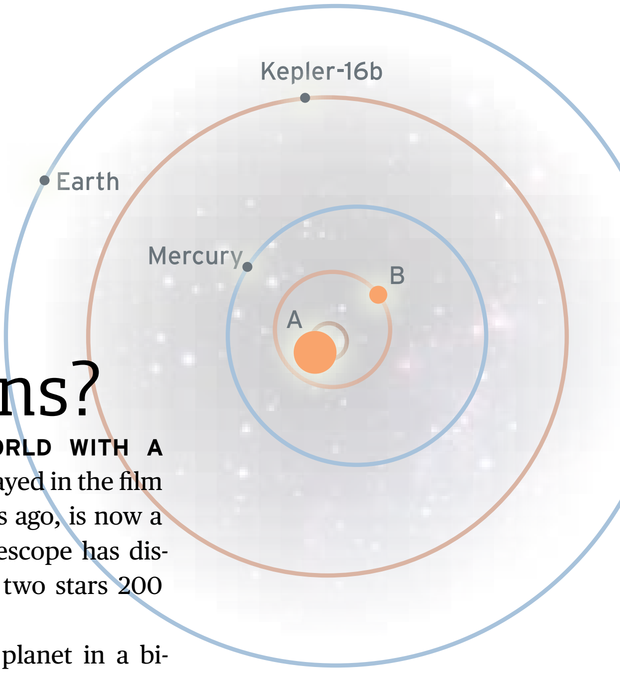
**THE EXISTENCE OF A WORLD WITH A** double sunset, like one portrayed in the film *Star Wars* more than 30 years ago, is now a reality. The Kepler space telescope has discovered a planet that orbits two stars 200 light-years from Earth.

Scientists found the new planet in a binary star system called Kepler-16, in which two eclipses are visible from Earth. The observers noticed, however, times other than eclipses when the brightness of the stars decreased at irregular intervals. Subsequent detection of tertiary and quaternary eclipses showed that a third object was circling both stars in a wide, circumbinary orbit.

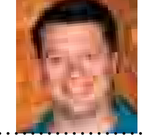
Kepler detected the planet, called Kepler-16b, by observing transits, when the brightness of a parent star is dimmed by a planet crossing in front of it. Kepler-16b is a cold, inhospitable world about the size of Saturn that appears to be made up of roughly half rock and half gas. It orbits the two stars (both smaller than our Sun) every 229 days. A report on these findings appeared in the September 16, 2011 issue of *Science*.

"Working in film, we often are tasked with creating something never before seen," said John Knoll of Industrial Light & Magic, a division of Lucasfilm, Ltd. "However, more often than not, scientific discoveries prove to be more spectacular than anything we dare imagine. There is no doubt these discoveries influence and inspire storytellers. Their very existence serves as cause to dream bigger and open our minds to new possibilities beyond what we think we 'know.'"

*–from NASA/JPL*




**ABOVE** *This diagram shows an overhead view of the eccentric Kepler-16 system, where two stars are orbited by one planet, Kepler-16b. For reference, the orbits of Mercury and Earth have been added in blue.*



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

# Launching Organisms, Solving Anomalies, and Naming an Asteroid

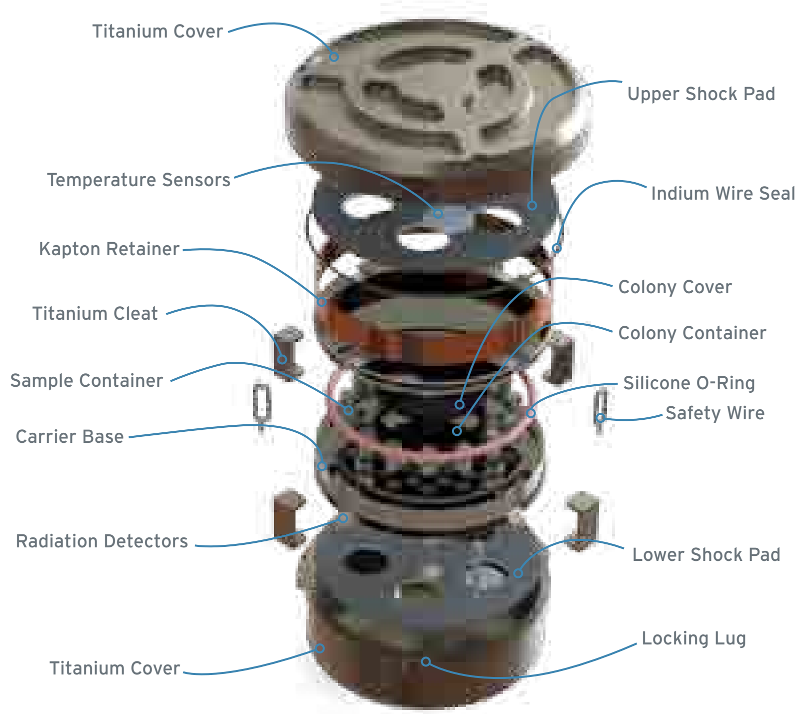
**RIGHT** *Millions of tiny organisms are set to travel to Mars' moon Phobos and back in this titanium-encased biomodule. This November, our Phobos LIFE (Living Interplanetary Life Experiment) will launch on board Russia's Phobos Sample Return mission.*

**BELOW** *An exploded view of Phobos LIFE shows where the samples will be contained throughout the course of the flight.*

**LOTS OF REALLY EXCITING THINGS ARE** happening in the next few months, including climactic phases of two major Society projects and a new contest for kids around the world.

## PHOBOS LIFE READY FOR LAUNCH

Years in the making, our Phobos LIFE (Living Interplanetary Flight Experiment) is nearing launch this November. Phobos LIFE will send millions of passengers on a 34-month journey to Mars' moon Phobos and back. These travelers include 11 kinds of tiny organisms from all three domains of life (bacteria, eukaryota, and archaea). This will be the first time organisms will be tested for survivability outside Earth's protective magnetosphere for more than just a few days.




LIFE Biomodule

We are testing the portion of the transpermia hypothesis that involves interplanetary flight: can life travel between planets naturally inside meteoroids?

Our simulated meteoroid is hitching a ride on board the Russian Phobos Sample Return mission. The mission includes a suite of lander instruments that will study Phobos as well as a process to collect samples from Phobos and send them back to Earth for study. A Chinese orbiter is also hitching a ride to Mars on this launch to study Mars' exosphere.

Images: Bruce Betts, Planetary Society

Our organisms range from bacteria to the tiny animals called *tardigrades* (nicknamed "water bears"). A subset of these organisms took a flight on the last flight of space shuttle *Endeavour* earlier this year. You can find out more about Shuttle LIFE in the June 2011 issue of *The Planetary Report*.

At the time of launch, we will open one of our three Phobos LIFE Earth "control" biomodules. The controls are identical to the flight biomodule. Opening one at the time of launch will allow us to study the effects of the loading of the module and sitting around on Earth waiting for launch, so that we can then "subtract" those results from our study of the flight organisms when they come back from space. That way, we can isolate the effects of spaceflight.

Learn more about Phobos LIFE and Shuttle LIFE at HTTP://BIT.LY/TPS0606.

Top photo: JPL; image at right: NASA/Goddard/University of Arizona

**LEFT** *Before the Planetary Society stepped in to help, only about 11 years of Pioneer Doppler data had been analyzed, and the Pioneer anomaly remained a mystery. Thanks to you—our Members—by June 2006, scientists and engineers were able to recover much of the more than 30 years of navigational histories of both spacecraft.*

## REDEFINING THE *PIONEER* ANOMALY

The mysterious *Pioneer* anomaly is closer to a solution, and key new pieces of the puzzle have just been published. (The *Pioneer* anomaly is an unexplained, very tiny deceleration of *Pioneer 10* and *11*, launched by NASA in 1972. Both are on trajectories leaving the solar system.)

Slava Turyshev and a team of researchers recently published results that better define the mysterious effect, including the fact that it is not constant over time, as originally thought. Their work was made possible by years of data that were recovered thanks to the support of Planetary Society Members. The recovered data came from a variety of sources, some that literally were scheduled to be thrown out.

Slava's team's work strengthens the case that the source of the anomaly lies in the spacecraft themselves, not in any mysterious outside force acting on them. The most likely cause is heat generated by spacecraft systems, producing a recoil force. Slava and his team are working on detailed thermal modeling of the spacecraft and making comparisons with the onboard temperature data that also were recovered as part of the Planetary Society-supported effort. We'll let you know when results of those studies are out. Meanwhile, here is a nice note from Slava:

*The recovery of Doppler and telemetry data and the entire effort in thermal analysis would not have happened without the Planetary Society. The members provided the money we needed to get started and demonstrated to NASA that the public was definitely interested in solving the mystery. Their interest and strong support made possible our work to solve the* Pioneer *anomaly.*

Learn more about the latest information on the *Pioneer* anomaly, including a link to the new scientific paper, at HTTP://BIT.LY/TPS0605. You can also listen to Slava Turyshev talking about the *Pioneer* anomaly on a recent episode of *Planetary Radio* (see the archives at *planetary.org/radio*).

## NAME AN ASTEROID CONTEST

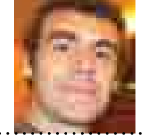
The Planetary Society is excited to be involved with many public outreach activities connected with NASA's recently selected *OSIRIS-REx* mission. Michael Drake* of the University of Arizona was the mission's principal investigator. After launching in 2016, *OSIRIS-REx* (*Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer*) will approach and sample asteroid 1999 RQ36 in 2019. The *OSIRIS-REx* mission will return the first samples ever taken from a special type of asteroid that holds clues to the origin of the solar system and likely contains organic molecules of types that may have seeded life on Earth.

Shortly, we plan to announce a contest for students to suggest an asteroid name that is a little easier to chew on than 1999 RQ36. The naming contest for the near-Earth asteroid is a partnership of the Planetary Society, MIT's Lincoln Laboratory—the discoverers of 1999 RQ36—and the University of Arizona. Look for details coming very soon on our website, *planetary.org*.

**ABOVE** *In this conceptual image,* OSIRIS-REx *hovers at asteroid 1999 RQ36 (soon to have a much snazzier name) and uses its arm to collect a sample from the asteroid's surface.*

**We are deeply sorry to report that Michael Drake died on September 21, 2011.* OSIRIS-REx *lives on as one of his many legacies. For more information, see* HTTP://BIT.LY/TPS0622.

*Thanks!* Planetary Society Members made the work on the *Pioneer* anomaly possible with their generous donations.



**PABLO GUTIERREZ-MARQUES** *is Dawn's Framing Camera Operations Manager. He is from Spain and is working with NASA in Germany.*

# Vesta: A Revelation

## Understanding why the thrill of discovery is important

**I ADMIT IT: I DID NOT UNDER-**stand why space science is important. This statement is bold, coming from a practicing aerospace engineer. Fortunately, recent events have corrected my lack of understanding.

In my youth in Spain, my engineering mind would play tricks on me, luring me into forbidden realms of toy deconstruction. I did not have any understanding of science whatsoever.

**BELOW** *The author makes the case for how international space projects like* Dawn, *shown below, are important to society.*

Image: NASA/Background: William K. Hartmann, Courtesy of UCLA; Image-NASA/MCREL

In high school, my parents, both surgeons, tried to entice me into less dangerous branches of knowledge, like physics or mathematics. But my attention faltered before I could formulate hypotheses, and I focused instead on dissecting and trying to replicate any computer program that crossed my path. My understanding of science had evolved to a cloudy concept of a certain type of research.

When deciding which degree to pursue in college, I veered toward aerospace engineering. The sciences were still inaccessible to me, but I understood that some of them were essential pillars in technology, which fascinated me.

After college I had the luck (or maybe not) of spending several years in pure engineering jobs, from the qualification of aircraft to the design of fire detection instruments. It was pleasurable, working endless hours doing what I liked best, putting things together.

Then fate requested my support on a space mission led by the Jet Propulsion Laboratory. I felt flattered by the attention, then amazed by the aura of NASA and its long-standing history of pioneering, and finally thrilled at the opportunity to live and work in a different country (Germany). I still had no clear understanding of the benefits that could be derived from planetary science.

I became a skillful mercenary of science, though the details of the project eluded my comprehension. The technical challenge was sufficiently enticing to reassure me in my decision. I spent seven years building parts, programs, and command sequences, questioning only on rare occasions the final purpose of my work, until we were in sight of Vesta. Even with the target within reach, I was unable to share the thrill, and I felt nothing more than a quiet complacency over the performance of the camera.

That was the situation as of July. Suddenly, Vesta changed my mind forever. Images of the approaching asteroid had been coming regularly, without significant improvements in quality, and the novelty had worn off. The new images, however, not only showed an incredible leap in resolution but also revealed a wealth of features on Vesta's surface. New portraits changed my understanding of the mission, space science, and even science in general.

I propose three major arguments in favor of fostering and nurturing scientific space missions like *Dawn*. First, the science that these missions produce contributes to advancement of knowledge, especially our understanding of Earth as a planet, its role in the solar system and the dynamics around it, and even the cosmos at large. This knowledge has immediate uses in diverse fields, like the operation of commercial satellites and study of the behavior and nature of near-Earth objects and the threat they pose to humankind.

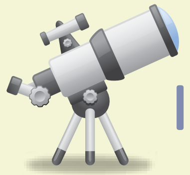
**1,300 W**

of power provided to three 30-inch xenon-fed ion thrusters by a 10-kW photovoltaic solar array on *Dawn*. Ion propulsion was first successfully tested on NASA's *Deep Space 1* in 1998, sending that craft to asteroid Braille and Comet Borrelly.

The second reason is economic. Space science pays the wages of many professors and postgrads, as well as involving purchases of equipment, materials, and specialized services. Furthermore, space missions often finance the development or advancement of given enabling technologies. In contrast to technologies in other fields, such as medicine or industrial processing, space technologies are harder to acquire and easier to lose from lack of upkeep. They become of strategic interest: just as no country can afford not to maintain its roads and highways because of the cost of rebuilding a rundown network, no country can afford to let its space science industry dwindle and allow its talented engineers to drift off to other industries, from which it might be difficult to dislodge them and where their space science skills would atrophy.

The most potent and incontestable motive, the one that Vesta showed to me a few weeks ago and is unique to space science, is that these missions are one of the few endeavors in which humankind can express the innate impulse of exploration and conquest. We have reached the tops of the mountains and the depths of the seas. Only space exploration offers the bewilderment of the encounter, the thrill of spotting territories never before seen by the human eye. All these sensations are more than a jolt of adrenaline for a few mission team members; they push forward the common consciousness of humankind, nurture the feeling of belonging to one human race, and inspire the spirit of adventure.





## IN THE SKY

A total lunar eclipse on December 10 will be visible from all of Asia and Australia as well as most of Europe, Africa, and North America. The time of greatest eclipse will be 14:32 UT. In the evening sky, Jupiter is the extremely bright starlike object, growing higher in the east as the weeks progress. Even brighter, Venus appears low in the west in December. In the predawn sky, reddish Mars is high in the east, and yellowish Saturn starts to appear low in the east late in October. The Geminid meteor shower peaks on December 13-14. Typically this is the best shower of the year, but this year moonlight will obscure the fainter meteors.

## RANDOM SPACE FACT

The Sun rotates faster at its equator (period of about 25.6 Earth days) than at its poles (period of about 33.5 Earth days).

## TRIVIA CONTEST

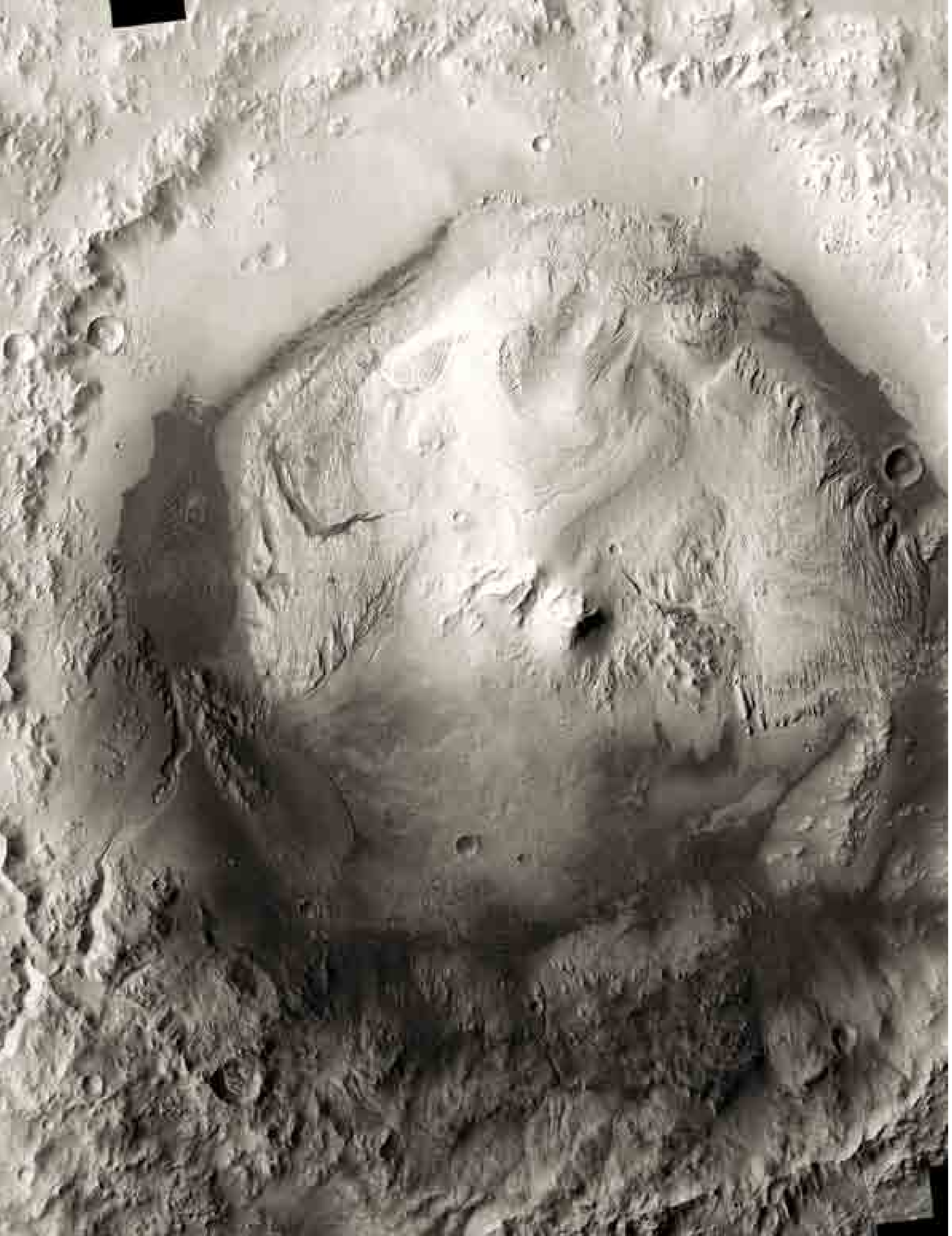
Our January/February contest winner is Lothar Flathmann of Limburg, Germany. Congratulations! **THE QUESTION WAS**: What are the only two vehicles to have performed fully autonomous re-entry and runway landings from Earth orbit? **THE ANSWER**: The Soviet *Buran* space shuttle with one flight in 1988, and the X-37B Orbital Test Vehicle, which had its first mission in 2010.

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

*What is the name/designation of the 400-meter-diameter asteroid that will fly within 0.85 lunar distances of Earth on November 8, 2011? (Note: it will reach 11th magnitude and be visible through amateur telescopes.)*

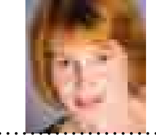
E-mail your answer to *planetaryreport@planetary.org* or mail your answer to *The Planetary Report*, 85 South Grand Avenue, Pasadena, CA 91105. Make sure you include the answer and your name, mailing address, and e-mail address (if you have one). Submissions must be received by December 1, 2011. The 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*.



Gale: NASA/JPL-Caltech/MSSS/Tanya Harrison; descent: NASA/JPL-Caltech





**EMILY STEWART LAKDAWALLA**
*blogs at* planetary.org/blog.

# Target: Gale

## *Curiosity* Will Soon Have a New Home

*by Emily Stewart Lakdawalla*

**SCREAMING STRAIGHT TOWARD** Mars from space, the cone-shaped capsule encasing the rover *Curiosity* will seem to ignite into a long-tailed fireball. But *Curiosity* is no shooting star, plummeting toward the ground, at the mercy of gravity. As soon as it's deep enough in Mars' atmosphere, its unevenly weighted heat shield will catch the air and it will surf the wind, zooming nearly horizontally along the ground, while rockets steer its course to a targeted point in the air above Mars' cratered surface.

Its target acquired and still traveling at supersonic speed, *Curiosity* will pull the trigger on its parachute, the largest ever sent to space. It will drop its blackened heat shield, exposing its six wheels directly to the Martian air. It will blow off the conical backshell and parachute, dropping into a heart-stopping, split-second free-fall before a back-mounted jetpack takes over, blasting downward with eight rockets to slow the robot's descent. Finally, the jetpack will lower the rover on three cable reels and set the wheels gently on the ground before cutting the cords and blasting off again, burning through all its remaining fuel to crash as far from the rover as possible.

When the dust settles and it's safe for *Curiosity* to open its eyes, the rover will find itself on a smooth, slightly dusty plain with rocks here and there, not so different from previous landing sites. The horizon, however, will contain something never before seen by a Martian rover. Gazing across the plains, *Curiosity* will look up and up and up at the nearly 6,000-meter-tall conical-shaped mountain that occupies the center of Gale crater.

Scientists hope that that mountain will contain answers to the questions that keep driving humans back to Mars: What was Mars like when water flowed on its surface? Could life ever have thrived here? If it did, do we have any hope of finding clues to its existence? While *Curiosity* attempts to answer those questions, it will return images of spectacular scenery from a mountainous landscape where ancient streams have carved canyons into layered rocks.

### WE FOLLOWED THE WATER. NOW WHAT?

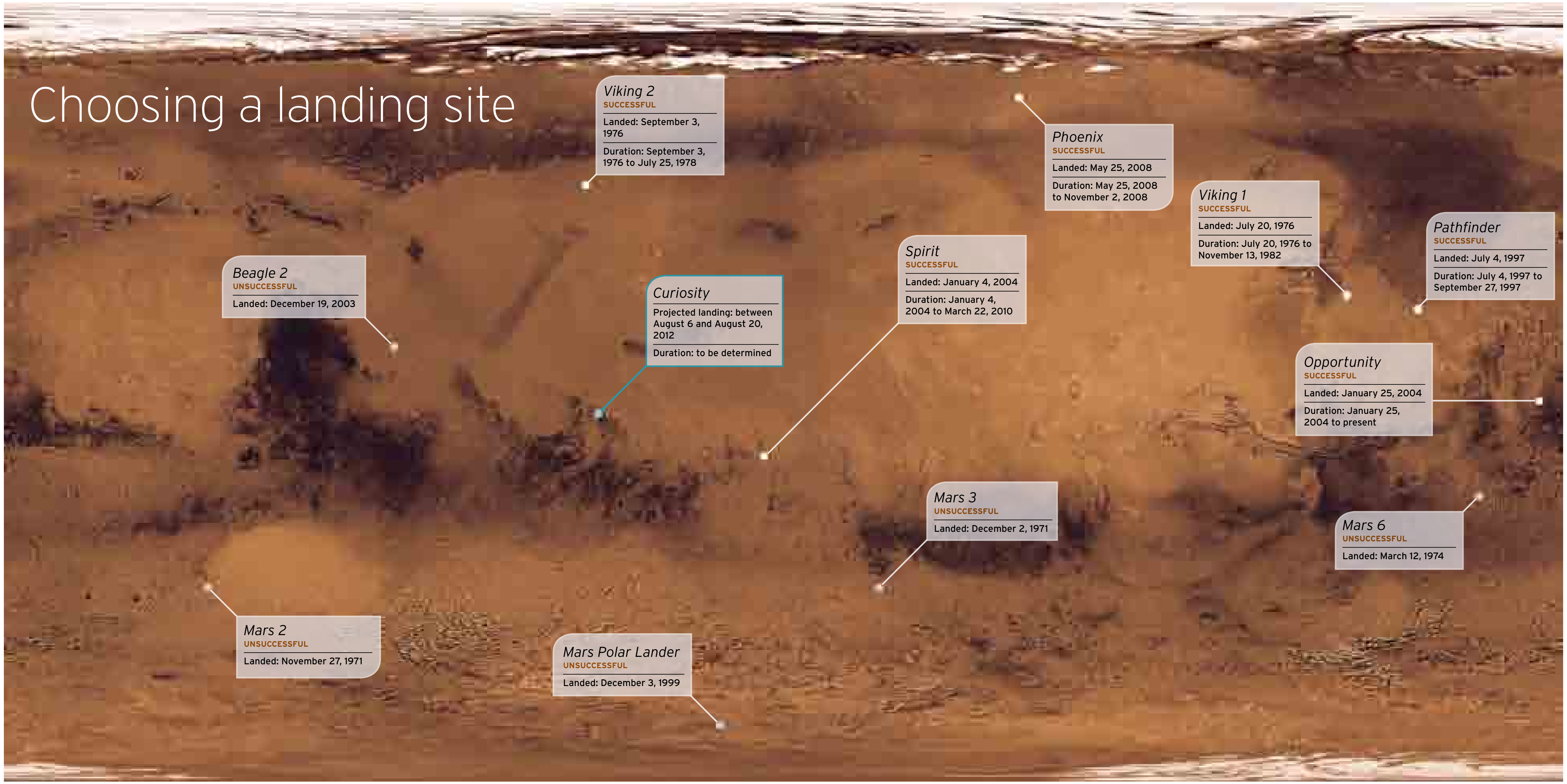
To understand why Gale crater was chosen above all other locations on Mars as the best hope for success of this $2.5 billion mission, it's necessary to step back and consider *Curiosity*'s science goals, which are quite different from those of *Spirit* and *Opportunity*. Those predecessors of *Curiosity* were sent to Mars to search for evidence that liquid water really did interact with Mars' rocks. They succeeded; *Spirit* and *Opportunity* truly have found plenty of evidence that water acted on some of the rocks they've studied, often in unexpected ways.

Now that we know that water's been there, the new question is, could life have existed in these watery environments? To help answer that question, *Curiosity* is focusing on the habitability of these ancient watery environments. Water is a start, but for watery places to support life, they also need chemical precursors for life's chemistry—namely, carbon-containing organic compounds. They also need a source of energy, such as the Sun or a geothermal environment.

How can we have any hope of landing in a place

**ABOVE** *This artist's concept from an animation depicts* Curiosity, *the rover to be launched in 2011 by NASA, as it is being lowered by the mission's rocket-powered descent stage during a critical moment of the "sky crane" landing in 2012.*

**LEFT** *A mosaic of* Mars Reconnaissance Orbiter *Context Camera images covering all of Gale crater. The whole crater is about 150 kilometers (93 miles) in diameter.* Curiosity *will be aiming for a spot inside Gale near the northern rim and will drive toward the five-kilometer-high mound of layered deposits in its center.*



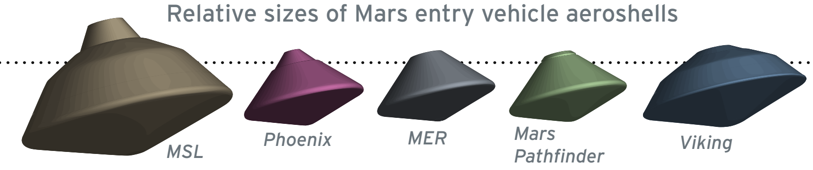

Map by Emily S. Lakdawalla atop *Viking* color MDIM

**LEFT** *Over the years, we have attempted to land in a variety of locations on Mars' surface, because each location teaches us more about the planet's history.* Curiosity *has the distinction of being the first lander that is able to control its descent and pinpoint a landing site, then drive to a location too hazardous to land in.* Curiosity *will land safely in the flat floor of Gale crater, then drive to a mountain built of rocks that contains minerals that formed in a wetter Mars more suitable for life.*

where we might find these building blocks of life? It's not enough just to say that water has been around. *Spirit*'s landing site provides a cautionary tale. Gusev crater clearly once contained a river and likely a lake of water–a huge channel enters it from the south and exits it from the north. When *Spirit* landed there, however, scientists found that they had arrived in a "basalt prison," where later lava flows had hidden any evidence of Gusev's watery past. Mars tricked us, and we can't let that happen again. Too much is at stake.

So where should *Curiosity* land to find more evidence of the existence of life? I wrote about the Mars Exploration Rover landing site selection process in the May/June 2003 issue of *The Planetary Report*. The *Curiosity* landing site selection process proceeded according to the same plan. First, engineers developed a list of parameters that constrained the locations in which the spacecraft is highly likely to land safely, and then Mars scientists were invited to propose sites and defend their choices to their peers in a series of community workshops. At each workshop, the site list was shortened. Between workshops, orbiting spacecraft were pointed at proposed sites to gather more data to aid in making the choice. Periodically, updates from the engineers changed the site constraints.

Relative sizes of Mars entry vehicle aeroshells




Aeroshell images by Loren A. Roberts using data from NASA/JPL-Caltech

## *Curiosity*'s Instruments and Tools

**MAST CAMERAS** (Mastcams) ▶ high-resolution HD color video cameras for viewing possible science targets from a distance.

**CHEMISTRY & CAMERA** (ChemCam) ▶ shoots a laser at nearby rocks and views the glowing plasma with a telescope to read elemental composition of rocks from a distance.

**NAVIGATIONAL CAMERAS** (Navcams) ▶ take wide-angle images for planning rover drives

**ROVER ENVIRONMENTAL MONITORING STATION** (REMS) ▶ instruments monitor weather features including wind speed and direction, pressure, humidity, temperature, and ultraviolet radiation.

**MARS DESCENT IMAGER** (MARDI) ▶ wide-angle, downward-pointing camera for taking photos during descent to help figure out where the rover landed.

**HAZARD AVOIDANCE CAMERAS** (Hazcams) ▶ take fish-eye views of terrain immediately in front of and behind the rover, for planning rock approaches and arm placement

**CHEMISTRY & MINERALOGY** (CheMin) ▶ measures mineral makeup of samples of powdered rocks and soils delivered by the arm

**SAMPLE ANALYSIS AT MARS** (SAM) ▶ can detect organic compounds in powdered rocks and soils and obtain isotopic ratios for carbon and oxygen compounds in samples and atmosphere

**RADIATION ASSESSMENT DETECTOR** (RAD) ▶ for measuring radiation dose that a human would receive on the Martian surface

**DYNAMIC ALBEDO OF NEUTRONS** (DAN) ▶ measures abundance of water in soil along the rover's path

**ROBOTIC ARM** (RA) ▶ can place five turret-mounted devices 1.9 meters away from the rover.

**ALPHA PARTICLE X-RAY SPECTROMETER** (APXS) ▶ detects elemental composition of rocks and soils within reach of the arm; sensitive to larger-mass elements than ChemCam

**MARS HAND LENS IMAGER** (MAHLI) ▶ color camera for magnified views of rocks and soils within reach of the arm

**DUST REMOVAL TOOL** (DRT) ▶ a brush

**POWDER ACQUISITION DRILL SYSTEM** (PADS) ▶ a percussive drill to take rock samples for CheMin and SAM

**COLLECTION AND HANDLING FOR INTERIOR MARTIAN ROCK ANALYSIS** (CHIMRA) ▶ sieves and portions samples for CheMin and SAM

Mounted to the front of the rover are **BIT BOXES** holding two spare bits for PADS and an **OBSERVATION TRAY**, onto which CHIMRA can dump sieved samples for examination by APXS and MAHLI.

The changes in safety constraints imposed severe restrictions on the landing site selection for *Spirit* and *Opportunity*. What was worse, each improvement in the quality of data concerning the proposed landing sites tended to reveal conditions that would be hazardous for an airbag-protected landing following a ballistic descent. Near the end of the process, scientists were forced to add one landing site that would be safe for landing but utterly uninteresting for science.

Although *Curiosity*'s landing site selection process proceeded according to the same broad outlines, it evolved in a totally different way. The two main differences had to do with improvements in mission design and with a revolution in our understanding of Mars.

### A SMART LANDER

Originally, this mission's acronym, *MSL*, stood for *Mars Smart Lander*, and the name still applies. *Spirit*'s and *Opportunity*'s landing locations were at the mercy of Mars' highly variable atmospheric density, which meant that the landing ellipses (the regions in which navigators could be more than 99% certain that the rovers would touch down) were 10 by 80 kilometers (6 by 50 miles) in size, highly elongated along their ground track. (As it turned out, the day of both landings proved to be particularly low-density, so *Spirit* and *Opportunity* "went long" in their ellipses, landing 13 and 15 kilometers [8 and 9 miles] down range from their predicted landing locations, respectively.) From the start, only about 150 locations on Mars were at low enough elevations and had flat enough areas that were big enough to squeeze in these long, skinny ellipses.

*Curiosity*'s landing will be much smarter. During *Curiosity*'s autonomously guided descent, the spacecraft will "fly out" any atmospheric variations it encounters, vastly reducing the uncertainty in its landing location. Its landing ellipse is about 20 by 25 kilometers (12 by 16 miles), a number that may even decrease. The nearly constant altitude of the guided phase of its descent also means that *Curiosity* can land at elevations higher than those of any previous landers.

The most exciting new ability of *Curiosity* is that it is designed to be capable of driving at least 20 kilometers (12 miles) if necessary, meaning that it could potentially drive right out of its landing ellipse. It could land on flat, scientifically uninteresting terrain and proceed to mountains and canyons beyond the safe landing zone. All this capability opened up thousands, even millions, of potential landing locations on or near virtually every type of terrain that Mars has to offer.

### INFORMATION IS A GOOD THING

While engineers were developing a smarter way to land a rover, scientists were amassing terabytes of data from two new orbiters: the European Space Agency's *Mars Express*, which arrived at Mars near the same time as *Spirit* and *Opportunity*, and NASA's *Mars Reconnaissance Orbiter*, which joined the party in 2005.

When the *Spirit* and *Opportunity* landing sites were being chosen, many of the presentations centered on guessing at the properties of the surface—how rocky it was likely to be, how thick the dust cover was likely to be, and what the rocks probably were made of.

Thanks to *Mars Express* and *Mars Reconnaissance Orbiter*, such guessing no longer is necessary. We can now see every single rock that is large enough to present a hazard to the rover's half-meter-high ground clearance upon landing, thanks to the sharp-eyed HiRISE camera, and we can automatically count them using algorithms developed for analyzing the *Phoenix* landing site. We have digital terrain models made from overlapping HiRISE images that provide amazingly sharp detail about the local and regional topography, so we can avoid hazardous places where the rover could land on slopes greater than 15 degrees.

In addition, now we can be completely confident that no matter where we go, we will find ourselves among rocks that have seen liquid water that has been active for more than transient, one-time events. This confidence comes from a revolution in the understanding of Mars' history based on data from two orbital instruments, both imaging spectrometers: OMEGA on *Mars Express* and CRISM on *Mars Reconnaissance Orbiter*.

OMEGA and CRISM are able to see Mars at higher resolution than their forebears (TES on *Mars Global Surveyor* and THEMIS on *Odyssey*), but the key to the new understanding didn't come from this sharper vision. The critical difference has to do with which wavelengths OMEGA and CRISM see.

TES and THEMIS operate in the thermal infrared part of the spectrum, where rock-forming silicate minerals express their presence as squiggles in the spectra. OMEGA and CRISM are sensitive to much shorter wavelengths, the visible and near-infrared. In that part of the spectrum, spectroscopists can spot evidence for water bound into crystals, either as water molecules or as hydroxyl groups (OH-ions), in clay minerals that form when rocks are broken down by liquid water. OMEGA and CRISM also can see sulfates and carbonates, the sorts of minerals you find where mineral-rich waters evaporate.

The two spectrometers found clays and sulfates all over Mars, but only in certain places. The clays, especially, were only in tiny exposures, because they seemed to exist only in Mars' most ancient and, hence, most deeply buried rocks.

The data from OMEGA and CRISM developed the following story. At present, Mars is cold and dry, with a strongly oxidizing atmosphere, the cause of its rusty red color. Very early in its history, however, Mars had a neutral and much wetter environment, where silicate minerals were weathered into clay minerals. Later, a last gasp of volcanic activity, which belched out noxious gases from Mars' interior, acidified the environment, producing sulfate minerals like those explored at Meridiani by *Opportunity*. After that volcanism ended, the modern cold, dry, oxidizing conditions prevailed.

It's clear that those most ancient rocks made in either of the two wetter eras—the era of clays or the era of sulfates—present a more favorable environment for the possible presence of Martian life than for the modern environment. We've visited a sulfate-rich environment (Meridiani, *Opportunity*'s landing site), but we've never landed in a place old enough to preserve those most ancient clay minerals.

### FOLLOW THE CLAYS

Narrowing the sites of interest down to those containing the telltale sign of clay minerals virtually guaranteed that the site at which *Curiosity* would land would have been habitable, according to the scientists' definition. With that in mind, as the site selection process matured and the choices were winnowed down to four, *Curiosity*'s science team focused more narrowly on habitable environments that might actually preserve evidence that organic materials were once present and available for prebiotic or even biologic chemistry. *Curiosity* will have the unique capability to detect and analyze organic materials in rocks and soils.

Once the focus shifted to preservation, scientists actually found themselves in the odd position of worrying that some of the proposed Martian landing sites might have seen *too much* water in the past. Water may be necessary to support life as we know it, but once an organism has metabolized its last, water is an enemy.

Even if a dead organism becomes buried, water flowing through the ground continues to serve as an effective medium for chemical

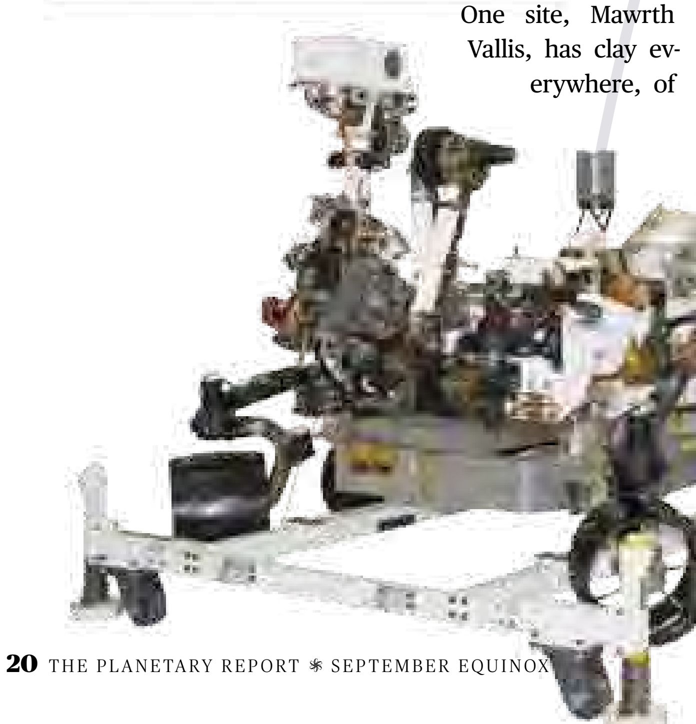
**The mound in the center of Gale crater could be a remnant of deposits that once covered the whole region but that more recently were stripped away, exhuming the ancient crater.**

reactions, and complex organic chemicals are quickly oxidized into simple inorganic compounds (mostly carbon dioxide). That's why fossils are relatively rare on Earth: most things that die are oxidized long before there is any chance of turning the dead thing into rock. The carbon's still present, but by the time the sediment becomes a rock, the carbon has become nothing more than the calcium carbonate cement that typically holds Earth's sedimentary rocks together.

Some environments are particularly bad at preserving organic materials. Examples include high-energy environments such as ocean shores and rushing rivers. Others are particularly good, such as the layers of very fine sediment that form in deep water at the toes of river deltas.

The four finalist sites were of two different types. One site, Mawrth Vallis, has clay everywhere, of diverse chemical composition, and it has the unique advantage of being a site where *Curiosity* would actually land on the rocks containing these desirable clay minerals. Mawrth was also the geologically most ancient of the four sites, more ancient even than the oldest rocks preserved on Earth. If it was early Mars that had the kinds of environments most likely to support life, Mawrth seemed like a good candidate.

The problem with clay-rich Mawrth was that despite many years of investigation, scientists don't understand the environment in which those clays formed. Did it consist of primary minerals? Were the clays laid down as sediments? Or were they formed when groundwater altered previously formed rocks? Just how much water has Mawrth seen? Is there any chance that organic materials could have survived to the present? This uncertainty caused concern among many scientists who attended the workshops.



**BELOW** *Curiosity is seen here inside the Spacecraft Assembly Facility at NASA's Jet Propulsion Laboratory, Pasadena, California, on April 4, 2011. Support equipment is holding the rover slightly off the floor. When the wheels are on the ground, the top of Curiosity's mast is about 2.2 meters above ground level.*

NASA/JPL-Caltech

The other three sites–Gale crater, Holden crater, and Eberswalde delta–are craters that served as enclosed basins holding crater lakes. For all three of these sites, the rover would land on flat areas with little evidence of clay minerals and drive out of the ellipse to the "good stuff," making them so-called go-to sites. Some scientists opined that it would be crazy to pick a go-to site, with the possibility of months of driving before the opportunity to hit "pay dirt," when an alternative–Mawrth–presented the possibility of doing science immediately upon landing.

Here was another topsy-turvy discussion: scientists were arguing for a timid, conservative approach to the mission, whereas the engineers present at the workshop responded that there was no need for worry. They claimed that *Curiosity* can handle driving over any terrain that it can land on and will go anywhere you want it to go.

The arguments concerning Mawrth versus the three crater sites split along familiar lines. Generally speaking, spectroscopists saw the beautiful mineral signatures blazing from Mawrth and wanted to land there. Geologists found Mawrth dull, preferring the spectacular geomorphology preserved in the river delta at Eberswalde or the enormous layered mound in Gale.

Pretty much the same groups of people had been at odds during the discussions surrounding the landing site selection for *Spirit* and *Opportunity*. Spectroscopists liked the clear spectral signals from Meridiani, whereas geomorphologists, dismayed by Meridiani's flatness, had higher hopes for Gusev. We know how that turned out: Gusev was, at least initially, a disaster in terms of the search for water.

It's not the same this time around. With the help of OMEGA and CRISM, scientists have found ample clays or sulfates at the three crater sites. Gale, uniquely, possesses both.

At the end of the final landing site selection meeting, there was no clear consensus on the best choice among the four. Surprisingly, the most common opinion seemed to be that all four sites held promise for a scientifically productive mission, with none of them standing out.

The engineers provided no help in differentiating among the sites; computational simulations of landings at all four revealed basically no hazards of any concern to the engineers. Provided that *Curiosity*'s entry, descent, and landing all occur according to design, all four sites are totally safe for landing.

### WHY GALE?

What made Gale stand out? One advantage is its diversity. It contains lots of rock types, which probably formed in different ways and at different times in Mars' history. It has river-carved canyons and windblown dunes, clays and sulfates. It was a crater once and a lake once, and at some point, it probably was buried completely by sediment.

What really makes Gale special is its central mound. It is enormous, nearly six kilometers (four miles) tall. Oddly, the mound actually stands taller than the crater rim. This suggests that the mound is a remnant of deposits that once covered the whole region but that more recently were stripped away, exhuming the ancient crater.

The amount of Mars' history that might be represented in that vertical pile of rocks could be huge. For comparison, the whole stratigraphic section exposed in the Grand Canyon of the Colorado River is less than three kilometers (two miles) thick. As with the Grand Canyon rocks, there's an *unconformity* in Gale's mound–a geologist's term for a place where the rock record is interrupted, where ancient rocks were uplifted and eroded and then more material was deposited on top. The unconformity represents the passage of some unknown amount of time, possibly quite a lot of time, so there may be more than one era of Martian history preserved in the mound, and more than one ancient environment to explore.

*Curiosity* would explore that mound the way any self-respecting field geologist would, beginning at the bottom, with the oldest rocks, and reading the story of this spot on Mars in order, from oldest to youngest, as the rover slowly climbed upward. It would study Mars' history in the order that that history unfolded.

The mission planners must be careful not to presume that this rover will last longer than its warranted lifetime of one year, or that NASA will provide funding to extend the mission beyond that. One year will be enough time for the rover to explore the alluvial fan on which it will land, drive to the toe of the mound, and explore the clay and sulfate rocks that are exposed at its base.

Once that year is over, and *Curiosity* has finished with those most ancient rocks, it will find itself at the bottom of a mountain with nowhere to go but up–up through Martian history, and up to ever more scenic vistas of canyons, mountainsides, the distant walls of the crater, and possibly beyond. Will *Curiosity* ever top Gale's wind-whipped summit? We can't predict that, but we'll be able to ride along on the adventure!

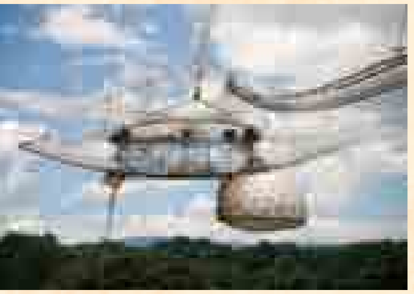
NASA/JPL-Caltech/ASU/UA

**154 km**

Gale crater's diameter (96 mi)

Gale holds a layered mountain rising almost 6 km (4 mi) above the crater floor

The portion of the crater within the landing area has an alluvial fan likely formed by water-carried sediments.



ARECIBO & the Lesser Antilles
January 26–February 4, 2012

MAYA WORLD & the Great Dinosaur Extinction
November 10–18, 2011

ANTARCTICA!
December 30, 2011–January 11, 2012

ALASKA's Aurora Borealis
March 15–21, 2012

The GRAND CANYON and the 2010 Annular Solar Eclipse
May 14–21, 2012

SIBERIA & LAKE BAIKAL for the Transit of Venus
June 1–12, 2012

Discover HAWAII and the Transit of Venus
June 4–12, 2012

## Explorers Wanted! Travel with the Planetary Society

The Planetary Society is calling explorers to travel with us to remote, beautiful, and even alien regions on planet Earth to witness some of our world's most breathtaking wonders. Escorted by knowledgeable guides and speakers, the tours we offer through Betchart Expeditions span the globe.

Coming up, we invite you to join us on an amazing adventure to the Caribbean, starting January 26, 2012. Our trip combines two tremendous opportunities—a chance to see the world's largest radio telescope near San Juan, Puerto Rico and an opportunity to explore the Lesser Antilles, a ring of volcanic islands that circles the eastern Caribbean.

We'll travel on board the 227-foot, five-masted *Royal Clipper*—one of the world's largest sailing yachts. Our own Bill Nye will join the group at the famous Arecibo Radio Telescope, where scientists search for extraterrestrial signals and conduct fascinating deep-sky research on topics ranging from quasars and pulsars to the origins of the universe starting at the moment of the Big Bang.

Join us for ARECIBO & the Lesser Antilles, January 26–February 4, 2012, or join us on one of these other great adventures!

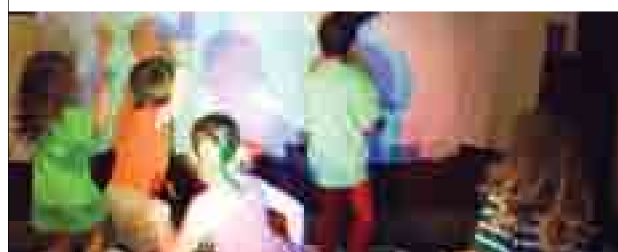
For more information or to sign up for any of these trips, visit *betchartexpeditions.com* or contact:

Betchart Expeditions
17050 Montebello Road
Cupertino, CA 95014-5435
Tel.: (800) 252-4910 or (408) 252-4910
Fax: (408) 252-1444
E-mail: *info@betchartexpeditions.com*



**LOVELY PORTLAND, OREGON WAS THE HOST** to more than 2,300 Mensans at the yearly Mensa Annual Gathering, held in a different city every summer. In line with the Planetary Society's commitment to reaching out to kids, I participated in the programming, doing presentations in the Planetary Society's name for two groups of gifted youth.

The first group of Mini-M's (4 to 6 years old) was in constant motion, little ones everywhere talking and playing. The teachers herded the children toward a space on the carpet so they could see the light show I'd prepared for them. Suddenly the room went still and the sounds of "whoaaah" filled the air. We looked at several different colors of light bulb through our rainbow peepholes, then we learned about how white light is made up of many colors. The highlight was letting the kids play in the light, dancing to their own shadows.



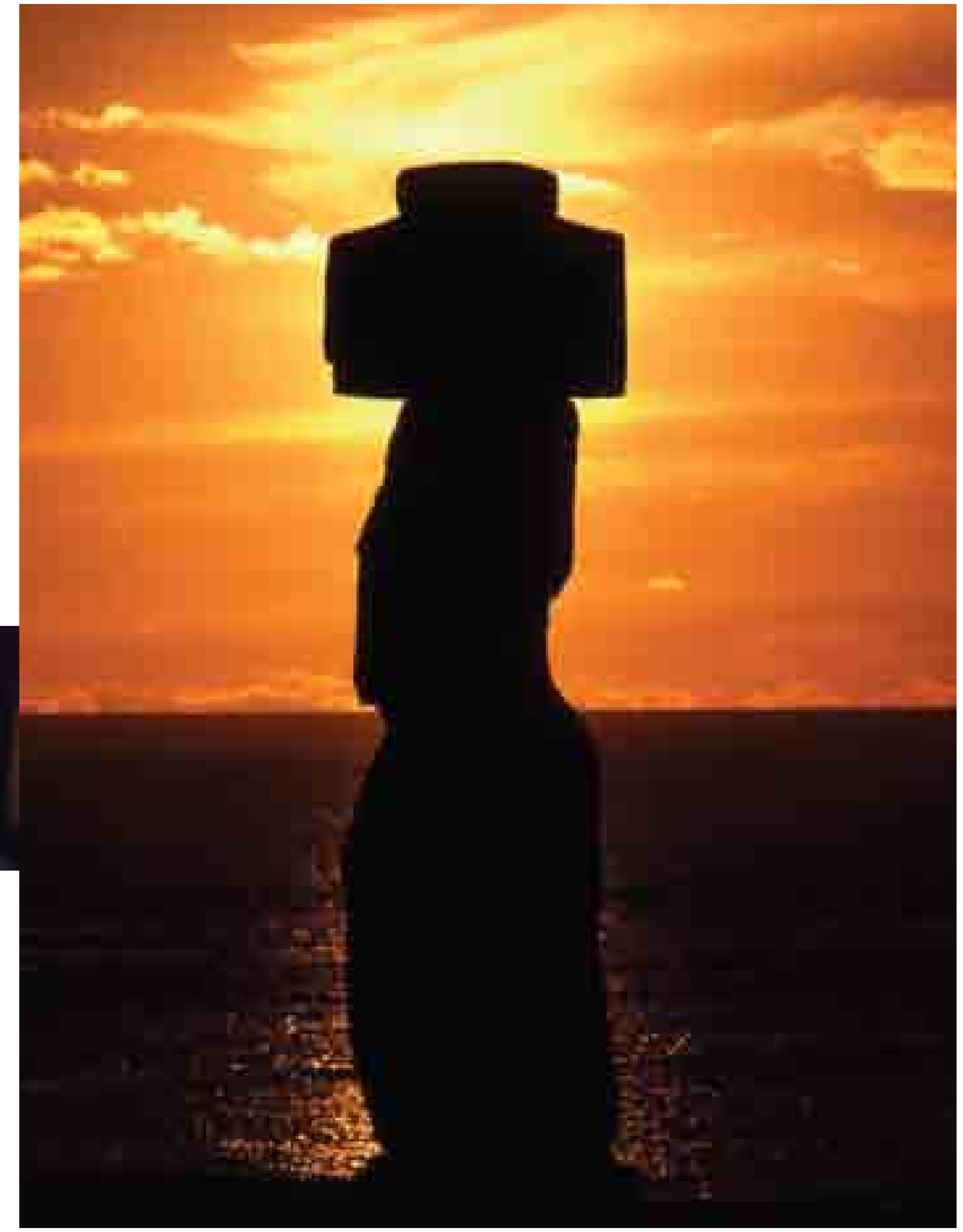
The second group I presented to was the Jr-M's (7 to 11 years old). I was impressed with how much they already knew about the science we were discussing. After taking some time to explore the lights and lasers, we moved on to making predictions about what we'd see. While I was teaching them such terms as *diffraction* and *focal length*, some of them were already quoting them to me. They kept me on my toes, and let's just say that there were several budding scientists in that crowd.

The Planetary Society has been invited back for next year' gathering, and we're already excitedly making plans to have a much larger role in the programming. Working with the kids was a treat. I can't wait to do it again!

*—Danielle Hannah*



*We thank all of our Members who have submitted photos since we launched "MySky" in the June 2011 issue of* The Planetary Report. *It's a lot of fun to see your personal views of the sky we all share! To see more of your fellow Members' entries, go to* HTTP://MYSKY.PLANETARY.ORG.



**I took this photo** of a lone moai at Ahu Tahai on Easter Island at sunset on October 26, 1994. I used a Canon AE-1 with Kodachrome 64 color slide film. My lens was a 300-millimeter f5.6 set at 1/125th of a second. I had to climb up the local hillside, lie on the ground, and wait for the right Sun position to shoot the statue at this angle. I am quite pleased with the result. *—Jay Arthurs, Saratoga, CA*

**I captured this image** of the Moon just outside my front door on May 20, 2007 using a web camera attached to a 114-millimeter Newtonian refractor. I shot six overlapping views as AVI video and then used Registax to create a still from each video. Finally, I merged these in Photoshop to create the finished product. This is a sample of what can be achieved with inexpensive equipment. Even Photoshop was a free version that came bundled with my scanner. *—David Liddicott, Barrow-in-Furness, United Kingdom*

**WANT TO SHARE YOUR SPACE IMAGE?** Send us an e-mail with a jpeg (less than 5 MB) attachment of your image to *planetaryreport@planetary.org*. Please use the subject line "MySky" and include a short caption (such as where you took the image and, if appropriate, with what equipment) and credit line for the image. Please include just one MySky image per submission. Also be sure to include your name, contact information, and membership number (it's on your membership card and on the mailing label of your magazine). We'd also love to receive a picture of you and to learn more about what is most important to you about being a Planetary Society Member. Questions? E-mail *andrea.carroll@planetary.org* or call (626) 793-5100, extension 214.

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



Illustration: Pat Rawlings, Eagle Applied Sciences for NASA

# Have you heard about the *New Millennium Committee*?

*New Millennium Committee* members are an important force within the Planetary Society.

They are individuals who each year give an unrestricted donation to the Society. Unrestricted funding means the Society can respond to opportunities and challenges quickly and confidently. Generous *New Millennium Committee* gifts seed initiatives, propel advocacy, and fuel projects.

*New Millennium Committee* members help invent the future of space exploration.

Your annual unrestricted gift of $500 or more will have a major impact:

- **$10,000** could defray the costs of forging crucial partnerships with space agency leaders, scientists, and policymakers.
- **$5,000** could help the Society reach more people in communities around the world by supporting local lectures, star parties, and mission-related events.
- **$2,500** could craft and promote an episode of *Planetary Radio* that takes listeners behind the scenes of space exploration.
- **$1,000** could fund a low-cost, high-impact project like the investigation of an asteroid impact in Patagonia.
- **$500** could provide the very necessary operating support that enables staff to carry out the Society's mission to explore other worlds, understand our own, and seek life elsewhere.

In recognition of your generous support, you will also receive benefits that include attendance at an annual meeting, participation in teleconferences, and other opportunities to delve into space exploration and discovery.

## Are you ready to join?

To RSVP, or for more information, please call or e-mail Director of Development Andrea Carroll at (626) 793-5100, extension 214, or *andrea.carroll@planetary.org*. You can also join online at *nmc.planetary.org*.