National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

JPL 400-1473 03/12

National Aeronautics and Space Administration

2011

Jet Propulsion Laboratory
ANNUAL REPORT

A new view of the North American nebula, combining infrared data from the Spitzer Space Telescope and optical data from the Digitized Sky Survey.

Cover: JPL's 2011 launches were (from left) Mars Science Laboratory, Aquarius, Juno and GRAIL. (Courtesy ULA)

CONTENTS

DIRECTOR'S MESSAGE

As years go, some move along at a calibrated simmer, but others erupt at a full boil. The latter is how it was for us in 2011 at the Jet Propulsion Laboratory. It was a year in which we seemed to be always catching our breath.

Nowhere was the pace more evident than in our launches of new missions. In one of our busiest seasons ever, we lofted five spacecraft in four launches from Florida and California, dispatching them month after month over the summer. A JPL-teamed international satellite took up station orbiting Earth to measure global sea salinity. A planetary mission headed to Jupiter to probe the giant planet's interior. Twin spacecraft flew in tandem to Earth's moon to plumb the history of our companion world. And, over the Thanksgiving weekend, we sent off the laboratory's latest flagship mission, a Mars rover far more sophisticated than any previously sent to the Red Planet.

While new robotic expeditions left the gate, the news was no less exciting from our flying missions that achieved historic milestones. One spacecraft that spent five years in dormant cruise mode after its primary mission of collecting comet samples made headlines when it flew by another comet. After years in transit, an ion-powered craft dropped into orbit at one of the solar system's largest asteroids, the protoplanet Vesta, where it is spending a year before continuing on toward the largest asteroid of all, the dwarf planet Ceres. The Kepler mission delivered exciting discoveries of planets around other stars. JPL moved forward with revolutionary technology initiatives in planetary descent systems, optical communications and an advanced atomic clock.

And then there was the serendipity of visitors to the neighborhood of our home planet. When an asteroid as wide as three football fields flew close to Earth, scientists used the big dish antenna at the Deep Space Network's ground station in the Mojave Desert to beam radar pulses at the rock, allowing them to assemble pictures showing surface features as small as gullies and boulders. Beyond that campaign, it continued to be a busy period for the Deep Space Network as it served as the communication gateway not only for our newly launched missions but also for nearly two dozen spacecraft currently operating throughout the solar system.

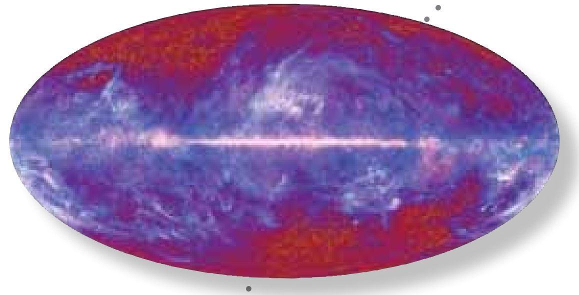
With these achievements under our belt, there is no shortage of concepts for future missions we would like to fly. In the months ahead, we will continue developing new proposals for NASA's competitive programs in planetary exploration, Earth science and astrophysics. We will work equally hard to define road maps in major exploration areas such as Mars and the moons of the outer planets. In the meantime, I hope that you will join me in savoring the high points of what was a remarkable year.

CHARLES ELACHI

Launch image courtesy ULA

In one of our busiest seasons ever, we lofted five spacecraft in four launches.

January



You might say the history of the universe is like a book — only there are pages missing, eras of cosmic time as yet unglimpsed by telescopes. The European Space Agency's **Planck** mission, in which JPL plays a key role, is working to remedy that. Planck is filling in a missing early chapter by surveying energy dating back to just a few hundred thousand years after the 13.7-billion-year-old Big Bang. In January, scientists released their first full catalog of data from the mission, revealing thousands of never-before-seen dusty cocoons where stars are forming, and some of the most massive clusters of galaxies ever uncovered.

The cosmic microwave background and the Milky Way are captured in this all-sky image from the Planck spacecraft. (Courtesy ESA)

01/10 Scientists announce the Kepler mission has discovered its first rocky planet.

01/11 Cassini spacecraft flies within 69 km (43 mi) of Saturn's moon Rhea.

01/11 Scientists release radar images of recently discovered asteroid 2010 JL33.

01/13 Wide-field Infrared Survey Explorer releases a new view of two companion galaxies, Messier 81 and Messier 82.

WEATHERING THE STORM

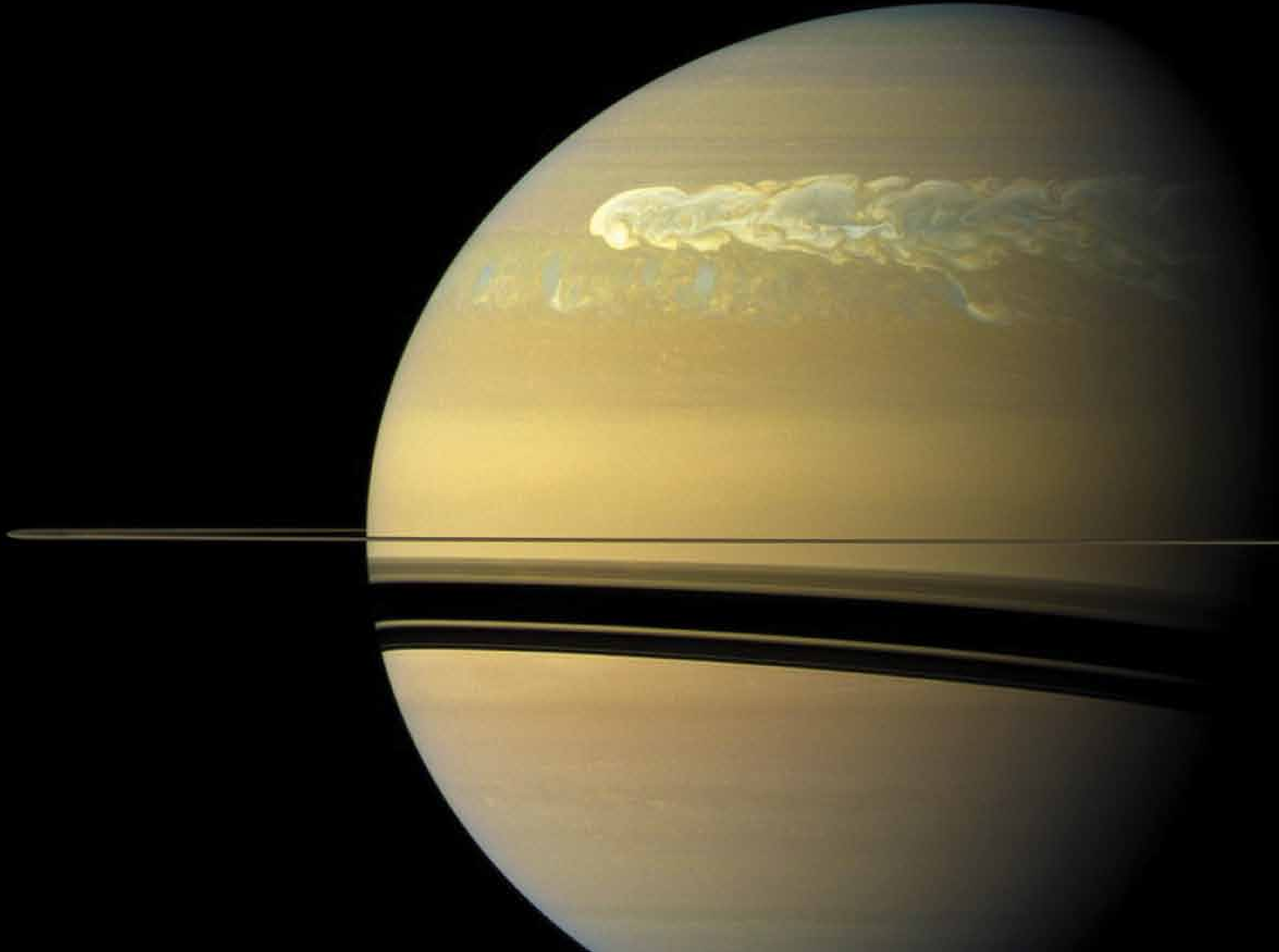
Gemlike though it may be, Saturn is hardly one of the most hospitable destinations in the solar system. The skies may be an inviting-looking butterscotch hue, but they're poisonous. Not to mention the fact that, with no solid surface, there isn't even a place to stand on the ringed world.

If that weren't enough, as 2011 began, along came the Great Northern Storm. And a whopper of a tempest it was. First detected when the radio and plasma wave instrument on the orbiting Cassini spacecraft picked up the noise from lightning flashing more than 10 times a second, the churning storm grew quickly, wrapping around the huge planet by the end of January. An enormous dark stain some 5,000 kilometers (3,000 miles) wide, the storm churned up huge amounts of ammonia from deep in Saturn's atmosphere before easing off later in the year.

But the maelstrom wasn't the only extreme weather at the solar system's second largest planet. Cassini scientists announced they had a front-row seat for vast rains at Saturn's biggest moon, Titan, the product of a gigantic cloud lingering over the haze-shrouded world. Not the kind of precipitation to bring spring flowers, however; the rain falling on frozen Titan was liquid methane.

Elsewhere around the Saturnian realm, Cassini found salt-rich ice in jets spewing from the south pole of the moon Enceladus — the best evidence yet for a large-scale saltwater reservoir beneath the icy crust of that satellite.

The churning Great Northern Storm at Saturn overtakes itself in this view captured by the Cassini spacecraft.



February

02/08 Santa Monica High School beats Arcadia in the JPL-co-hosted regional Ocean Sciences Bowl.

02/10 Spitzer Space Telescope's science team releases a new image of the North American nebula.

02/16 Herschel spacecraft measures how much dark matter it takes to form a new galaxy.

02/18 Cassini performs a close flyby of Saturn's moon Titan.

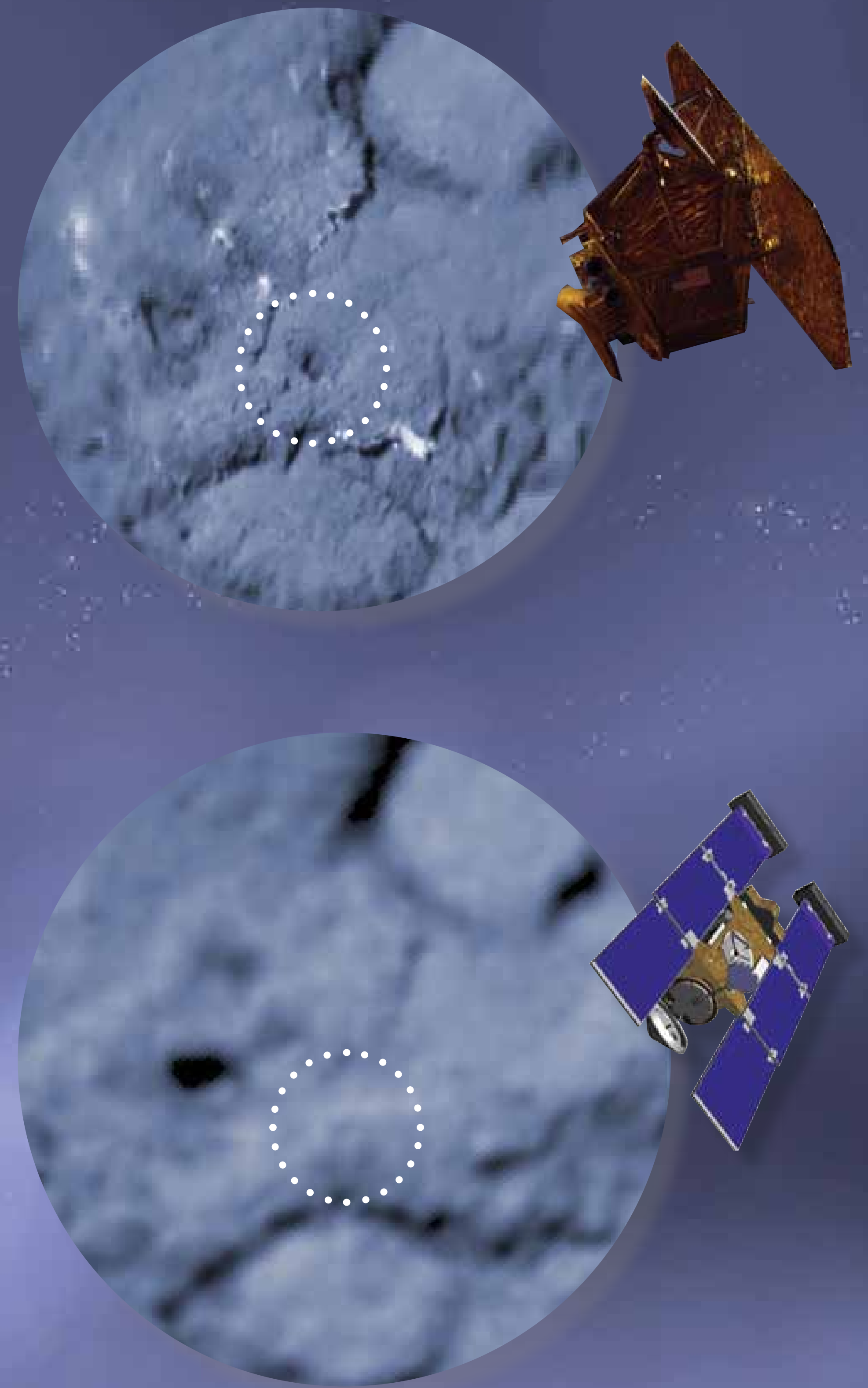
BACK FOR ANOTHER COMET

Staging a comeback after a long layoff can be grueling. Then there are those who make it look effortless — the Stardust mission, for one. The spacecraft had logged five years quietly clocking laps around the sun after a banner mission bringing particles to Earth it scooped up when it sailed past a comet called Wild 2 in 2004.

Then Stardust got the chance to go on a new mission: dropping in on yet another comet, Tempel 1. Scientists were eager to get a close look at this comet because another spacecraft, Deep Impact, had previously blasted a crater in it, but so much dust was thrown up that results of the impact were partially obscured.

Stardust took up this new opportunity and steered close to the frozen ball of dirty ice on Valentine's Day 2011. The spacecraft not only got a look at the crater excavated by Deep Impact, but also saw how the comet nucleus had changed in the five years between the two spacecraft visits.

With that encounter out of the way, Stardust's ticket was punched — its tanks of thruster fuel were by then hovering on zero. Flight controllers drained the final drops, then switched off the lights — leaving Stardust, after 12 years in space, to a well-deserved rest circling the sun.



Artist's depiction of comet Tempel 1, visited by Deep Impact in 2005 and Stardust in 2011. Before and after views (insets) captured by the two spacecraft of the spot hit by Deep Impact's penetrator.

March

03/09 Mars Reconnaissance Orbiter catches the rover Opportunity at work on Mars' surface in a new color image.

03/16 Students from across Southern California compete in a Lego robotics challenge at JPL.

03/18 Mars Science Laboratory undergoes testing in a sealed chamber to simulate conditions on Mars.

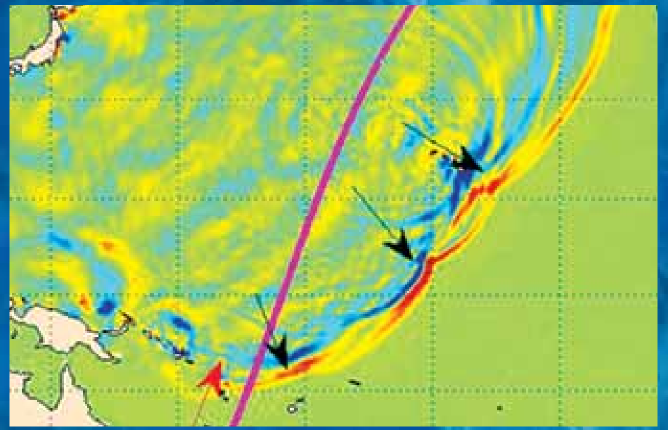
DESTRUCTION IN JAPAN

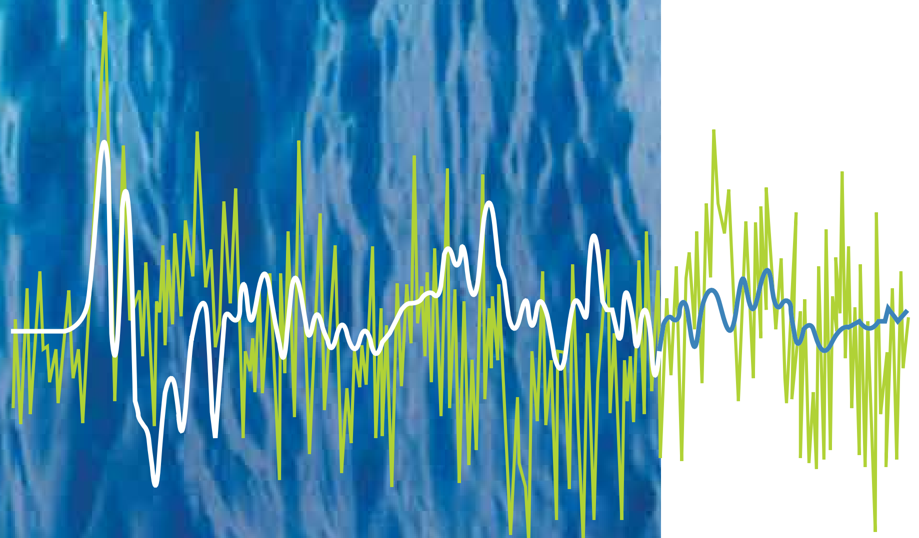
For Japan, it was a terrible three-part disaster. First, a magnitude 9.0 earthquake occurred off the coast of the country's northern coastal city of Sendai — the strongest ever to hit Japan, and the fifth worst anywhere since earthquakes have been accurately recorded. The massive quake also triggered a tsunami with waves up to 40 meters (133 feet) high that traveled as far as 10 kilometers (6 miles) inland, causing a series of incidents at nuclear power plants.

As Japan recovered, JPL scientists pored over data from satellites to see what light they could shed. The earthquake, they found, was of a type called a megathrust. The undersea segment of the fault that broke was actually only about half as long as would be expected for such a powerful quake, but the event caused strains up to 10 times larger than those seen in similar quakes.

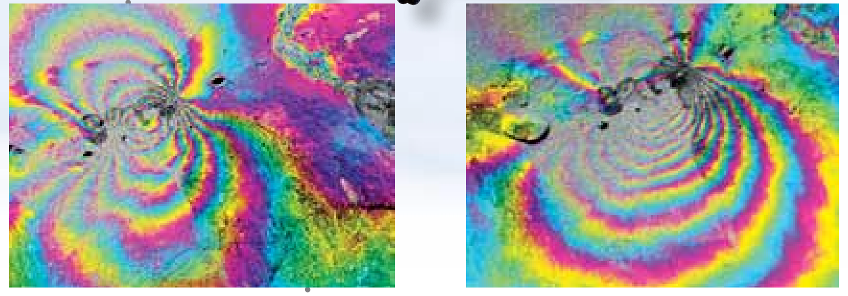
JPL's Jason 1 and Jason 2 satellites, which monitor sea levels, also provided insight into the tsunami. Scientists discovered the topography of the ocean floor focused the tsunami's energy in certain directions, causing waves to merge and form a single, double-high wave. This confirmed a long-held hypothesis of why tsunamis can cause massive destruction at some locations, while leaving others unscathed. Scientists say the fault area off the coast of Japan, previously largely unstudied, will be the focus for much future research.

Data from the Jason 1 and 2 satellites revealing the forces at work in the Japanese earthquake and tsunami.





April



04/12 The Spitzer Space Telescope and Hawaii's Keck Observatory are among instruments observing one of the earliest galaxies in the universe.

04/14 The first bundle of data from the Wide-field Infrared Survey Explorer mission is released, allowing astronomers to sift through hundreds of millions of galaxies, stars and asteroids.

04/21 Mars Reconnaissance Orbiter scientists report that the planet's atmosphere changes dramatically as Mars' axis tilt varies.

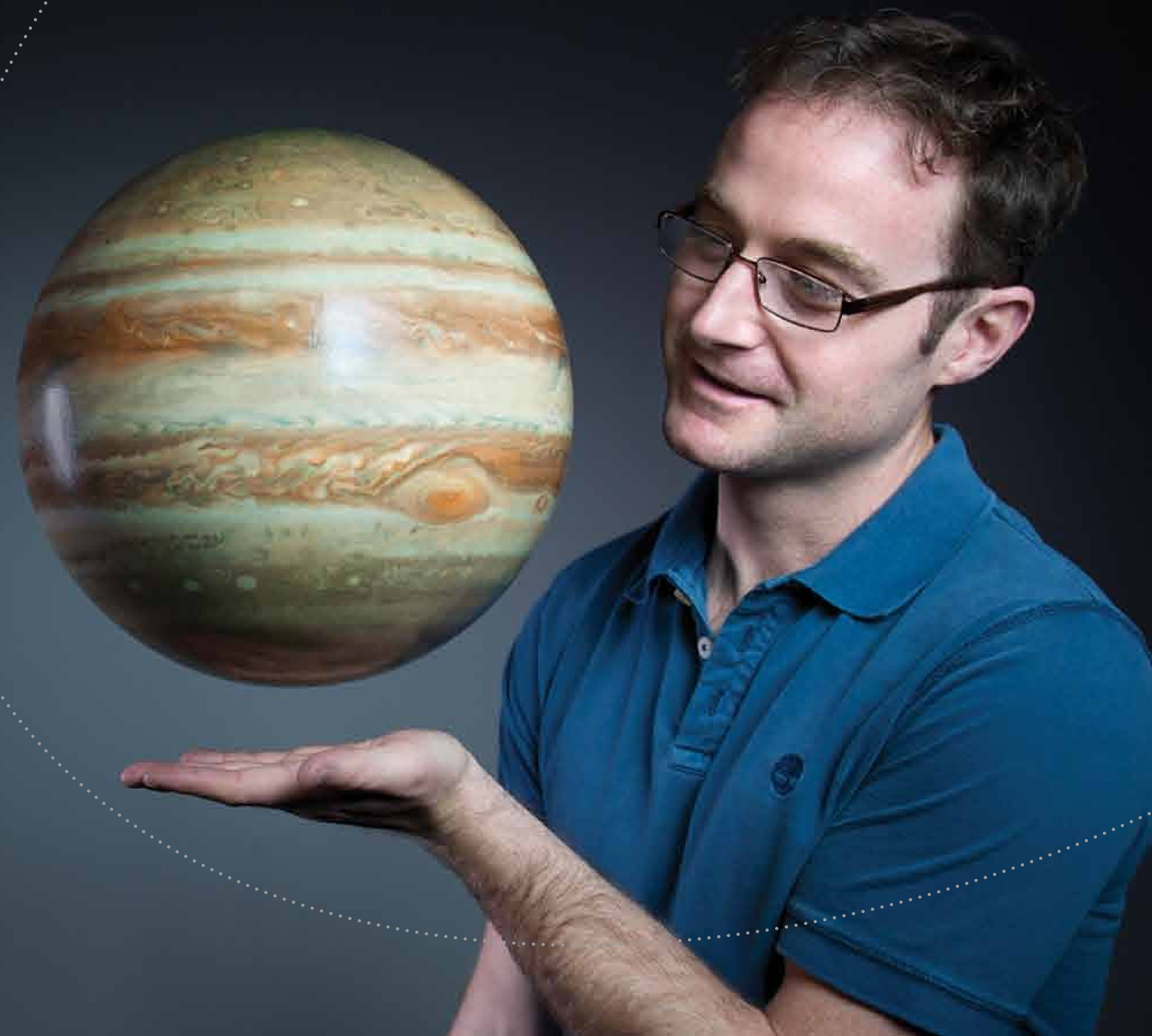
What kind of volcanic forces are shaping the Hawaiian islands? One JPL airborne instrument intends to find out. When fresh eruptions took place in one fissure at the Kilauea volcano on Hawaii's Big Island, a NASA plane carrying JPL's **Uninhabited Aerial Vehicle Synthetic Aperture Radar** set out to chart the area with imaging radar.

The campaign helped scientists understand the movement of magma beneath Hawaii's most active volcano.

Above, color-enhanced aerial radar images of Hawaii's Kilauea volcano.

PROFILES

Kevin Hand



Growing up in the ski resort countryside of Vermont, Kevin Hand strapped on his first pair of skis at age 2½. It wouldn't have been hard to imagine a future life as a ski bum — if it weren't for the way he felt when looking up at the dark, jewel-studded night sky.

"That brought home all kinds of questions — what's the origin of the universe? Is there life elsewhere?" says Hand, now deputy chief scientist for solar system exploration at JPL. "That really got me started on the big questions."

Answering those questions has turned Hand into a classic Renaissance personality, mingling a love for hard science with interests in other fields. For college, he went to Dartmouth and came away with dual bachelor's degrees, in physics and psychology. "Why psychology?" he says. "My interest was at the cognitive neuroscience level — trying to dive into the question of what is consciousness?"

After college, Hand worked as a research assistant at NASA's Ames Research Center and the SETI Institute, giving him an opportunity finally to explore astrobiology at the professional level. Taking a break before graduate school, he headed to Africa, where he hitchhiked from Johannesburg to Nairobi, catching trains here and there. "Along the way I'd stop at schools and talk to teachers and students," he remembers. "It was a fantastic experience. The students were so full of insatiable curiosity." After starting a nonprofit dedicated to science education, the next year he and his team of international volunteers rented a big truck and took it from school to school in Africa, working with kids and doing hands-on science experiments.

In graduate school at Stanford, his wide-ranging interests continued. He earned a master's in mechanical engineering, with a focus on robotics, but to pay the bills he did research for an international security think tank on bioterrorism and nuclear smuggling. Hand then went on to do a PhD at Stanford, choosing Europa as his dissertation topic.

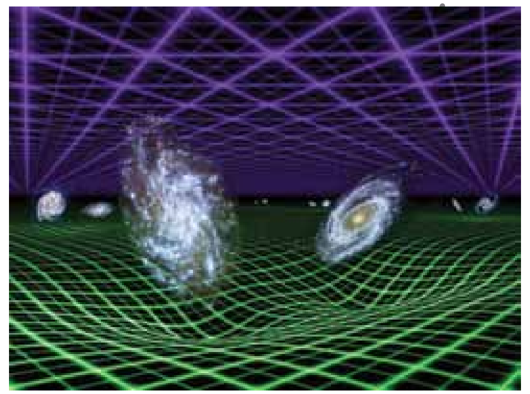
Then, "I got a call from a friend who knew a guy who knew a guy who knew [filmmaker] James Cameron," Hand recalls. "Cameron was looking for a young scientist to talk about Europa at the bottom of the ocean. The next thing I knew I was in a Russian boat in the middle of the Atlantic, climbing into a submersible headed to the bottom of the ocean." In turn, he was featured in Cameron's 2005 documentary *Aliens of the Deep*.

After Hand earned his PhD — with a brief stint as a visiting scholar at Princeton — he joined JPL where he and Robert Carlson continued doing lab simulations of the Jovian moon in an experiment they call "Europa in a Can."

In 2011 Hand shifted gears into his current role helping lead solar system science for the lab. "I really enjoy it," he says. "It's really about being a bridge between science and engineering as we develop new missions."

No matter what his current assignment, Hand's passion for science and exploration is as strong as ever. "I feel I'm still asking the same fundamental questions I was when I was 10," he says. "I'm just doing it with more math and more sophisticated tools."

May



Release the Kraken! Dark energy, the highly mysterious force that has cropped up increasingly in discussions of astronomy in recent years, may very likely be what is pushing our universe apart at accelerating speeds. A five-year study of 200,000 galaxies by **Galaxy Evolution Explorer** and ground-based astronomers in Australia provided one of the best pieces of proof that dark energy rules the universe — dominating over the effects of its nemesis, gravity, which has weakened as space has expanded. Another point for Albert Einstein's theory of gravitation.

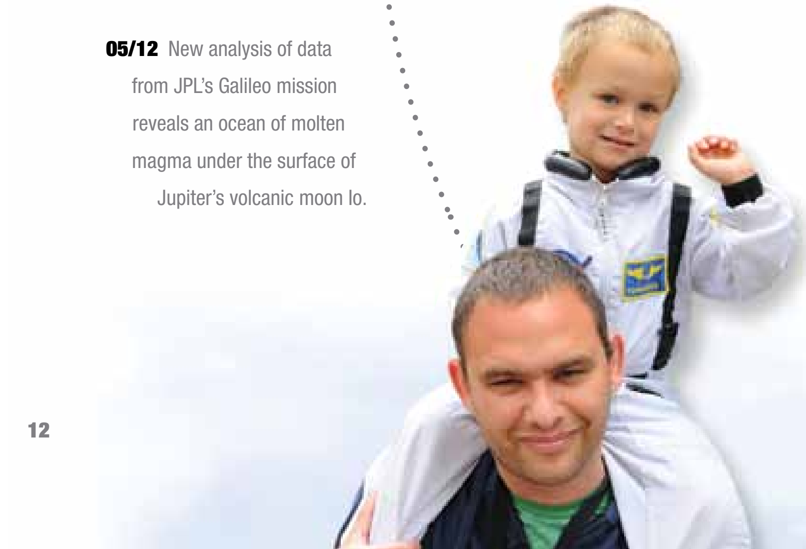
Above left, dark energy (represented by purple grid) is a smooth, uniform force that now dominates over the effects of gravity (green grid).

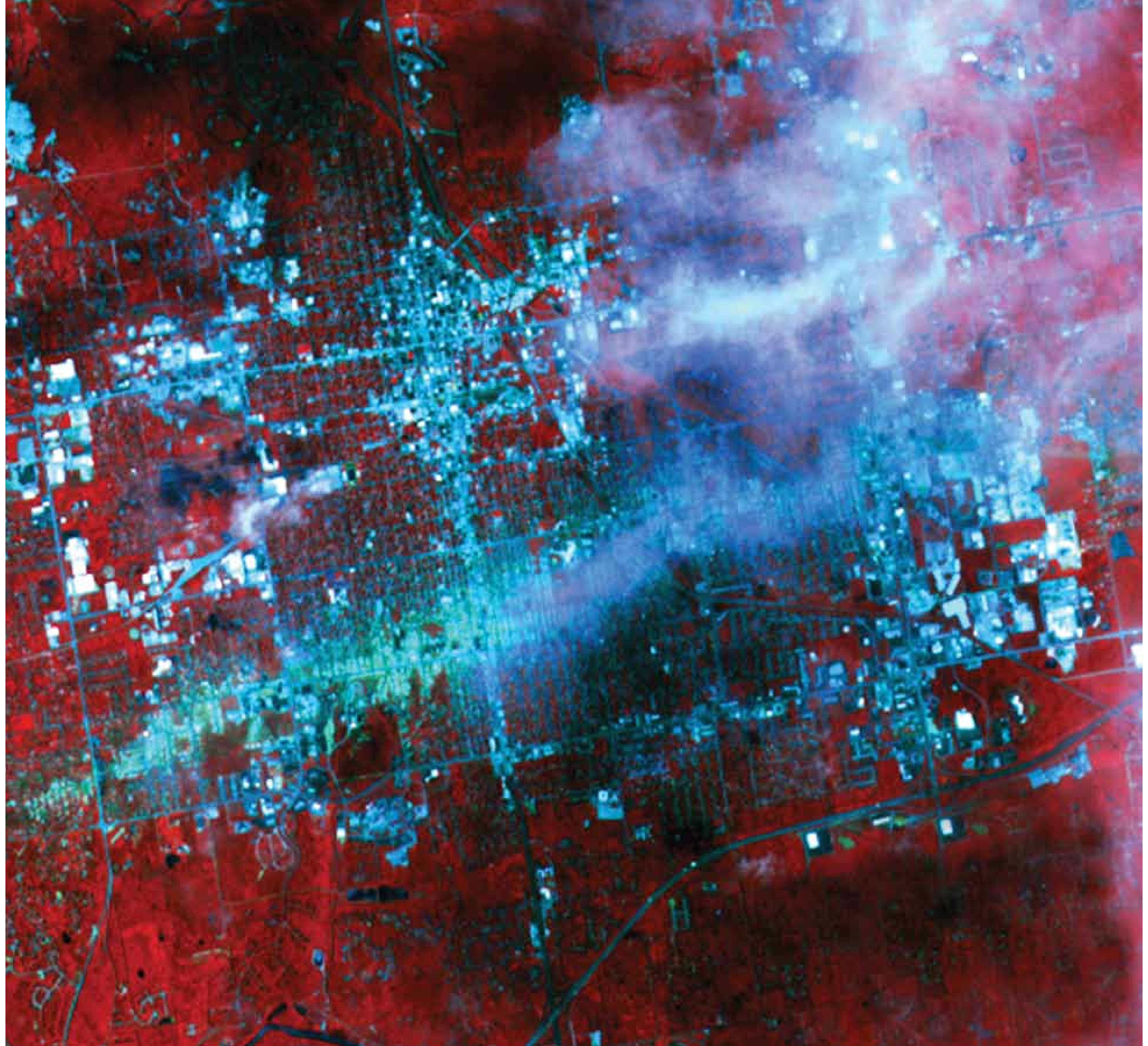
05/03 JPL's Global Climate Change website wins a Webby award for best science site.

05/03 The Dawn spacecraft captures its first picture of the giant asteroid Vesta as it makes its final approach.

05/12 New analysis of data from JPL's Galileo mission reveals an ocean of molten magma under the surface of Jupiter's volcanic moon Io.

Again JPL proved to be one of the public's most stimulating and fun places to visit when the laboratory threw its annual **Open House**, a two-day event that drew 38,000 visitors. Among the highlights: viewing the Mars Science Laboratory's Curiosity rover being assembled. Visitors waited patiently in long lines to get a glimpse of the rover before it was packed up for its launch from Florida.





INTENSE WEATHER, AND THEN SOME

What a year for the weather reporters. A seemingly apocalyptic series of weather and climate disasters ravaged the globe through the entirety of 2011.

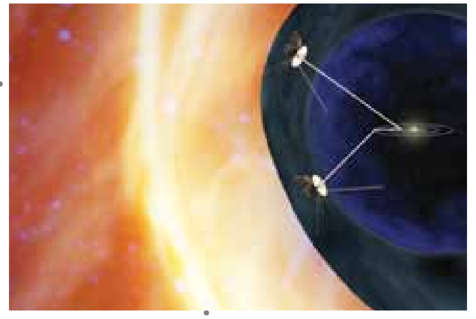
The United States took a heavy beating in April and May as the largest recorded outbreak of tornados ripped across the South, Midwest and East Coast not long after a flood along the Mississippi River affected several Midwestern states. Over the year, the nation endured a record 12 weather and climate disasters that caused at least $1 billion in damages each, including the first hurricane to make landfall in the U.S. since 2008, the largest wildfire in Arizona history and an extreme drought in Texas that ignited more than 170 wildfires in one month.

As the destruction unfolded, JPL's Earth satellites and instruments mobilized across the globe. Meteorologists looked to data from the Atmospheric Infrared Sounder, which is used to create 3-D maps of atmospheric temperature, water vapor and clouds, to improve their forecasts. And two JPL-built instruments on NASA's Terra spacecraft — the Multi-angle Imaging SpectroRadiometer and the Advanced Spaceborne Thermal Emission and Reflection Radiometer — collected high-resolution images of the landscapes affected by the floods, fires and tornados.

But where did all the extreme weather come from? JPL climatologists say much of it can be chalked up to one fierce La Niña mixed with fluctuations in Arctic patterns that brought cold air southward.

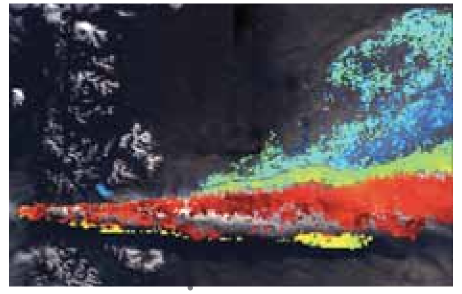
The track of a deadly tornado in Joplin, Missouri, revealed by the Advanced Spaceborne Thermal Emission and Reflection Radiometer.

June



You would think it would be smooth sailing for the **Voyager 1** and **2** spacecraft as they head out of the solar system decades after their last planetary flybys. But some scientists theorized that the environment in those outer reaches may be a turbulent sea of magnetic bubbles. Other mission scientists reported that Voyager 1 had entered a new region between the solar system and interstellar space dubbed the "stagnation region." There, the sun's magnetic field piles up, and higher-energy particles from the solar system appear to be leaking into interstellar space.

Voyagers 1 and 2 in the solar system's outer reaches.



When Chile's Puyehue-Cordon volcano started erupting June 10, plumes rose more than 16 kilometers (10 miles) and thick ash disrupted air traffic as far away as New Zealand. From its orbital vantage point, JPL's **Multi-angle Imaging SpectroRadiometer** was in a good position to scrutinize the event. The instrument was able to show distinct parts of the plume, and document where ash settled in the region.

Left, the plume from Chile's Puyehue-Cordon volcano imaged by the Multi-angle Imaging SpectroRadiometer.

06/01 Mars rover Opportunity passes 30 km (18.64 mi) of total driving on the Red Planet.

06/18 Cassini executes a close flyby of Saturn's icy moon Helene.

06/23 New analysis of samples from 2004's Genesis mission suggest that the inner planets formed from different materials than the sun did.

More than 5,000 of Southern California's disadvantaged youth had a better summer thanks to JPL. For the second year in a row, laboratory staffers worked with community groups, camps and school districts in underserved communities to offer a hands-on educational summer curriculum of science, technology, engineering and mathematics activities as part of NASA's **Summer of Innovation.** Students did projects like building a foam rocket in order to learn about its launch mathematics. For many of these students, the program didn't end when summer did; some continued with projects on into the school year.

A performer at Summer of Innovation.

SALTS OF THE SEA

Any sailor or beachgoer knows that the seas are briny — saltiness, after all, is what sets the ocean apart from Earth's rivers and lakes. But it isn't equally salty all around the globe. The Atlantic tends to be saltier than the Pacific or Indian oceans. The arid subtropics are more so than, say, rainy belts near the equator. Understanding how ocean saltiness waxes and wanes over time is an important part of sorting out the global water cycle and ocean circulation, and scientists have long sought to know more about salt's impact.

When NASA launched an Argentine satellite from California it toted Aquarius, an instrument built by JPL in collaboration with NASA's Goddard Space Flight Center. Aquarius measures microwave radiation to gauge salt content at the ocean's surface, all across the globe each seven days. The device is sensitive enough to detect changes in salinity as slight as two parts in 10,000, about an eighth of a teaspoon of salt in a gallon of water. Three months after its June launch, Aquarius produced its first global map. Scientists are now using this precise information to discover what impact salt is having on the oceans and climate. Ancient Greek soothsayers thought they could see the future in patterns of sprinkled salt; now Aquarius data are helping scientists foresee the future of Earth's climate.

Aquarius taking flight on an Argentine satellite lofted from California's Vandenberg Air Force Base. (Courtesy ULA)

July

The environments of space are harsh, so it's no surprise that technologies developed for spacecraft can be of use in challenging niches on Earth. To make the most of them, JPL signed a multi-year partnership with **Chevron Corporation** to develop technologies that can be used both in space and for energy exploration. JPL researchers expect the collaboration to produce innovations like advances in valves, pumps, sensors and electronics.

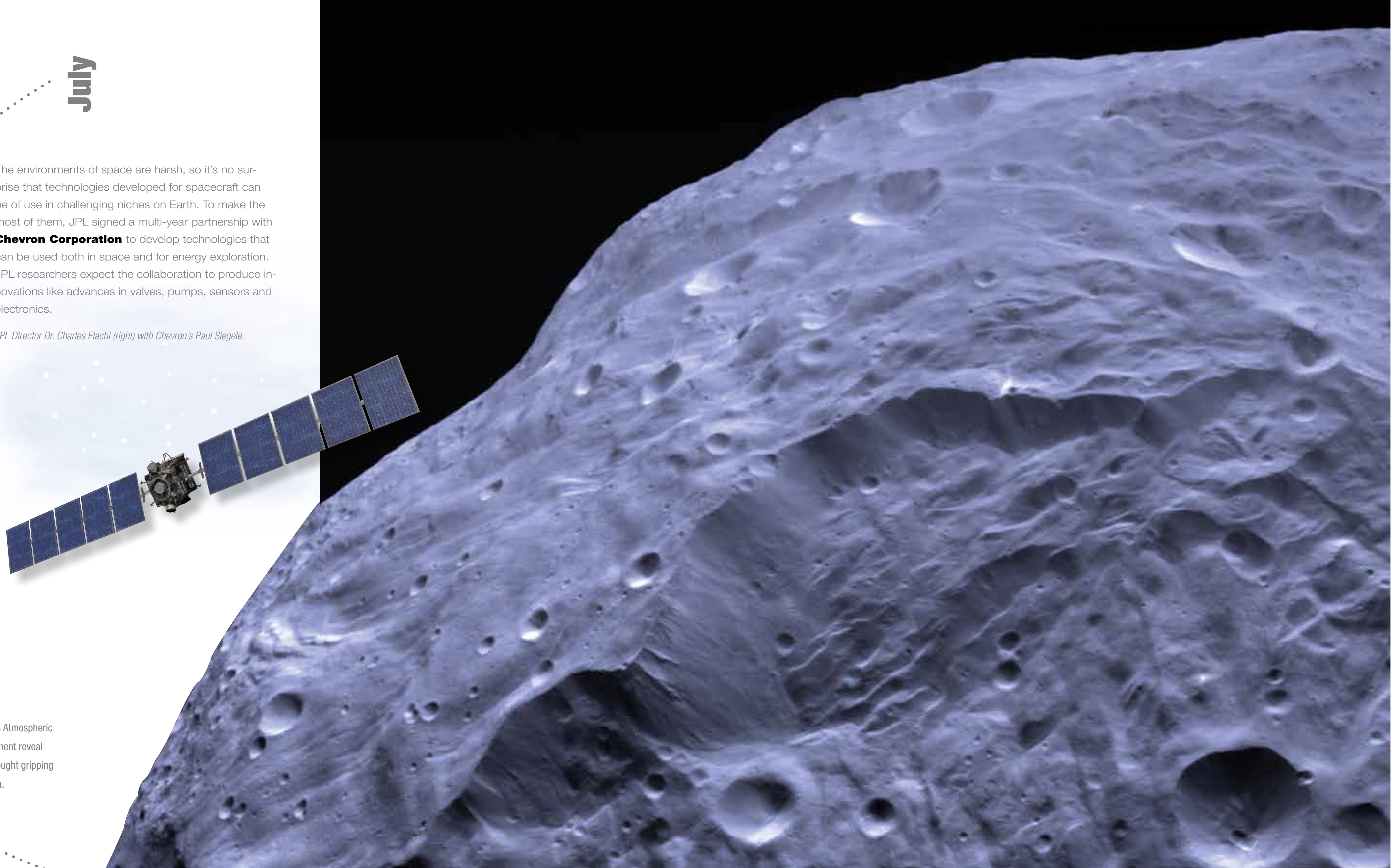
JPL Director Dr. Charles Elachi (right) with Chevron's Paul Siegele.

07/04 New observations from the Herschel spacecraft reveal an exploding star expelled dust with the mass of 160,000 to 230,000 Earth-sized planets.

07/22 NASA selects Gale Crater as the landing site for Mars Science Laboratory's Curiosity rover.

07/27 The Wide-field Infrared Survey Explorer discovers the first known Trojan asteroid orbiting the sun along with Earth.

07/28 New data from JPL's Atmospheric Infrared Sounder instrument reveal the severity of a drought gripping northeast Africa.



THE PLANET THAT ALMOST WAS

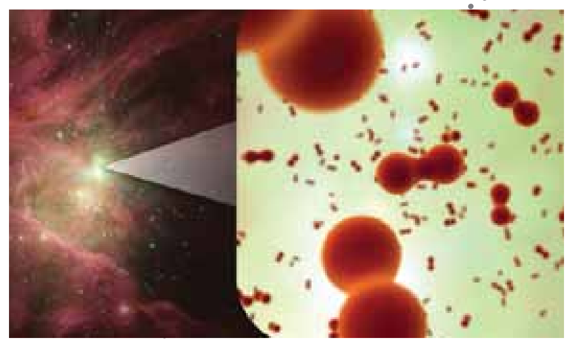
Sometimes slow and steady wins the race. Each of the three ion engines on the Dawn spacecraft may only emit as much oomph as a sheet of paper resting on your hand, but over time it adds up — big-time. After thrusting most of the time for nearly four years following a 2007 launch, in mid-July Dawn slipped easily into orbit around the brightest asteroid in the sky, Vesta. A squashed ball about as big across as the distance from Los Angeles to San Francisco, Vesta — almost a planet, but not quite — orbits more than twice as far from the sun as Earth.

With Dawn in orbit around Vesta, scientists set about mapping this small, ancient world. Most prominent among its features is an enormous crater near the south pole, the lingering scar of a collision with another asteroid perhaps a billion years ago. The surface of Vesta shows strong variations in brightness, reflecting a surprising diversity of rock types.

Late in the year, Dawn activated one of its ion engines to ease it into a low-altitude orbit, passing as low as 167 kilometers (104 miles) above the surface. In August 2012 it will slip away and spend more than two years journeying to the dwarf planet Ceres — making Dawn the first craft to orbit two target bodies one after the other. While Vesta is dry, the nearly twice as large Ceres is suspected to hold more water ice than all the fresh water on Earth. Between them, they should keep scientists busy understanding the realm between Mars and Jupiter inhabited by denizens from planetoids to rubble.

A new view of the giant asteroid Vesta from the Dawn spacecraft.

August



Astronomers have long known that single atoms of oxygen are common in space. But they've never been able to find oxygen as molecules — the form it takes in the air we breathe. JPL scientists using the European Space Agency's **Herschel** space observatory have now accomplished that. They found molecular oxygen in a star-forming region in the Orion nebula. Why was it so elusive? Scientists theorized that oxygen in space is usually locked up in water ice; they were able to detect it because starlight in the nebula warmed the ice, releasing the oxygen.

Above, Orion nebula with artist's depiction of oxygen molecules.

08/18 Researchers release the first complete map of the speed and direction of ice flow in Antarctica, critical for tracking future increases in sea level.

08/18 The Mid-Infrared Instrument for NASA's James Webb Space Telescope, built by JPL and international partners, completes cryogenic testing.

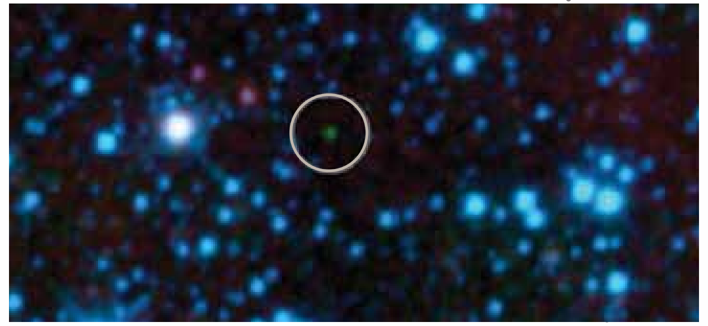
JUPITER'S WATERY SECRET

Chalk it up to luck. When the Galileo spacecraft arrived at Jupiter in 1995, the descent probe it dispatched into the giant planet's atmosphere happened to hit an unusually dry spot. Without a reliable reading on how much water the planet holds, theorists were unable to settle basic questions about how the solar system formed. Did Jupiter condense from cosmic gas where it is now, relative to the sun? Or did it take shape farther out, then move in toward the sun for some reason? The answer requires better numbers.

Sixteen years later, a new spacecraft called Juno set out for a fresh look. Following its August launch, Juno will spend five years traveling to the solar system's largest planet, where it will take up an orbital plan that would do Evel Knievel proud. Unlike Galileo, Juno will not deploy a probe. Instead, it will drop into a widely looping polar orbit that every 11 days will bring it in to race past the planet, shooting between Jupiter's colorful cloud tops and powerful radiation belts to avoid cooking its electronics. This narrow corridor should be the perfect vantage point to measure Jupiter's water content.

Besides seeking to settle how much water Jupiter holds, Juno will look for evidence of a rocky core and study the planet's deep winds, which can whip up to 600 kilometers per hour (370 mph). After a year and 33 orbits, the spacecraft will plunge into Jupiter itself — thus ensuring that any hardy microbial life that may have hitchhiked aboard the spacecraft will not contaminate any of the planet's moons.

Artist's concept of the Jupiter-bound Juno spacecraft departing from Earth.



They could be called the also-rans of the stellar world. Observations by the **Wide-field Infrared Survey Explorer** revealed the coldest class of star-like bodies — spheres of gas that are almost stars, but not quite. Astronomers had sought the dark orbs, called Y dwarfs, for more than a decade, but didn't find any until the infrared space telescope netted six close to our solar system. In its extended mission, the spacecraft concentrated on finding mid-sized asteroids that could threaten Earth. The results: not as many as they expected. Astronomers now say there are roughly 19,500 — not the previously estimated 35,000 — mid-sized asteroids in Earth's neighborhood. Good news.

Top, the coldest brown dwarf yet found, imaged by the Wide-field Infrared Survey Explorer.

08/22 A deep space atomic clock developed at JPL is selected by NASA to fly as a technology demonstration mission.

08/23 While global sea levels have been rising remarkably steadily for two decades, scientists announce that from 2010 to 2011 it fell by about half a centimeter, or a quarter inch.

08/26 Cassini flies by Saturn's oddly shaped moon Hyperion.

08/28 Instruments including JPL's Atmospheric Infrared Sounder track Hurricane Irene as it moves up the United States' East Coast.

HITTING PAYDIRT

Sometimes the journey is its own reward — but for the Mars rover Opportunity, the destination was definitely the thing. The Mars Exploration Rover spent three years trekking from a crater nearer its landing site to Endeavour Crater, a much larger bowl 21 kilometers (13 miles) away. What it found there was unlike anything it had seen in its first seven and a half years on Mars.

After pulling up to Endeavour's rim in August, the first rock Opportunity examined was a flat, bright-colored outcropping the size of a footstool. The science team declared it different from any rock ever seen on Mars, holding much more zinc and bromine than previous specimens — materials possibly delivered by water. Another rock turned up evidence of gypsum, which was called the clearest evidence for liquid water in the planet's past. Scientists concluded that this older terrain around Endeavour's rim was likely a spot that could have been more conducive to life than other areas so far explored.

With the advent of Martian winter and its solar panels caked in dust, Opportunity parked on a south-facing slope to keep itself charged until spring arrives in mid-2012. As their top priority during the winter layover, ground controllers began carefully monitoring Opportunity's radio signal to make precise measurements of Mars' wobble as it turns. That, in turn, may show whether the planet has a molten core.

For the rover team, 2011 also brought a farewell. Spirit, Opportunity's twin on the other side of the planet, had been silent since 2010, but ground controllers scheduled listening sessions in early 2011 on the off-chance that it might have roused itself when the weather warmed. Spirit never phoned home. The silence spelled the end of Spirit's mission, but her inspiring legacy lives on.

Right, a closeup view of texture on a rock at Endeavour Crater, recorded by Mars rover Opportunity.

PROFILES

Carmen Boening

For Carmen Boening, the turning point that set her on her career path came in 2005 after she had earned college degrees in math and computer science not far from her hometown in northwest Germany.

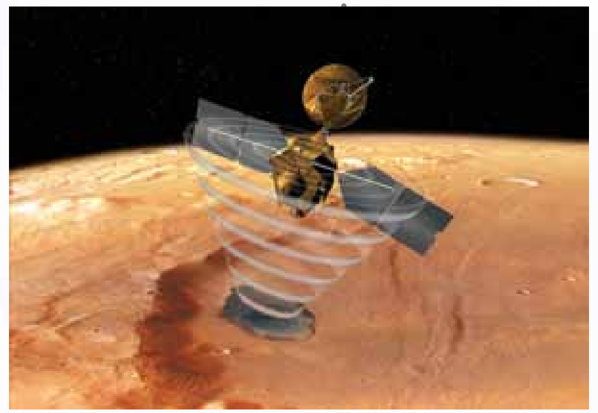
"I was thinking, how can I use that knowledge to do something that would make a difference in the real world?" recalls Boening. Her answer: take those math and computer skills to sea.

In her case, that meant getting into a PhD program at a German research institute as a physical oceanographer. One of her advisors was involved in a joint satellite mission with the United States — the Gravity Recovery and Climate Experiment, or GRACE. Soon Boening was analyzing gravity data from the mission to study sea levels around the globe.

Of all the climate niches around the world, Boening's interest was piqued by the Southern Ocean, the storm-swept waters surrounding Antarctica. It turned into her topic for her dissertation, and Boening found herself on a 2½-month trip to the bottom of the world on a research vessel, weathering violent typhoons and pitching seas. "Then one morning I woke up, looked out and saw this huge iceberg," she says. "I'd never seen anything like that in my life. As an oceanographer, it was great to be able to see in front of me what we spent so much time studying."

Back on terra firma, Boening began looking around for positions after getting her doctorate in 2009. Through her work on GRACE, she'd made acquaintances with scientists at JPL. Applying to the lab's postdoc program, she was one of eight selected from 100 applications that year. Two years later, she was hired for a permanent scientist position.

Boening says her research interests are now evolving as she looks at topics like global sea level changes. And she's enjoying JPL's Southern California setting. "I really like the interdisciplinary setting of the laboratory — its missions provide insights not only about our planet Earth, but also planets and asteroids far away in our solar system," she says. "And coming from northern Germany, I can't complain about the weather."



The technology was there all along, it was just spending all its time at Mars. After flying **ground-penetrating radar** instruments on two orbiters to detect buried water ice at the Red Planet, JPL engineers and scientists repurposed it back home. Flying a similar instrument on a helicopter, the team spent two weeks crisscrossing northern Kuwait to create high-resolution maps of aquifers suspected to be buried deep beneath the desert floor. Scientists said the technology could also be adapted to answer larger questions of climate change and how water moves under the ground.

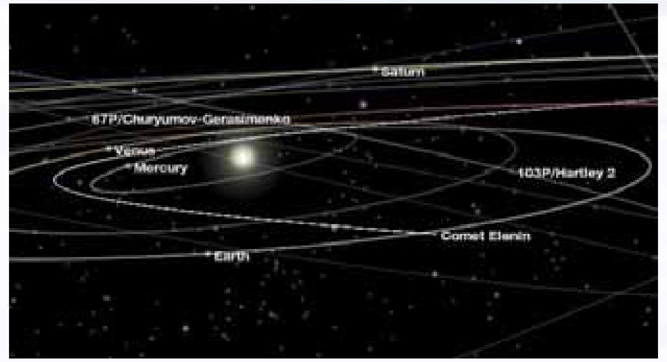
Left, ground-penetrating radar at Mars, repurposed for terrestrial use.

September

09/02 JPL offers the public a virtual ride between the planets in "Eyes on the Solar System," a new web-based interactive site.

09/07 JPL's Multi-angle Imaging Spectro-Radiometer images several of more than 170 major wildfires erupting throughout drought-stricken Texas.

09/11 NASA announces that two memorials to victims of the 9/11/01 terrorist attacks reside in tools on the Mars rovers Opportunity and Spirit.



To astronomers it had always looked routine, but that was before the rumors started flying on the Internet. As **comet Elenin**, a small icy ball discovered in late 2010 by a Russian amateur astronomer, wheeled inward toward the sun, claims started circulating on the web that the innocuous object was more than it seemed. Inaccurate stories circulated that the comet was in fact a deadly body with black hole–like gravitational pull that would bring destruction to Earth. As Elenin heated up in the inner solar system, it broke into pieces and disappeared from telescopes — and the story became a nonstory. But not before JPL public websites logged millions of visitors looking for the scientific lowdown.

Above, comet Elenin's orbital path through the inner solar system.

MYSTERIES OF THE MOON

Like a neighbor you see often but never really get to know, Earth's moon may have some surprises for us.

Our closest companion in space, the moon has been studied by more missions than any other body beyond Earth. But the space age brought a new mystery: like a two-faced Janus, missions of the 1960s disclosed, the moon has two starkly different sides. The near side that perpetually faces Earth is smoothed by low, lava-filled "seas," while the far side is ruggedly mountainous, littered with far more craters. Why? There are theories, but no conclusive answer. And then there is the question of the moon's origin. Most scientists believe it was formed when a Mars-sized body hit Earth, but many questions are unanswered about how that became the moon we see today.

To fill in the gaps, scientists have turned to gravity mapping. Knowing what parts of the moon are relatively dense can offer clues to the nature of its interior. That, in turn, will help explain how the moon has heated and cooled over its lifetime, which could bolster or rule out theories of how Earth's satellite was formed.

Gravity maps of the moon already exist, but vastly better new ones will be produced by the twin spacecraft of the Gravity Recovery and Interior Laboratory — or Grail — mission launched in September. Arriving at the moon just as 2011 was ending, the two craft will orbit the moon for three months. With any luck, they may help scientists better understand our closest neighbor.

The Grail spacecraft depart from Cape Canaveral. (Courtesy ULA)

October

When in this part of this galaxy, stay away from a star called Eta Corvi. Or if you have to go there, make sure your deflector shields are up. That's the word from the **Spitzer Space Telescope**, which has detected signs of icy bodies raining down from the nascent planetary system surrounding the star 50 light years from Earth. Scientists say the downpour of comets and other frosty bodies resembles our own solar system several billion years ago during a period known as the "Late Heavy Bombardment," which may have brought water and other life-forming ingredients to Earth.

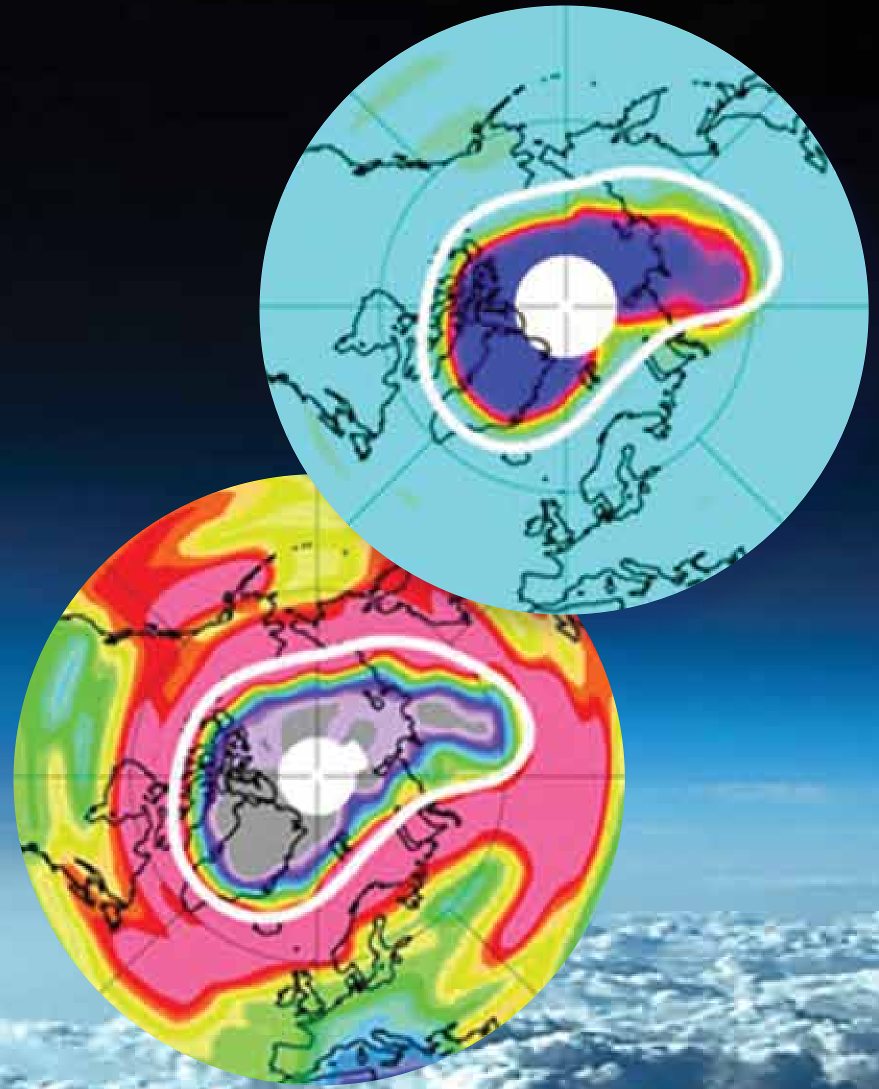
Above left, artist's concept of a comet storm around Eta Corvi.

10/01 Cassini flies by Saturn's moon Enceladus, imaging its dramatic plumes of water vapor and ice.

10/20 For the first time ever, the Herschel spacecraft detects oceans of cool water enveloping a dusty disc around a young star.

They were "The Suicide Squad," the men who on Halloween morning 1936 conducted their first rocket engine test, marking the beginnings of what would become JPL. In honor of the event's 75th anniversary, JPL released a documentary film profiling **Frank Malina**, the engineer who led the ragtag team and helped found what became the laboratory.

THE OZONE HOLE IN THE NORTH



First, the good news: Thanks to the phaseout of chlorofluorocarbons, or CFCs, more than 20 years ago, ozone depletion in the atmosphere is no longer worsening overall. But now the bad news: the durable CFC molecules take a long time to break down, so ozone depletion will be with us for decades to come.

Though the ozone hole over the Antarctic has received the most attention, some ozone destruction occurs over the Arctic as well. In both hemispheres, ozone is destroyed in winter, when low temperatures promote the conversion of chlorine released from CFCs into ozone-destroying forms.

In October, an international study led by JPL scientists found that the previous winter's ozone loss in the northern hemisphere was for the first time severe enough to be considered an ozone hole. The ozone-depleted region covered an area three times the size of the state of California. It wasn't because the winter was colder than normal, but rather because the cold lasted longer than in previous years. The data came from JPL's Microwave Limb Sounder and numerous other sensors. With overhead ozone reduced, exposure to the sun's ultraviolet radiation could be more dangerous to humans and other life on Earth.

Stratospheric ozone (below) and chlorine monoxide (above), recorded near the peak of the 2011 Arctic ozone loss.

November

11/06 Cassini captures the first detailed radar images of Saturn's Enceladus during a flyby.

11/10 The very first stars in the universe were not the behemoths scientists once thought, according to new simulations by JPL scientists.

11/14 Voyager 2 switches to backup thrusters to control its roll as it moves through space, allowing engineers to reduce the spacecraft's electrical power needs.

A ROVER, AND THEN SOME

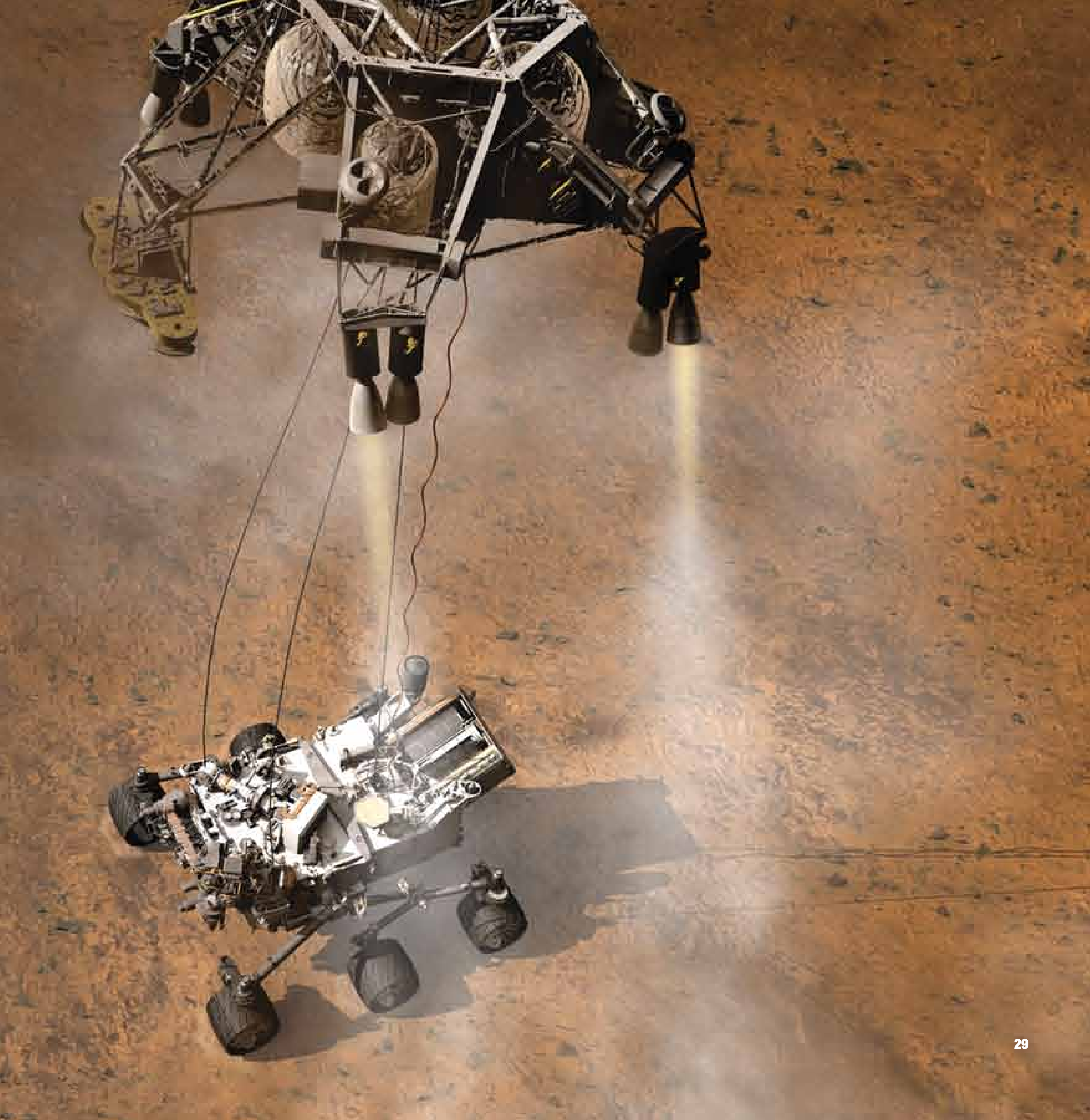
"Supersize it" may sound like bad news for a dieter, but in space exploration it can be a good thing. Take Mars rovers. The size increase from 1997's Sojourner rover (think a microwave oven) to 2004's Spirit and Opportunity (golf carts) made them vastly more capable, able to traverse long distances and haul a more extensive set of tools.

In 2011, that trend reached its next logical phase when Mars Science Laboratory's Curiosity rover set off for the Red Planet. Golf carts? Curiosity is nearly an SUV. And while earlier rovers sometimes had to bivouac to recharge their solar panels, Curiosity will be able to roll on, winter and summer, thanks to a nuclear battery. And if the engine under the hood is impressive, this rover is carrying a full range of instruments that is a scientist's dream come true.

Curiosity's mission is to seek answers to the question of whether Mars once — or may still — be an environment that could sustain life. Curiosity isn't instrumented to find life itself, but it will go beyond the mineral prospecting performed by Spirit and Opportunity with a dazzling toolkit. There is a laser that will vaporize and analyze rocks at a distance; another instrument will zap soil samples with X-rays to tease out their chemical makeup. Perhaps the most elaborate is a mobile lab that will use gas chromatography and mass spectrometry to sniff out organic molecules in Mars' atmosphere and soil. They will all be put to use in the months following Curiosity's landing in August 2012 at Gale Crater, a dish with a central mountain that has so many layers of sediment that scientists liken it to a walk through time.

And then there's the mission's ingenious delivery system. Curiosity is too big to bounce to the surface on airbags, as previous Mars rovers have. A traditional landing with retrorockets would create other complications getting the rover off its landing platform. Thus, enter the Sky Crane. A rocket-equipped descent stage will lower Curiosity on a bridle just before touchdown; think of a soldier rappelling down from a helicopter, and you have the idea. As unusual as it sounds, engineers are confident it will work. Still, come August, they will be eating their good-luck peanuts — a JPL tradition.

Innovative hardware called the Sky Crane will deliver the Curiosity rover to the surface of Mars in August 2012.



11/17 Researchers using Mars Reconnaissance Orbiter report sand dunes and ripples moving across the planet's surface at dozens of locations, shifting up to several yards.

11/30 The twin Gravity Recovery and Climate Experiment satellites map a record-breaking drought in Texas that reduced groundwater to its lowest levels in more than 60 years.

CLOSE, BUT NO NAIL-BITER

While some threats from space alleged on the Internet were imaginary, there was one close visit to Earth by a space rock that, were it to make a direct hit, could have taken out a good-sized city. Instead, the flyby by the largest asteroid to pass close to Earth in decades proved a rare close-up observing opportunity for astronomers.

While some used backyard telescopes to eye the incoming rock — discovered six years ago by an Arizona astronomer, it has the prosaic name 2005 YU55 — the technologists of the Deep Space Network used the 70-meter-wide (230-foot) dish antenna in the California desert at Goldstone to grab radar images of the asteroid.

At 400 meters (1,300 feet) in diameter, YU55 is far slighter than the rock that did in the dinosaurs, and its flight path on this visit took it within 325,000 kilometers (202,000 miles) of Earth — inside the moon's orbit, but amply far that no alarm bells began ringing. Scientists initially were puzzled by the features they saw in radar images gathered as YU55 sailed past, but later concluded the asteroid has an interesting assortment of concave depressions, a large ridge and numerous features that might be large boulders.

As YU55 sailed off, there was plenty else to keep busy all the Deep Space Network complexes in California, Spain and Australia, with new launches joining JPL's 20 already active missions. In Australia, workers were busy pouring foundations for new dish antennas at the Deep Space Network complex there. By the middle of the decade, many spacecraft events will be taking place in the southern hemisphere as viewed from Earth — making it important to beef up the network's capability down under.

Right, asteroid 2005 YU55 captured in radar images using the Deep Space Network's 70-meter (230-foot) antenna in Goldstone, California.

December

12/07 The Jason 1 ocean-monitoring satellite passes its first decade in orbit around Earth.

12/09 Twenty-three student teams showcase devices to kick a football into a can at JPL's annual Invention Challenge.

12/12 Cassini makes flybys of Saturn's moons Dione and Titan.

12/12 Dawn successfully maneuvers into a low orbit around the protoplanet Vesta, beginning a new phase of science observations.

NOT TOO BIG, SMALL, COLD OR WARM

Think of it as a post-modern rewrite of the Goldilocks fable. Our heroine steps into the bears' abode, discovering not the traditional three beds — papa-sized, mama-sized and baby-sized — but many. Some of the beds are big and freezing, some are small and overheated. Some are big and hot, some small and chilly. Somewhere, there has to be a bed just right. That's what happened in our solar system, and that "just right" bed we call Earth.

Now scientists are seeking out Earth-like exoplanets around other stars. To qualify as good candidates to support life, planets have to be roughly Earth-sized; too big and they turn into gas giants with no solid surface, while too small there's not enough gravity to keep hold of their atmospheres. Just as important, they must reside in the "habitable zone" surrounding any given star, where temperatures are just right for liquid water to flow.

The JPL-developed Kepler mission is gradually sifting through all those possibilities as it measures the light from stars in a patch of sky around the constellations of Cygnus, Lyra and Draco in search of planets like ours. The process has been moving at a measured pace in the years since Kepler's 2009 launch. Not ones to shout "Eureka" too soon, the Kepler scientists have a maxim that they must detect the signs of a planet three times before they are ready to confirm it.

In December, the team announced a breakthrough. For the first time, they confirmed the existence of two roughly Earth-sized planets. One is somewhat smaller than Earth, about the size of Venus, while the other is just a skosh larger than our home planet. Both orbit a star named Kepler 20, some 950 light years from Earth.

The discovery of these two planets was a signal event, but there was a catch. Both planets are in the room of the bear mansion with the thermostat turned up — which is to say, much too hot for anything that we would call life. The bigger planet checks in at 427 degrees Celsius (800 Fahrenheit), while vacationers on the smaller world would find a scorching 760 Celsius (1,400 Fahrenheit).

So we haven't found just the right place, not too hot, not too cold. But it's looking more and more like it's just a matter of time.

Artist's concept of a planetary system analyzed by the Kepler spacecraft.

PROFILES

Jamie Bock

Don't tell Jamie Bock not to dwell on the past. Vastly ancient epochs of cosmological time suit him just fine. In fact, 13 billion years ago is perfect.

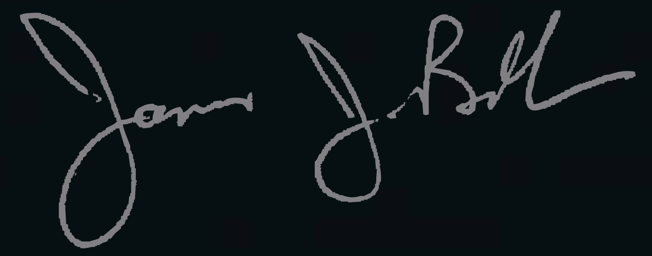
Bock in fact has spent most of his 17-year JPL career focused on that era. Its remnant is seen today as the cosmic microwave background radiation, a faint glow of energy almost exactly the same in all directions in space, left over from an early time when the young universe, expanding and cooling, started forming atoms. Bock and his colleagues have examined the glow with instruments at the South Pole, hoisted on balloons and sent out on spacecraft.

Their sensor of choice? The ancient glow is best detected by a device called a bolometer. It detects this faint radiation by turning it into heat, which is then measured with a sensitive thermometer. To sense minute variations in the cosmic microwave background, the equipment must be chilled to within a couple of tenths of a degree of absolute zero.

In recent years, Bock and technologists at JPL's Microdevices Lab developed the bolometers that flew on the European Space Agency's Herschel and Planck observatories. "Now I am developing improved bolometer arrays that incorporate all the optical functions in the detector," he says. "And a new generation of superconducting sensors is emerging that promise another leap in capability."

But for the Ohio-born Bock, life isn't only about bolometers. "I've worked on novel millimeter-wave spectrometers, and recently have been searching for the background light produced by the first galaxies with a near-infrared camera and spectrometers on a sounding rocket."

Straddling the fence between scientist and technologist, Bock says, "I'm definitely motivated by science. My specialty is identifying a difficult problem in cosmology, and developing new technologies that help us find the answer."



MAJOR EXTERNAL AWARDS

Shari Asplund
Society for Technical Communication
Spotlight Award of Excellence

Gajanana Birur
Society of Automotive Engineers
International Forest R. McFarland Award

Thierry Caillat
International Thermoelectric Academy
Named Academician

Steve Chien
American Institute of Aeronautics and Astronautics
Intelligent Systems Award

Eric Conway
History of Science Society
Best General Audience Book

Dawn Team
National Space Club
Astronautics Engineer Award

Dave Diner
American Association for Aerosol Research
Benjamin Y.H. Liu Award

Steven Durden
Institute of Electrical and Electronics Engineers
Named Fellow

Charles Elachi
American Astronautical Society
Carl Sagan Memorial Award

Occidental College
Honorary Doctorate

Republic of France
Chevalier de la Légion d'Honneur

Space Foundation
2011 General James E. Hill Lifetime Space Achievement Award

Eric Fossum
National Inventors Hall of Fame
Inducted

Dan Goebel
American Institute of Aeronautics and Astronautics
Named Fellow

Kevin Hand
National Geographic
Emerging Explorers, Class of 2011

JPL
International Thermoelectric Academy
Golden Prize, Outstanding Achievements in Thermoelectricity

Rosaly Lopes
Division of Planetary Sciences
American Astronomical Society
Elected Vice Chair

Mars Exploration Rover Project
Popular Mechanics
Breakthrough Mechanical Lifetime Achievement Award

Ruth Neilan
International Association of Geodesy
Levallois Medal

Bill Patzert
American Geophysical Union
Athelstan Spilhaus Award

James Rinaldi
Federal Computer Week
Federal 100 Award

Paul Rosen
Institute of Electrical and Electronics Engineering
Named Fellow

Jill Seubert
American Institute of Aeronautics and Astronautics
Orville and Wilbur Wright Graduate Award

Peter Siegel
Institute of Electrical and Electronics Engineers
Named Editor in Chief, Transactions on Terahertz Science and Technology

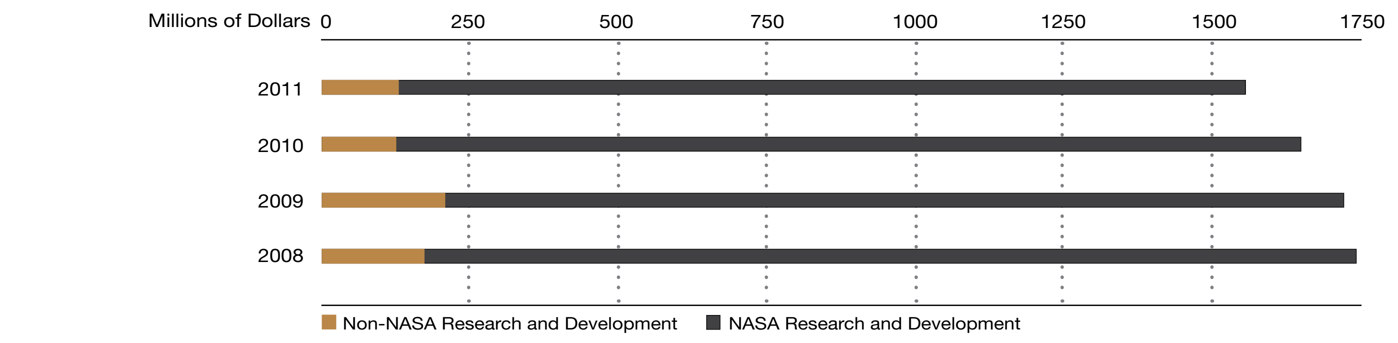
Spitzer Space Telescope Project Team
Space Center Rotary Club of Houston
Stellar Award

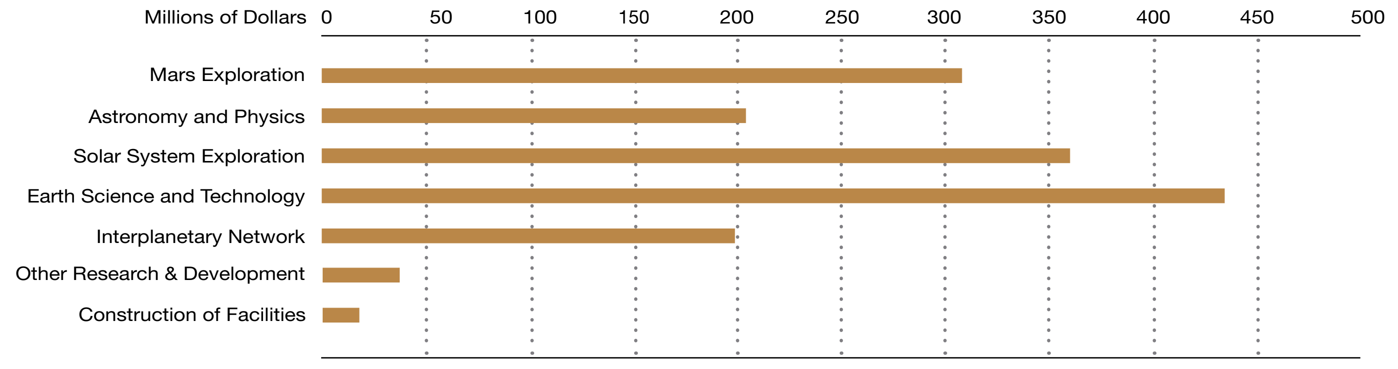
Sherry Stukes
International Society of Parametric Analysts
Frank Frieman Award

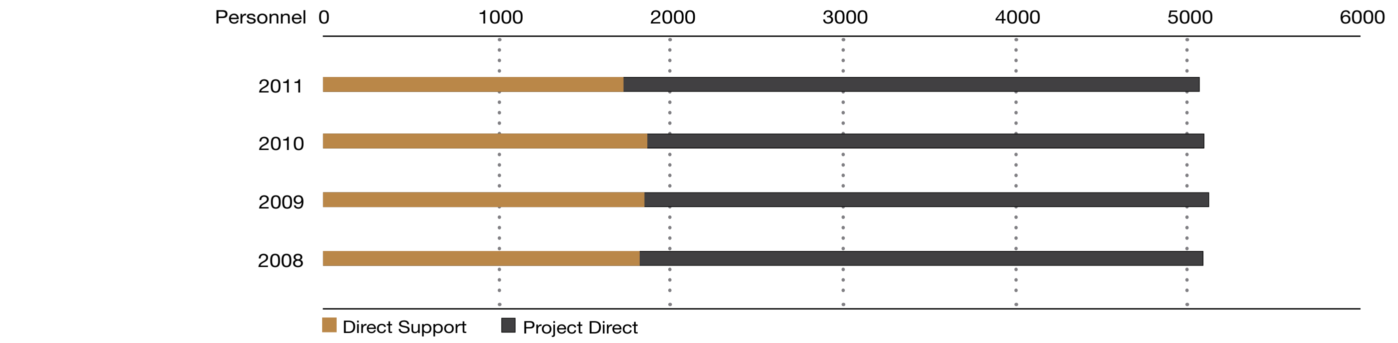
Vatché Vorpérian
Institute of Electrical and Electronics Engineers
Named Fellow

Josh Willis
American Geophysical Union
Ocean Sciences Early Career Award

BUDGET AND WORKFORCE







LEADERSHIP

Caltech Board of Trustees Committee on JPL

Charles R. Trimble (Chair)
Founder and Former Chief Executive Officer
Trimble Navigation

Jon B. Kutler (Vice Chair)
Chairman and Chief Executive Officer
Admiralty Partners, Inc.

Robert C. Bonner
Senior Partner
Sentinel HS Group, LLC

Lounette M. Dyer
Entrepreneur

Thomas E. Everhart
President Emeritus
Caltech

Frederick J. Hameetman
Chairman
Cal-American

Shirley M. Hufstedler
Senior Of Counsel
Morrison & Foerster

Bobby R. Inman
Professor, Lyndon B. Johnson Centennial Chair in National Policy
University of Texas at Austin

Louise Kirkbride
Board Member
State of California Contractors State License Board

Deborah D. McWhinney
Head of Global Digital Merchant Acquiring
Citi Global Enterprise Payments

Richard N. Merkin, M.D.
Founder and Chief Executive Officer
Heritage Provider Network

Philip M. Neches
Chairman
Foundation Ventures LLC

Peter Norton
Norton Family Office

Ronald L. Olson
Senior Partner
Munger, Tolles & Olson

Stephen R. Onderdonk
President and Chief Executive Officer, Ret.
Econolite Control Products, Inc.

Pedro J. Pizarro
President
Edison Mission Energy

Stewart A. Resnick
Chairman
Roll International Corporation

Walter L. Weisman
Former Chairman and Chief Executive Officer
American Medical International, Inc.

Gayle E. Wilson
Nonprofit Consultant

Suzanne H. Woolsey
Woolsey Partners, LLC

Ex Officio Members

Jean-Lou A. Chameau
President
Caltech

Kent Kresa
Chairman, Board of Trustees
Caltech
Chairman Emeritus
Northrop Grumman Corp.

Consulting Members

Harold Brown
President Emeritus
Caltech
Counselor
Center for Strategic and International Studies

Gordon E. Moore
Chairman Emeritus, Board of Trustees
Caltech
Chairman Emeritus
Intel Corp.

Charles H. Townes
Nobel Laureate and Professor in the Graduate School Department of Physics
University of California, Berkeley

Standing Attendees

Dean W. Currie
Vice President for Business and Finance
Caltech

Hall P. Daily
Director of Government Relations
Caltech

Peter B. Dervan
Vice President for Development and Institute Relations
Caltech

Charles Elachi
Vice President
Caltech
Director
JPL

Jennifer Lum
Deputy General Counsel
Caltech

Richard P. O'Toole
Executive Manager
Office of Legislative Affairs
JPL

Edward M. Stolper
Provost
William E. Leonhard Professor of Geology
Caltech

Victoria D. Stratman
General Counsel
Caltech

Eugene L. Tattini
Deputy Director
JPL

JPL Advisory Council

Bradford W. Parkinson (Chair)
Stanford University

Susan Avery
Director
Woods Hole Oceanographic Institution

William Ballhaus, Jr.
Aerospace Corporation, Ret.

Bobby Braun
Georgia Tech

Vint Cerf
Google, Inc.

Philip Christensen
Arizona State University

Ken Farley
Caltech

Lennard A. Fisk
University of Michigan

Scott Fraser
Caltech

Brad Hager
Massachusetts Institute of Technology

Wesley T. Huntress, Jr.
Carnegie Institution of Washington

Jonathan Lunine
Cornell University

Geoff Marcy
University of California, Berkeley

Berrien Moore
University of Oklahoma

Bradford Parkinson
Stanford University

Ares Rosakis
Caltech

Maxine Savitz
Vice President
National Academy of Engineering

David Southwood
Director
European Space Agency, Ret.

David Spergel
Princeton University

Vice Admiral Richard Truly (USN, Ret.)
Former Administrator
NASA

Paul Wennberg
Caltech

A. Thomas Young
Lockheed Martin Corporation, Ret.

Maria Zuber
Massachusetts Institute of Technology

MAJOR CONTRACTOR PARTNERS

Lockheed Martin Corporation
Gravity Recovery and Interior Laboratory, Juno, Mars Odyssey, Mars Reconnaissance Orbiter, Mars Science Laboratory, Rosetta, Spitzer Space Telescope, Stardust

ITT Corporation
Deep Space Network Operations

Lockheed Martin Integrated Systems
Desktop Institutional Computing

Computer Science Corporation
Information Technology Infrastructure Support

Northrop Grumman Systems Corporation
James Webb Space Telescope Mid-Infrared Instrument, Orbiting Carbon Observatory 2, Soil Moisture Active Passive

Raytheon
Data Systems Implementation and Operations

Orbital Sciences Corporation
Active Cavity Radiometer Irradiance Monitor, Dawn, Ocean Surface Topography Mission/Jason 2, Orbiting Carbon Observatory 2

Emcor Government Services Incorporated
Facilities Maintenance and Operations

The Boeing Company
Soil Moisture Active Passive

G4S Government Solutions Incorporated
Security and Fire Services

JPL EXECUTIVE COUNCIL

Charles Elachi
Director

Eugene L. Tattini
Deputy Director

Chris P. Jones
Associate Director,
Flight Projects and Mission Success

Jakob van Zyl
Associate Director,
Project Formulation and Strategy

Blaine Baggett
Director for Communications
and Education

Diane L. Evans
Director for Earth Science and
Technology

Dave Gallagher
Director for Astronomy, Physics and
Space Technology

Cozette M. Hart
Director for Human Resources

Matthew R. Landano
Director for Safety and Mission Success

Fuk K. Li
Director for Mars Exploration

Leslie Livesay
Director for Engineering and Science

Daniel McCleese
Chief Scientist

John McNamee
Director for Interplanetary
Network

Brian Muirhead
Chief Engineer

Firouz M. Naderi
Director for Solar System Exploration

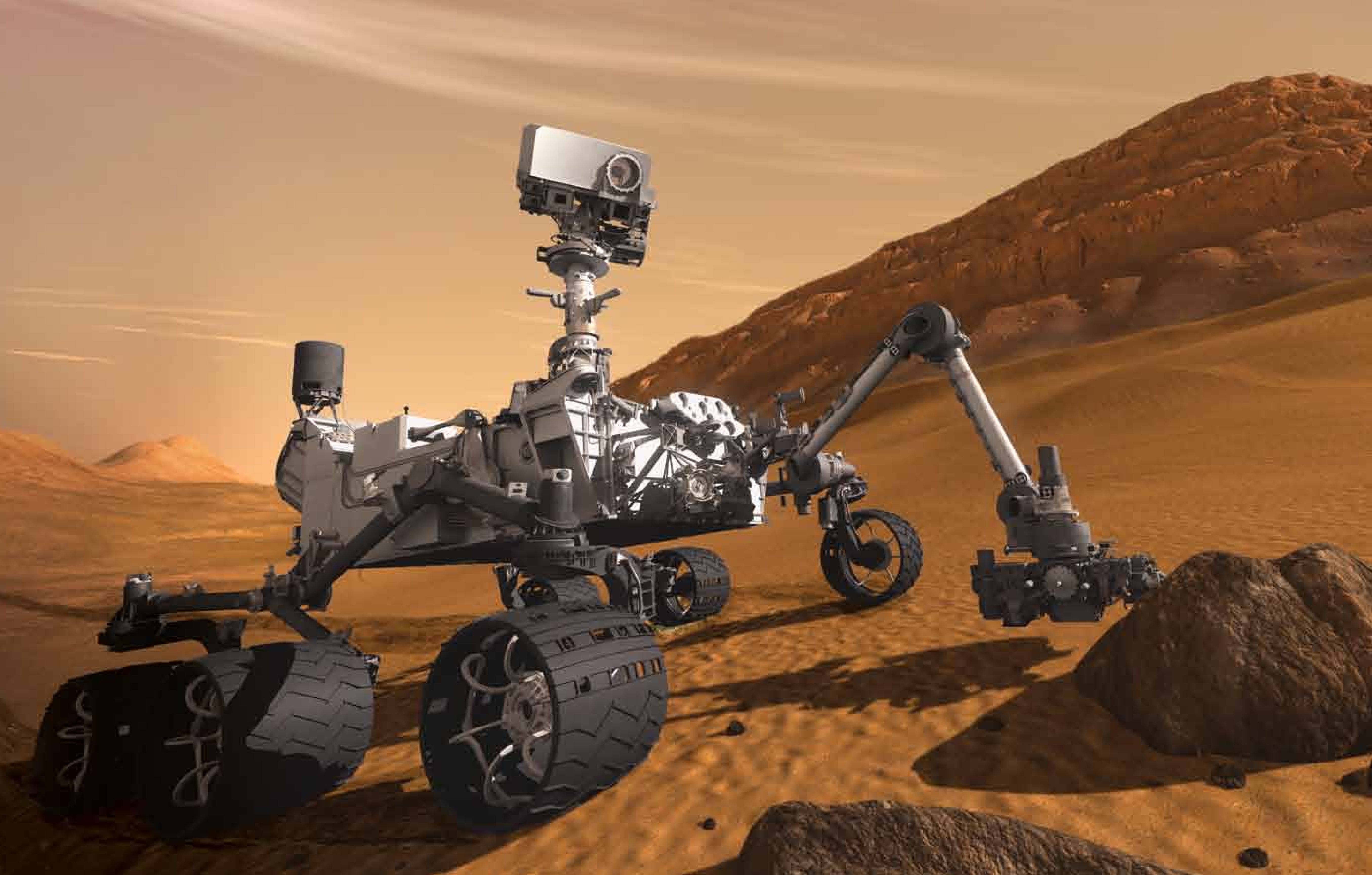
Richard P. O'Toole
Executive Manager, Office of Legislative
Affairs

Steve Proia
Chief Financial Officer and Director
for Business Operations

James Rinaldi
Chief Information Officer and Director
for Information Technology

Victoria Stratman
General Counsel, Caltech

Jonas Zmuidzinas
Chief Technologist



Curiosity rover at Mars (artist's concept).