National Aeronautics and Space Administration

Jet Propulsion Laboratory Annual Report 2005

National Aeronautics and Space Administration

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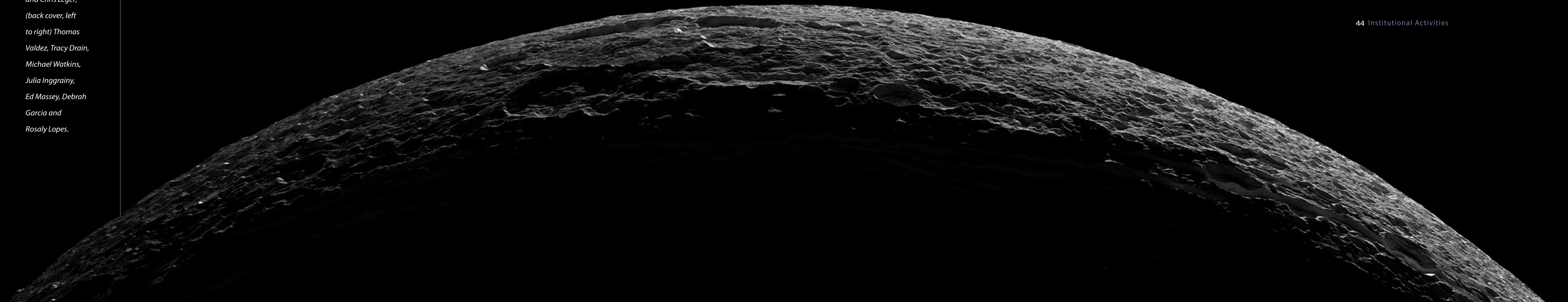
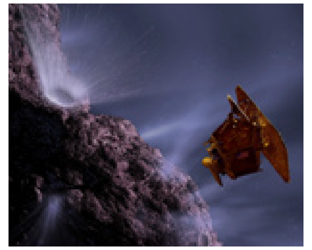
Saturn's moon *Dione, viewed by the Cassini orbiter.*

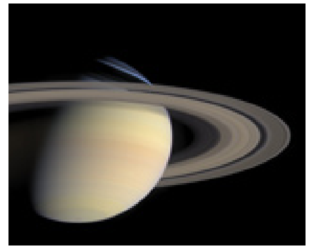
Covers: *JPL personnel (front cover, left to right) Yoseph Bar-Cohen, Sandy Gutheinz, Linda Spilker, Dennis McMurray, Rick Grammier and Chris Leger; (back cover, left to right) Thomas Valdez, Tracy Drain, Michael Watkins, Julia Inggrainy, Ed Massey, Debrah Garcia and Rosaly Lopes.*



Director's message

WHAT AN AMAZING HOST OF NEW SIGHTS 2005 BROUGHT US. With impeccable choreography, one spacecraft sent an impactor slamming into a comet, reversing the traditional view of these space wayfarers by revealing it to be buried in deep drifts of a fine talcum-like powder. Another spacecraft delivered a probe from our European partners to the surface of Saturn's haze-shrouded moon Titan, disclosing a landscape eerily like Earth's — if we had methane rivers cascading down hillsides of ice. An orbiting observatory for the first time showed us the light from planets circling other stars, which astronomers previously knew to exist only from indirect clues.





These were all visions that were absolutely new to us — on the very edge of our exploration of space. Throughout the year we also amassed continually expanding views of Earth as well as Mars, by far the most-explored planet after our own. In all, 18 spacecraft and five instruments were stationed across the solar system, studying our own world, other planets, comets and the deeper universe.

These missions were enabled by the efforts of everyone at JPL. The Deep Space Network of communications complexes across three continents continued to experience a period of remarkable activity. Others were at work creating technologies both for NASA missions and other uses. JPL's contingent of scientific researchers was equally busy coordinating the science activities of our missions or pursuing independent investigations. None of this would be possible without the support of world-class business and administrative teams. All of our missions in one way or another support our nation's Vision for Space Exploration, which envisages a gradually widening robotic and human presence across the solar system in the years ahead.

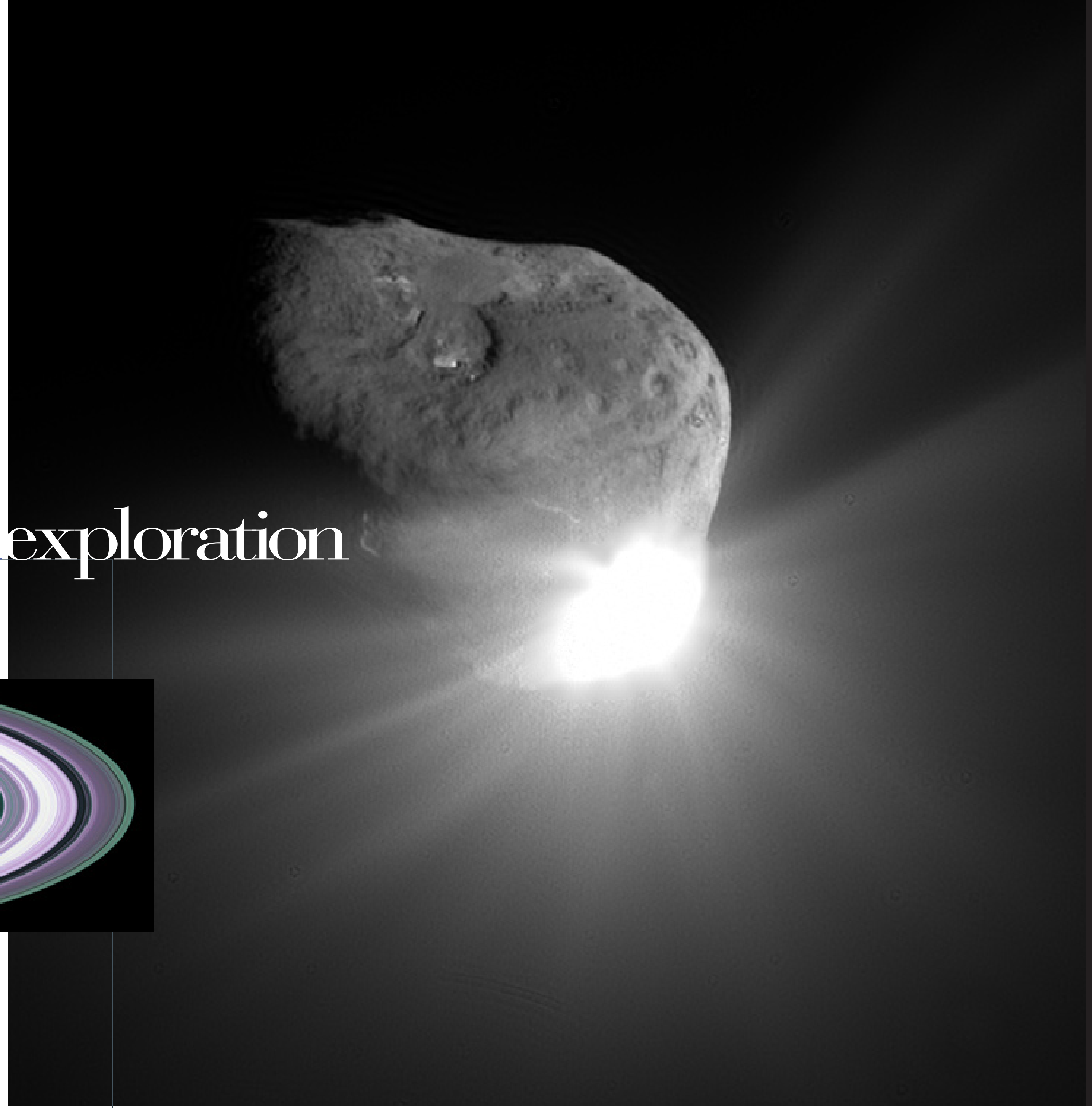
Of course, space missions do not happen on their own, and in 2005 we took many steps to ensure that JPL remains an environment where the imagination and skill of all our staff can be realized. This included efforts ranging from strategic technology planning and cultivation of our university hiring pipeline to improvements in our facilities. We also sought to sustain and extend JPL's connection to the California Institute of Technology campus, where a new graduate program in aerospace engineering will be started with significant investment of JPL personnel. I believe our unique relationship as a NASA facility staffed and managed by Caltech is one of JPL's great intellectual strengths.

The year was not without its challenges. NASA set forth to implement the Vision for Space Exploration, which resulted in some flight projects and technology efforts being terminated. To adjust to this new direction, it was necessary for us to reduce the JPL workforce by about five percent. Taking steps like this is painful, but we tried to make the process as orderly as possible. In the end, I believe the adjustments we made left us on a healthy footing for the years ahead.

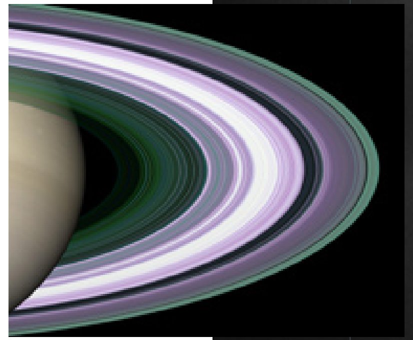
While the great mission events of the past two years might seem like a crescendo of sorts, there are still great things to come. I am especially excited by the wonderful progress in technologies that will allow us to build space-based platforms to search for Earth-like planets around other stars, not to mention the possibilities for the exploration of Europa and Titan, and new generations of Earth observers. In the nearer term, we have a fantastic array of spacecraft flying that are returning first-rate science every day.

Charles Elachi

Solar System exploration



Deep Impact hit *a bull's-eye when it sent an impactor to strike Comet Tempel 1, resulting in an enormous flash of light.*



Cassini sent *its radio signal through Saturn's rings to measure the size of ring particles. Here, purple indicates large particles, while green and blue signify smaller ones.*

The feat itself was exceptional — likened to firing a speeding bullet at another speeding bullet while taking pictures from a third speeding bullet.

AS THE MIDNIGHT HOUR USHERED IN THE FOURTH OF JULY ACROSS AMERICA, all eyes were on a spot hundreds of millions of kilometers from Earth where a robotic spacecraft and city-sized comet nucleus rushed toward each other. With uncanny precision the spacecraft, Deep Impact, released a coffeetable-sized impactor that guided itself toward Comet Tempel 1 — blasting a hole and generating a mighty flash far brighter than expected.

The feat itself was exceptional — likened to firing a speeding bullet at another speeding bullet while taking pictures from a third speeding bullet. It was a great win for the mission, which teamed JPL with university and industrial partners. But what was equally remarkable was what it told scientists about the comet — not only with the impact event but, in the process, taking by far the highest-resolution pictures of a comet. "The flash of light and the plume that followed it were much larger than we expected," said Dr. Donald Yeomans, a JPL astronomer on the Deep Impact science team. "In fact, what it revealed was that the comet was very different from the popular idea of what comets are like."

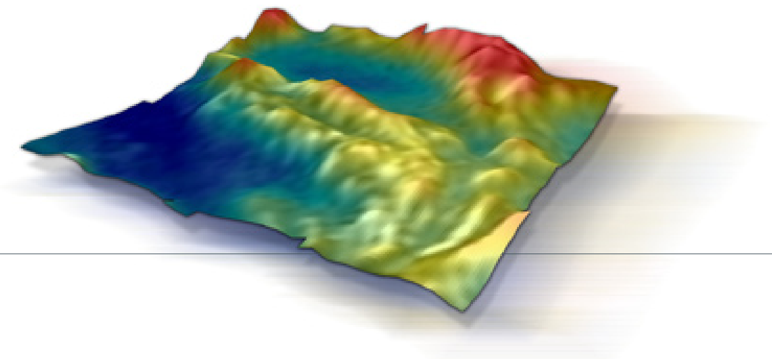
That traditional model held that comets are "dirty snowballs" of ice, dust and rock that heat up and give off glowing material as they spin inward toward the Sun. But Deep Impact showed Tempel 1 to be covered in a fine talcum-like powder tens of meters deep. "The surface is very fragile — like a weak soufflé," said Yeomans. "There's only a little bit of ice on the surface. When we hit the nucleus, we didn't excavate anything but this fine dust — no chunks of anything solid." As a result, "It's changing the way we think about comets. We're getting away from solid, dirty ice balls and talking about very deep, dusty surfaces with icy particles underneath."

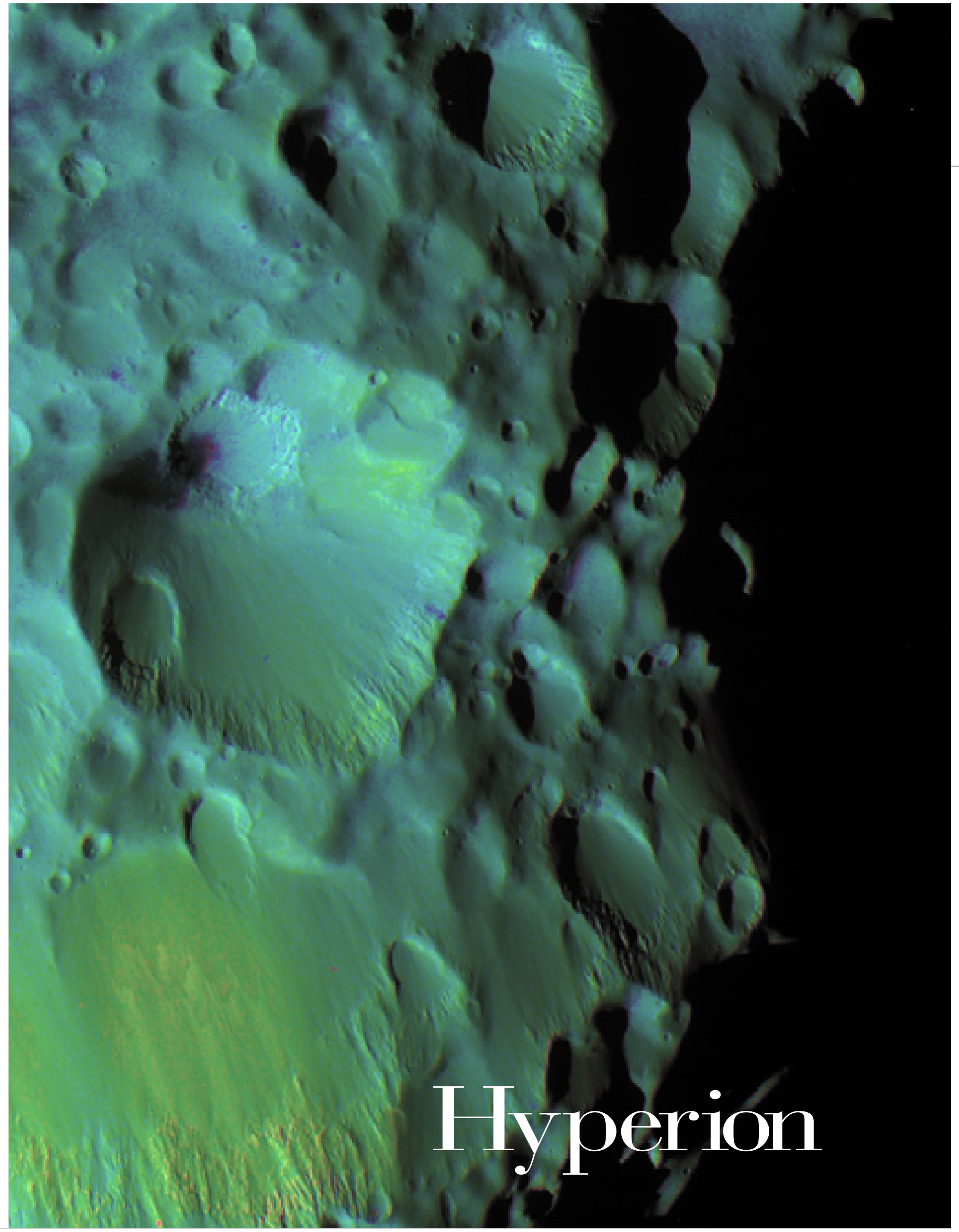
Deep Impact beat a hasty path to the comet in just five and a half months following its January launch. Though the impactor is long-vaporized, the Deep Impact mothership fired its thrusters shortly after the event to put it on course to fly by Earth in late 2007. NASA is considering the possibility of sending it on to an encounter with another comet.

Hundreds of millions of kilometers away in the outer solar system, Cassini added a high spot to its orbital tour at Saturn when it delivered the European Space Agency's Huygens probe, which descended to the surface of Saturn's moon Titan. Scientists were long intrigued by the world, which resembled a featureless, orange billiard ball in the earliest flyby pictures from Voyager nearly 25 years previously; its opaque, hazy atmosphere was known to contain organic chemistry perhaps like that of the early Earth. But Titan was like a frozen vault — if water existed it was almost certainly ice, and rivers or seas, if any, would likely be methane.

During its January descent, Huygens collected data and took pictures as it neared Titan's surface, landing in what appeared to be a dry riverbed. Scientists likened the surface to wet clay or lightly packed snow. "What was most remarkable was how Earth-like the surface appeared," said Dr. Linda Spilker, Cassini's deputy project scientist at JPL. "Titan has what appear to be river channels and many features we find on our own planet. However, on Earth you have rock and water, while on Titan it's ice and the liquid is methane. The likeness was striking, given that conditions are really so different on Titan and Earth." Huygens continued to send data for more than 72 minutes from Titan's surface, far longer than expected.

Besides delivering Huygens, the Cassini orbiter spent much of 2005 making five close targeted flybys of Saturn's icy moons, and an additional seven of Titan. Cassini used a trio of imaging instruments to pierce the haze that perpetually cloaks Titan's surface. Radar images show what appear to be shorelines, while one camera image includes a feature that could be a lake near the moon's south pole.





"THOSE SEVEN MINUTES—WELL . . ."

For **DAN KUBITSCHEK,** *the nail-biting part wasn't just that Deep Impact was going to release an impactor that had to guide itself to collide with a comet's nucleus — a no-second-chance, never-been-done-before event. It was the seven minutes of silence that was nerve-wracking.*

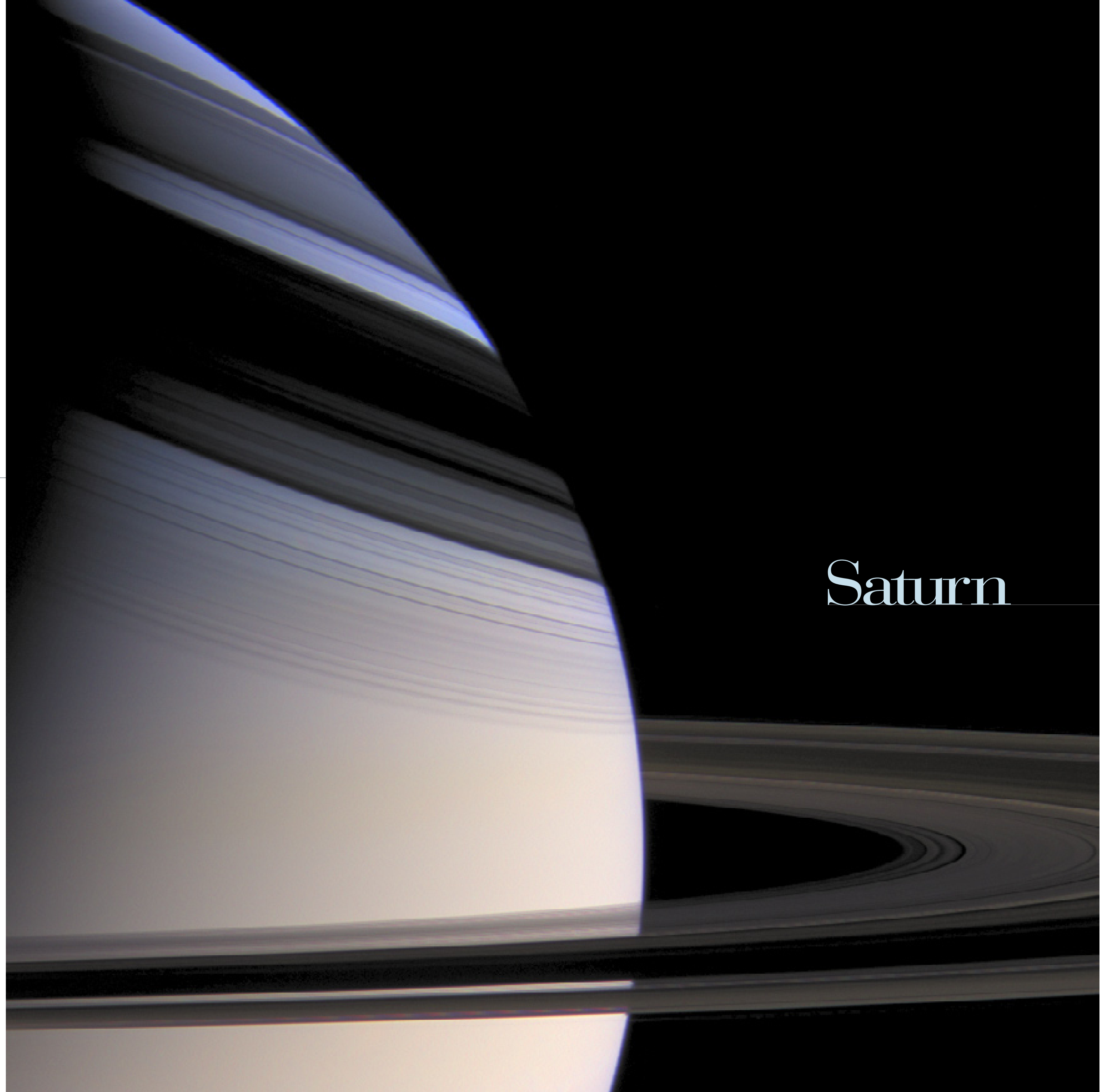
"After the impactor was released, there was seven minutes before we heard from it," recalls Kubitschek, flight director for the impactor. "We had to wait that long to allow the impactor spacecraft to attain sufficient separation before it could fire its thrusters, then detumble, reorient itself and turn on its transmitter. Those seven minutes — well, it was interesting, to be sure."

And when the team did hear from the impactor, it was just the beginning of a wild ride that ended with a colossal flash as the automated craft struck home, sending a plume of comet material into space. It was the job of Kubitschek's team to design onboard algorithms and the complex sequence of commands by which the impactor used its camera to recognize the comet nucleus and guide itself to hit it at the optimal spot.

"We went into it with a lot of unknowns," says Kubitschek, who joined JPL in 2000 after receiving a Ph.D. in aerospace engineering from the University of Colorado in 1997. "But we couldn't be happier with the way things turned out."

***The view from** Deep Impact's probe on its final approach to plunge into Comet Tempel 1 (above).*

***As it descended,** Huygens captured a perspective of Titan's dark plains, color-coded by elevation (far left). Variations in colors around the crater Meri on Saturn's moon Hyperion are revealed in an extreme color-enhanced view from the Cassini orbiter (left).*



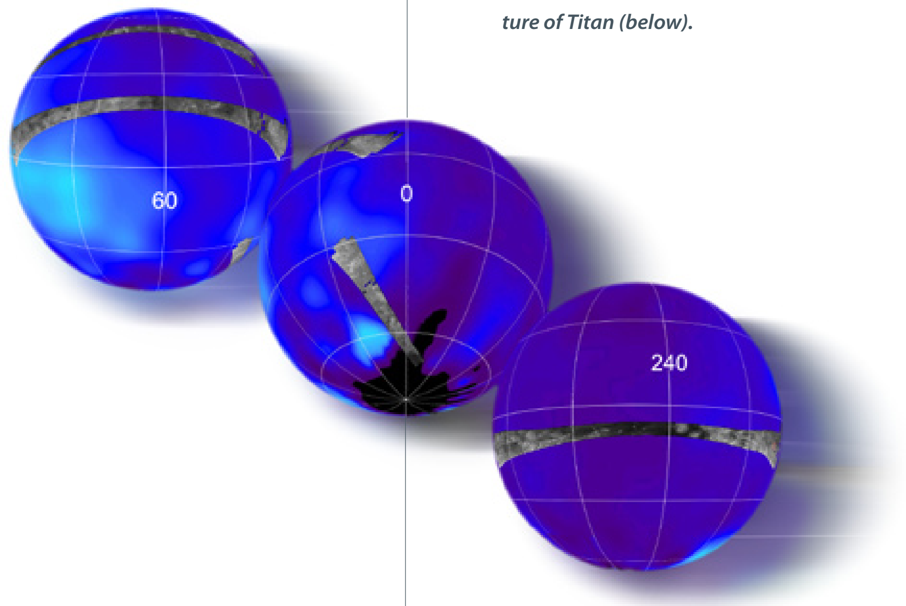
Saturn

Flybys of the other icy moons, meanwhile, revealed many new surprises unsuspected from the Voyager flybys of more than two decades ago. Enceladus proved to harbor chasms running for many tens of kilometers dubbed "tiger stripes" near its south pole that spew ice particles providing the raw material for Saturn's E ring. Given the combination of water in at least ice form along with organic compounds — and the possibility that the moon could have an internal heat source — scientists view Enceladus with new interest as one of the solar system's niches with the ingredients that might lead to life.

Hyperion's appearance astounded scientists, resembling a marine sponge or piece of coral. Lacking defined poles, Hyperion tumbles as it orbits Saturn; given its unusual shape, engineers feel they got very lucky to capture a definitive portrait during Cassini's close flyby in September. Another moon, Iapetus, turned out to have a great mountain ridge that appears to extend all the way around it at its equator. Scientists concluded that one of Saturn's smaller moons, Phoebe, is an interloper captured by Saturn but formed in the outer solar system, likely kin to Pluto.

As for Saturn itself, Cassini used infrared imaging to look deep into the atmosphere, finding very fine structures of bands, belts and zones reminiscent of Jupiter's more colorful, roiling atmosphere. New findings in Saturn's rings include the reappearance of tenuous spokes in the B ring, tremendous variations in the opaqueness of that ring, ringlets that have changed position in the D ring in the twenty years since Voyager, moonlets that wander through the F ring and a new arc of material in the G ring.

Among other solar system exploration missions, Stardust performed a trajectory correction maneuver in November to fine-tune its flight path. At year's end it was scheduled to return to Earth in January 2006 with samples of comet dust collected during a flyby of Comet Wild 2 in 2004.



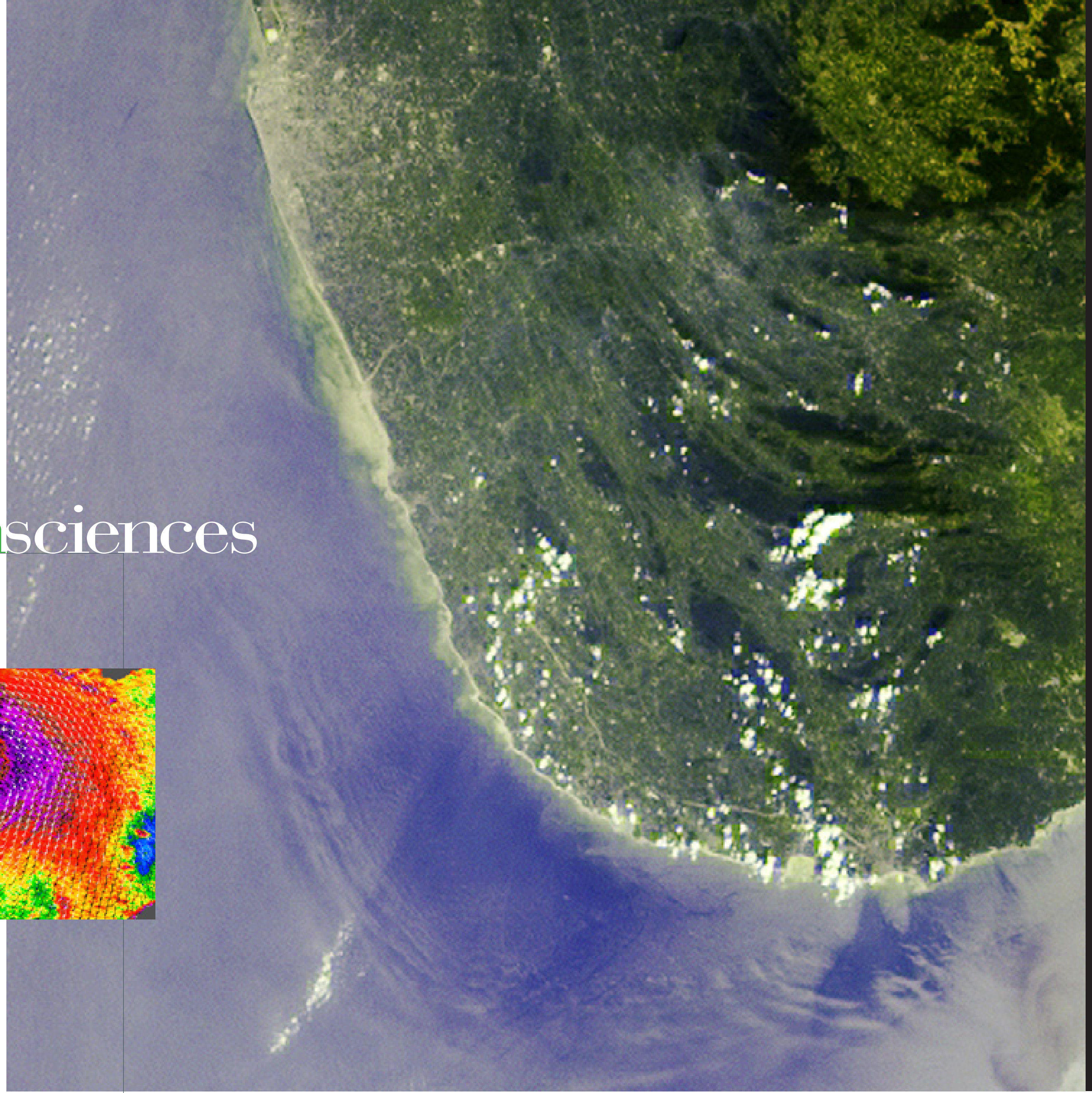
***Ring shadows** drape across Saturn's northern hemisphere (left). The hue of the planet's atmosphere subtly transitions from gold near the equator to azure in the north.*

***Image slices** from Cassini's radar mapper are laid over a Hubble Space Telescope picture of Titan (below).*

Earthsciences

An ominous image *from JPL's Multi-angle Imaging SpectroRadiometer instrument on NASA's Terra satellite caught the December 2004 tsunami as it approached southwestern Sri Lanka (far right).*

Hurricane Katrina *imaged by the QuikScat satellite (inset).*



> 2005 was the most active Atlantic hurricane season on record, with an unprecedented 27 tropical storms, of which 15 became hurricanes.

EARTH WAS A RESTLESS PLANET IN 2005, teams that study our home planet were to find. Thanks to an array of satellites and instruments as well as ground-based technology, they were able to demonstrate the research tools they can bring to bear to help us adapt.

Earthquakes and their consequences were much on the minds of JPL's Earth scientists. In the final week of 2004, a massive undersea quake in the Indian Ocean unleashed a tsunami that had devastating effects on coastal areas of Indonesia and other countries. As 2005 began, several missions released data to help scientists understand the event — including observations from the Jason 1 and Gravity Recovery and Climate Experiment (Grace) satellites; JPL's Multi-angle Imaging SpectroRadiometer and the Advanced Spaceborne Thermal Emission and Reflection Radiometer on NASA's Terra satellite; and data from the Shuttle Radar Topography Mission.

Data from these instruments have proven invaluable in updating models to understand deformation of Earth's crust caused by the quake, as well as for predicting future tsunamis. Working with a NASA colleague, JPL's Dr. Richard Gross examined the effect the undersea quake had on Earth's rotation, finding that it moved the north pole by about 2.5 centimeters (1 inch) and decreased the length of a day by 2.68 microseconds. Otherwise in earthquake studies, a team led by Dr. Donald Argus confirmed that northern metropolitan Los Angeles is being squeezed at a rate of 5 millimeters (0.2 inch) a year, straining an area between two earthquake faults that serve as geologic bookends north and south of the affected region. As part of another effort called QuakeSim led by Dr. Andrea Donnellan, JPL Distinguished Visiting Scientist Dr. John Rundle released results of a new study on earthquake risk in the San Francisco Bay area.

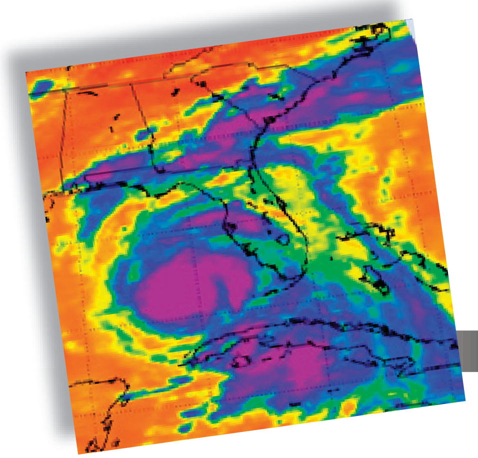
Ground motion was far from the only sign of Earth's restlessness during the year — 2005 was the most active Atlantic hurricane season on record, with an unprecedented 27 tropical storms, of which 15 became hurricanes. The impact was devastating, with more than $100 billion in damage and high numbers of deaths. The hurricane season included Katrina in August, which caused widespread damage in New Orleans; Rita in September, which affected Florida, Texas and Louisiana, reflooding New Orleans; and Wilma in October, the most intense cyclone ever recorded in the Atlantic basin, which affected Florida, Cuba and Mexico's Yucatán peninsula.

Mount St. Helens

was imaged by the Advanced Spaceborne Thermal Emission and Reflection Radiometer shortly after a fresh eruption in March 2005 (far right).

Hurricane Dennis

as seen by the Atmospheric Infrared Sounder (below).

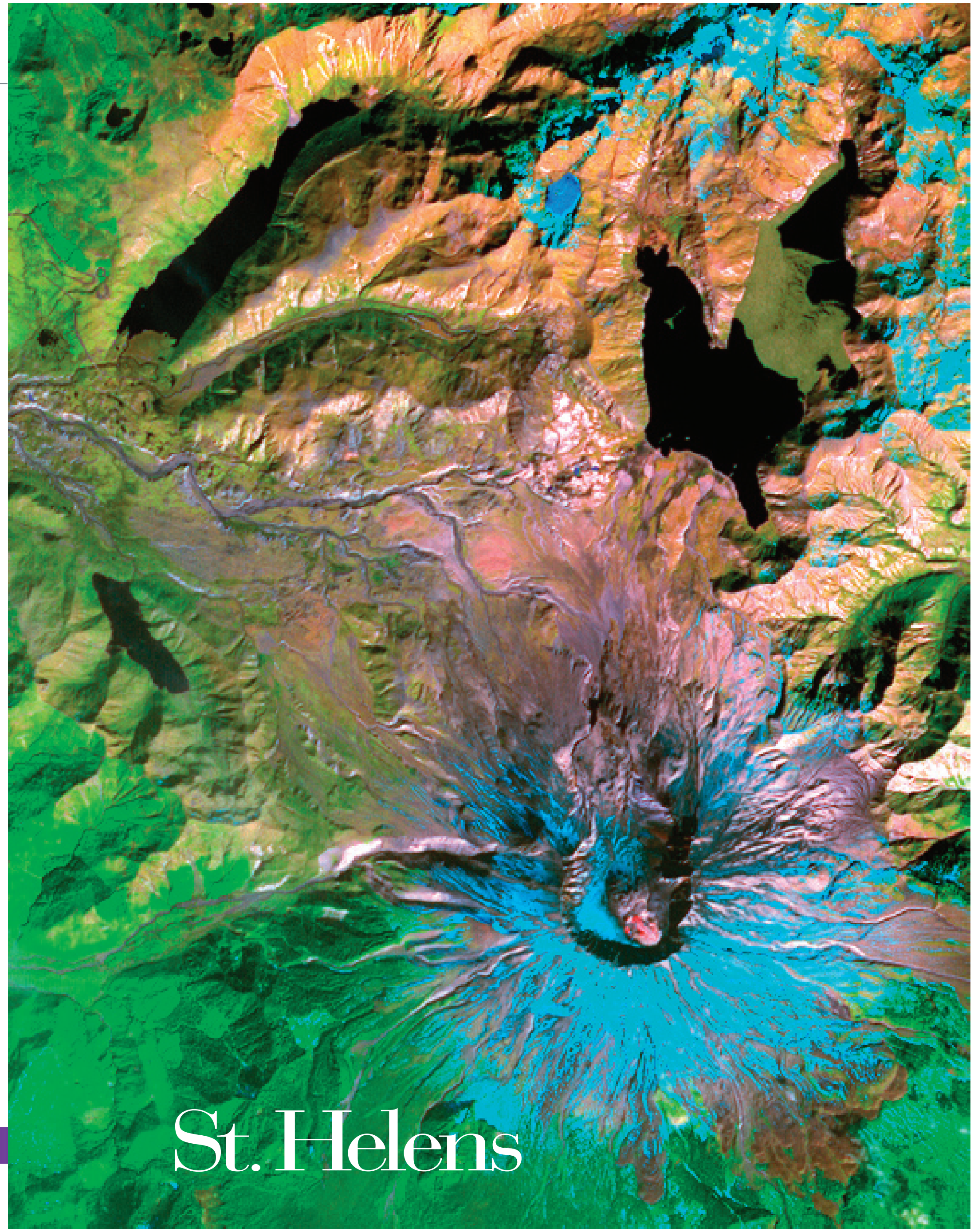


Every once in a while, you can stand outdoors in Southern California and see brown haze over the ocean that in fact is dust that was carried far across the Pacific in the upper atmosphere from Southeast Asia. More often than we realize, more harmful pollutants such as ozone and vehicle emissions can ply the same route.

Understanding how airborne pollutants cross continents has become the career focus of **QINBIN LI,** *a Chinese-born atmospheric chemist trained at Beijing University and Harvard who joined JPL in 2004. "You have the rising emissions from the developing economies of China and India," says Li. "These pollutants can travel over long distances on the prevailing westerly winds. So the problem isn't limited to one region."*

To understand pollution, Li has worked with data from several different JPL Earth-orbiting instruments, and has developed a sophisticated computer model that simulates the chemistry of the atmosphere. "You can even take a simulated spacecraft and fly it in the simulated model to help you design better instruments," says Li.

Does his work point to any pollution solutions? Not yet. "At this point we are trying to understand what is going on in the atmosphere," he says. "But I just came from a meeting in Washington where we shared our work with the Environmental Protection Agency. So it could very well be that it will eventually have policy implications."

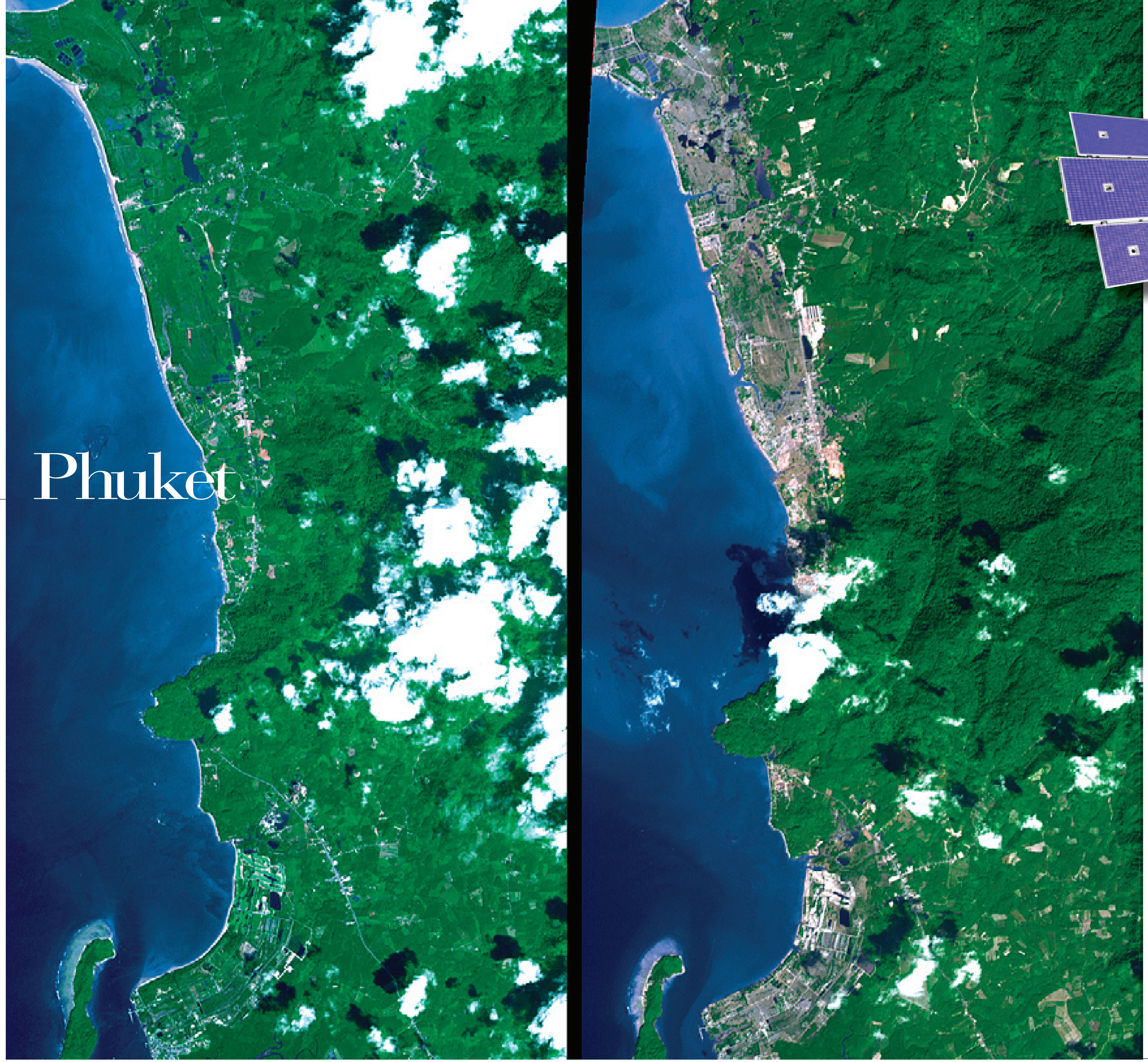


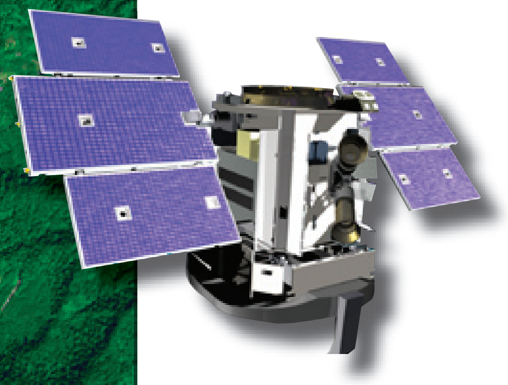
As the hurricanes approached landfall, Jason 1 data improved forecasts of their intensity by providing information on the ocean's heat content. Before Hurricane Rita, JPL released an uncannily accurate prediction of how the region would flood, based on data from the Shuttle Radar Topography Mission. In the hurricanes' aftermath, several JPL satellites and instruments provided data used for analysis and recovery efforts.

New evidence for global climate change was announced by several JPL teams. Dr. Josh Willis participated in an important NASA study that found Earth is absorbing more energy from the Sun than it is emitting back to space. Precise measurements of ocean warming were found to be in excellent agreement with the rate of energy absorption predicted by a climate model driven by greenhouse gases. A NASA briefing on global sea level rise featured data from JPL's Topex/Poseidon, Jason and Grace satellites, and Dr. Eric Rignot participated on the panel to discuss his findings of Antarctic ice melting. Science results from the twin Grace satellites, launched to study Earth's gravity field, moved into new territory when their data showed the highest level on record of Greenland ice sheet melting.

The mission of Topex/Poseidon, a joint U.S.–French satellite that spent 13 years and 62,000 orbits of Earth monitoring the ocean, came to an end when the second of four gyroscope-like devices called reaction wheels that are used to stabilize and maneuver it finally stopped functioning. The satellite required three operating reaction wheels to control its orientation in space.

Phuket





Tsunami damage *along the coast of the island Phuket off Thailand is revealed in before and after images from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (left).*

The CloudSat *satellite (above) was readied for launch, while Topex/Poseidon (right) concluded a highly successful 13-year orbital mission.*

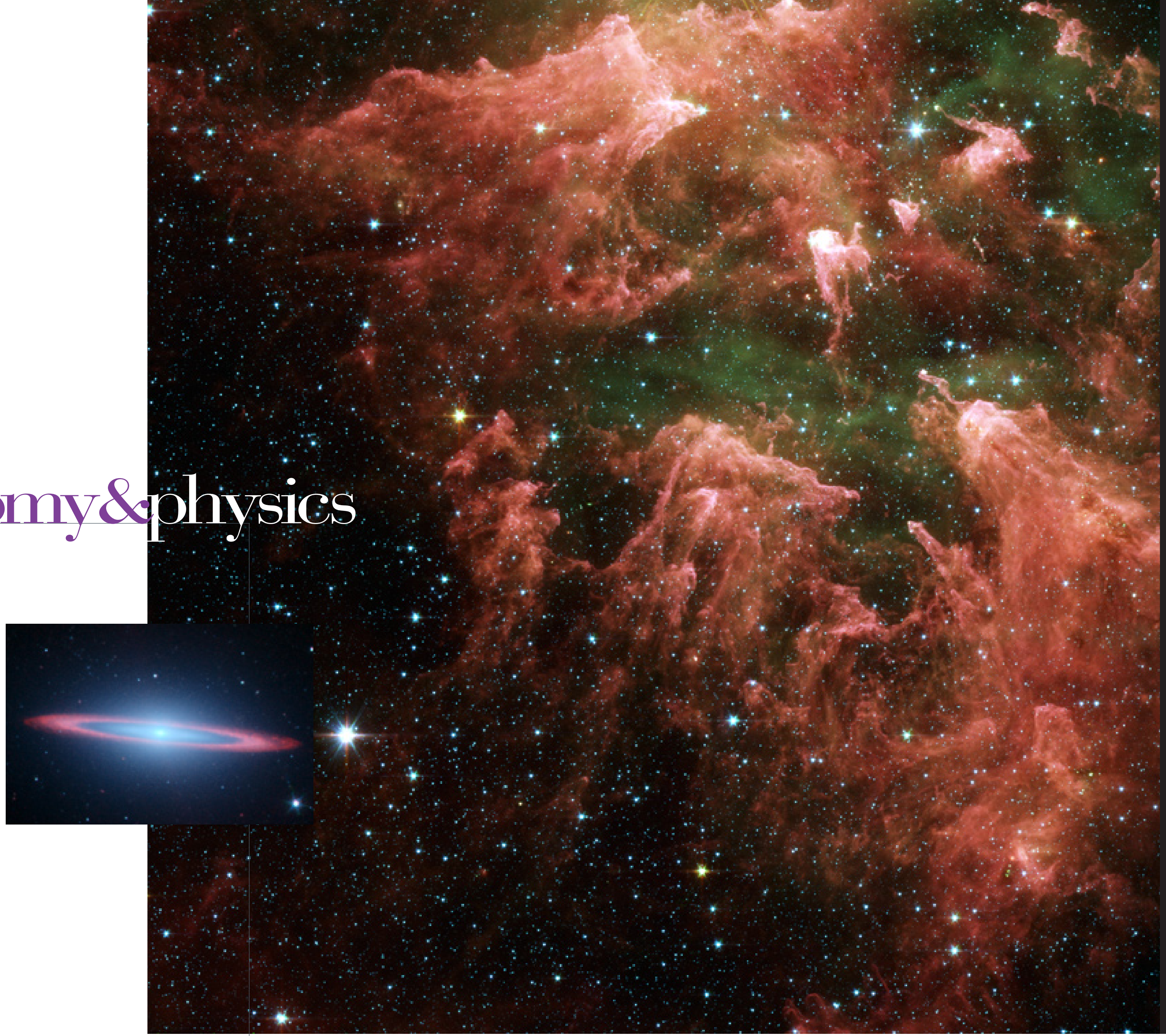
Even so, Topex/Poseidon far exceeded its original design lifetime of three to five years and provided the first continuous, global coverage of the topography of ocean surfaces, leading to follow-on missions Jason 1 and the Ocean Surface Topography Mission.

Ozone loss over the Arctic was the focus of one study led by JPL's Dr. Gloria Manney using data from the Microwave Limb Sounder instrument on NASA's Aura satellite. Her team found that an unusually large chemical ozone loss occurred during the 2004–2005 Arctic winter, but natural atmospheric motions worked to mitigate the effects of this loss on levels of harmful ultraviolet radiation reaching Earth's surface. Other JPL researchers were looking at ozone not as a protective layer in the upper atmosphere, but a potential pollutant in the lower atmosphere, or troposphere. Dr. Reinhard Beer and colleagues used measurements from JPL's Tropospheric Emission Spectrometer to show persistent high levels of ozone across Southern California and off its coast in July. The scientists are working to understand how much of that ozone is transported from Northern California rather than produced from local emissions.

Government weather forecasters found they could make a major improvement in medium-range weather predictions using data from JPL's Atmospheric Infrared Sounder instrument on NASA's Aqua satellite. The instrument effectively peels back cloud cover to reveal three-dimensional views of a storm's water vapor content. Data from the instrument have been officially incorporated into the National Oceanic and Atmospheric Administration's National Weather Service operational weather forecasts.

CloudSat, designed as the first satellite to study clouds on a global basis using an advanced radar to slice through clouds to reveal their vertical structure, was prepared for launch. Issues with the satellite's launch vehicle put off the launch until 2006. Once launched, CloudSat is expected not only to improve weather forecasts, but also help refine climate models and estimates of freshwater availability.

Astronomy&physics



The spectacular *south pillar of the star-forming region called the Carina Nebula was captured in a portrait by the Spitzer Space Telescope (far right).*

Sombrero Galaxy *(inset), as viewed by Spitzer.*

In one of the year's most significant science findings, the Spitzer Space Telescope for the first time captured light from two known planets orbiting other stars.

AMONG JPL'S FLIGHT PROJECTS THAT TARGET THE UNIVERSE BEYOND THE SOLAR SYSTEM, two missions hit their stride of delivering science results on a regular basis, while important technological corners were turned to pave the way for an effort to find other planets like our own.

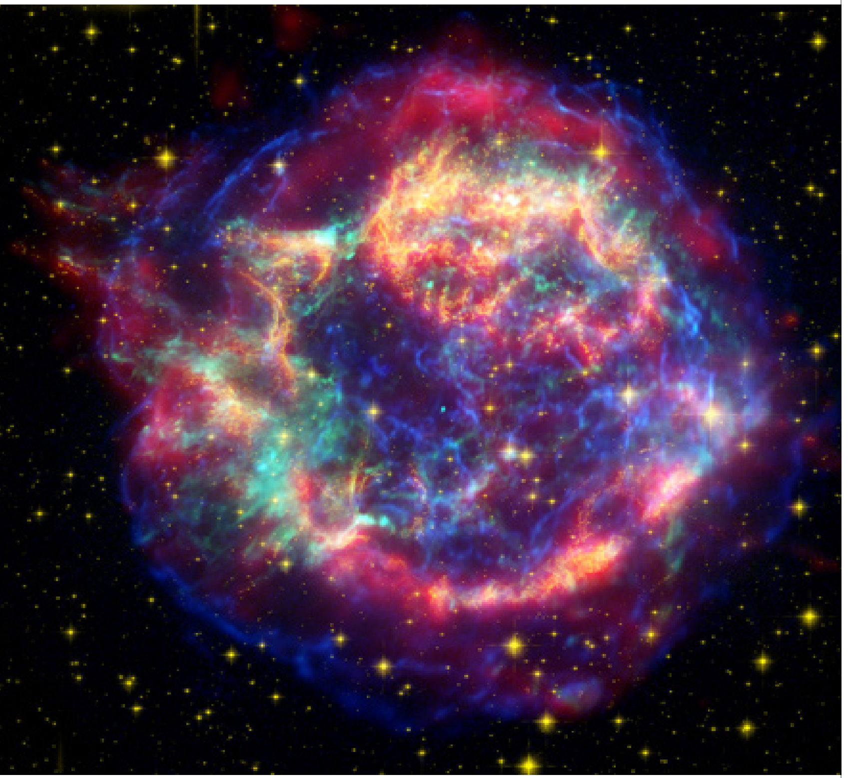
In one of the year's most significant science findings, the Spitzer Space Telescope for the first time captured light from two known planets orbiting other stars. Previously, all confirmed extrasolar planets were detected only indirectly, either by observing how the gravity of large planets causes the star they orbit to "wobble," or by seeing how the light of the star darkens slightly when a planet moves in front of it.

Spitzer directly observed the warm infrared glows of two previously detected planets, called HD 209458b and TrES-1. They are both what astronomers call "hot Jupiter" planets, gas giants that zip closely around their parent stars. In visible light, the glare of the star overwhelms the bit of light reflected by the planet, but in the infrared the planet emits its own light and is easier to distinguish. "This is very big," said Dr. Michael Werner of JPL, Spitzer's project scientist. "It marks the beginning of a new age of planetary science."

Spitzer, which was launched in 2003, was responsible for numerous other science findings as it built up a substantial log of observations. JPL/Caltech astronomer Dr. Charles Beichman and colleagues used the space telescope to discover what appears to be an asteroid belt orbiting another star like our Sun called HD 69830, located 41 light-years away. There are two other known distant asteroid belts, but they circle younger, more massive stars. "Asteroids are the leftover building blocks of rocky planets like Earth," said Beichman. "We can't directly see other terrestrial planets, but now we can study their dusty fossils."

Another team used Spitzer to detect light that may be from the earliest objects in the universe. If confirmed, the observation provides a glimpse of an era more than 13 billion years ago when, after the fading embers of the theorized Big Bang gave way to millions of years of darkness, the universe came alive.

But not everything the telescope viewed was at such immense distances. Closer to home, Spitzer was one of several platforms that watched while the Deep Impact spacecraft delivered an impactor that hit Comet



Tempel 1 in July. Using its infrared spectrograph, Spitzer scrutinized the cloud of material thrown into space when the impactor plunged below the comet's surface. In addition to standard comet components such as sand, scientists were surprised to see clay and chemicals found in seashells called carbonates, both of which are thought to require liquid water to form.

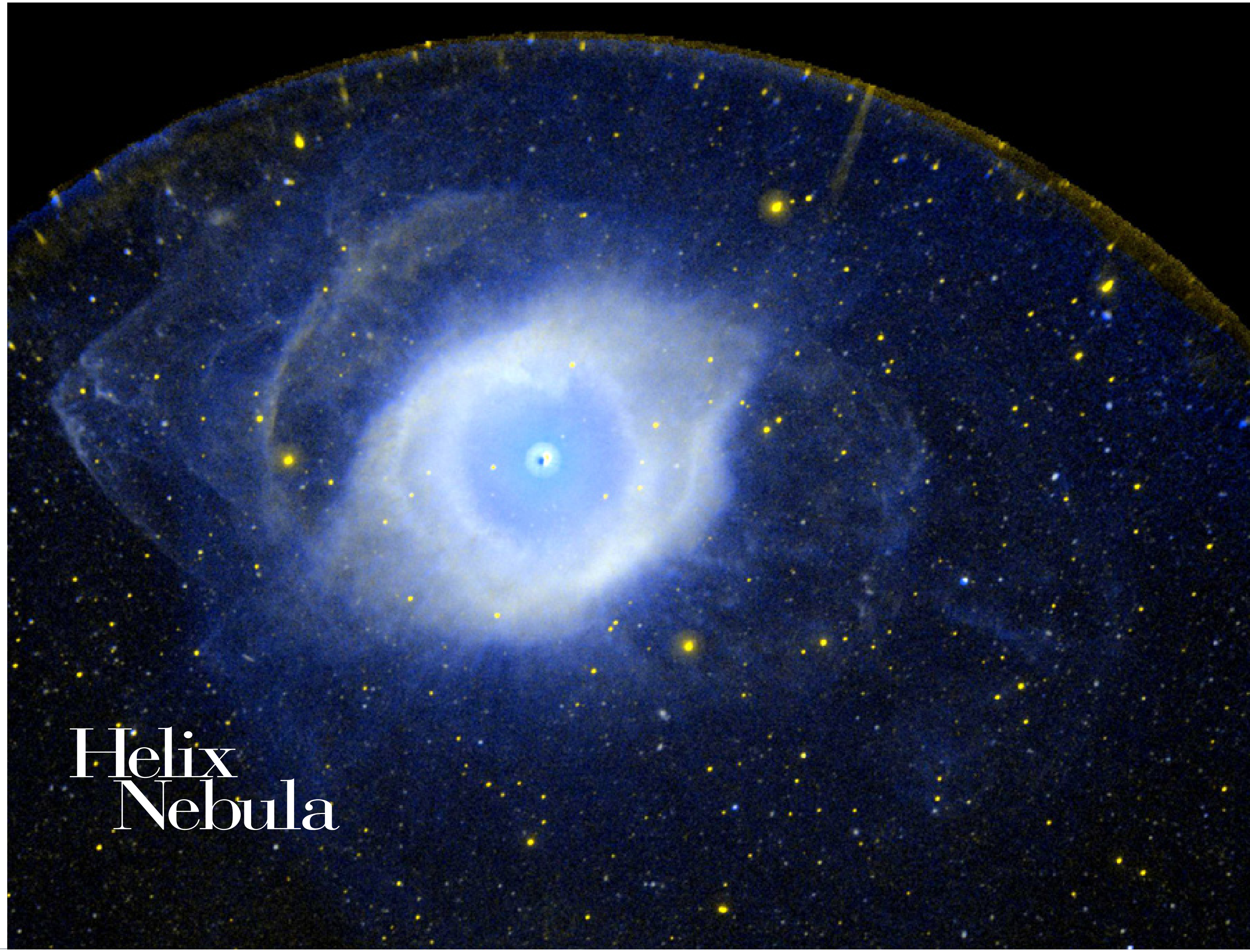
While Spitzer foraged through the universe in the infrared, another spacecraft looked in the ultraviolet. The Galaxy Evolution Explorer, also launched in 2003, was similarly responsible for steady science output in 2005. Astronomers were taking a routine observation when a nearby star called GJ 3685A suddenly exploded with light, brightening by a factor of at least 10,000 and nearly overloading the telescope's detectors. Through happenstance, they recorded a giant star eruption, or flare, about a million times more energetic than those from our Sun.

In another observation, an image from the Galaxy Evolution Explorer shows that a galaxy once thought to be rather plain and old is actually endowed with a gorgeous set of young spiral arms that are invisible in normal light. The unusual galaxy, called NGC 4625, was a remarkable find because it is relatively nearby; until then, astronomers thought that the kind of glow it exhibited was only found in very young and faraway galaxies from the dawn of the universe.

While much excitement surrounded JPL's telescopes in space, there were active projects at ground-based observatories. In 2005 JPL installed and tested a system called a laser guide star on the 5-meter (200-inch) telescope at Southern California's Palomar Observatory. The system bounces a laser beam off the thin layer of sodium in Earth's upper atmosphere. The telescope looks at this artificial star created with the laser beam at the same time it is observing a real star or galaxy. Since Earth's atmosphere will distort the artificial star and the real star in the same way, the system subtracts out the distortion to result in a truer view of the real star. This technique is called adaptive optics.

Supernova remnant *Cassiopeia A sparkles in a false-color view (left) created from observations by the Spitzer Space Telescope, the Hubble Space Telescope and Chandra X-Ray Observatory.*

Helix Nebula *(right), recorded in the ultraviolet by the Galaxy Evolution Explorer.*



There were new developments at the JPL-managed Keck Interferometer linking two 10-meter (33-foot) telescopes on Mauna Kea in Hawaii, thus forming the world's most powerful optical telescope system. This year saw the first engineering tests of an instrument called a nuller that blocks the light from nearby stars, enabling infrared measurements of the dust orbiting close in to the star. Future space missions, such as the Terrestrial Planet Finders, will image Earth-like planets orbiting nearby stars against these dusty backgrounds. The Keck Interferometer will survey target stars to determine how much dust is out there, and help the Terrestrial Planet Finders select their targets.

Some of the brightest news from 2005 was in technology development for another future space-based observatory designed to look for Earth-like planets around other stars. In order to achieve that ambitious goal, the Space Interferometry Mission PlanetQuest depends on an optical system whose motion is measured and stabilized with nearly inhuman precision. Positions must be tracked to within a fraction of the diameter of a hydrogen atom, and vibrations held at the nanometer level — or 40 billionths of an inch. "We took a technological challenge and conquered it," said Robert Laskin, chief engineer and project technologist for the mission. "This year we established that we are ready to do this mission."

In other news from the year, the Ulysses mission, a joint U.S.–European effort to study the Sun, marked the 15th anniversary of its launch. The spacecraft demonstrated that it could communicate with a new European Space Agency tracking station in Australia.

"THIS IMPOSSIBLE TASK WAS POSSIBLE . . ."

Extraordinary claims, so the saying goes, require extraordinary proof. So when JPL told NASA it wanted to build a space observatory to find Earth-like planets around other stars — which would require making measurements within the telescope a fraction of the size of a hydrogen atom — **GARY BLACKWOOD** *recalled that NASA had "justified skepticism."*

"They wanted us to prove we could do it," says Blackwood, one of the subsystem managers on the Space Interferometry Mission PlanetQuest. "And I'm happy to say that we did."

Getting there required assembling components from many sources. The heart of the measurement system is a set of 14 laser gauges that measure the positions of the telescope's optical elements with almost unthinkable precision. The team had to establish new relationships with vendors for many parts.

"When we were starting out, we had to convince even our own team that this impossible task was possible," said Blackwood, a New Jersey native who has a Ph.D. in aerospace engineering from MIT. "Now we're in the position of knowing that was true."

Earth-like planets *(above) will be the quarry of the Space Interferometry Mission PlanetQuest.*

Star surveys *to help future missions such as the Terrestrial Planet Finders are in the works at the Keck Interferometer in Hawaii, which combines light from the pair of telescopes at right here.*

Mars exploration

A new generation *of science instruments enables Mars Reconnaissance Orbiter (far right), launched in August.*

An iron meteorite *was found by Mars Exploration Rover Opportunity, the first meteorite of any type ever identified on another planet.*

Mars Reconnaissance Orbiter is equipped with a payload of six instruments that will collect more data about Mars than all previous missions combined.

IN THE ENLARGING CONTINGENT OF ROBOTIC EXPLORERS at the red planet, a new orbiter craft was sent to join several long-lived robotic explorers.

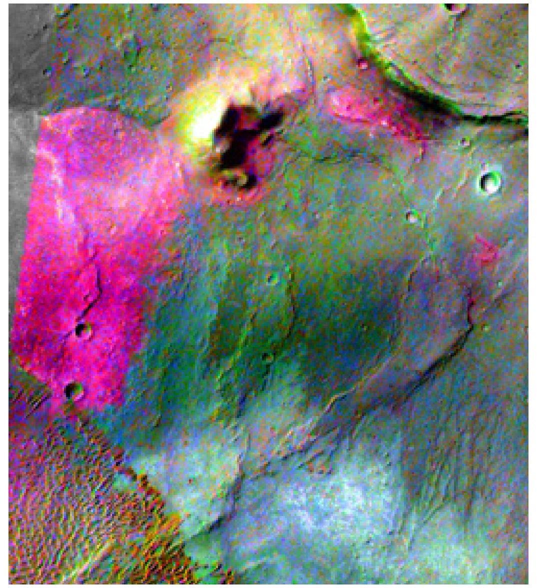
The new recruit, Mars Reconnaissance Orbiter, blasted off from Cape Canaveral in August en route to Mars arrival early in 2006. The spacecraft is equipped with a payload of six instruments that will collect more data about Mars than all previous missions combined, probing the atmosphere, surface and subsurface to understand the planet and how it changed over time.

One of the orbiter's three cameras will be the largest-diameter telescopic camera ever sent to another planet, revealing rocks and layers as small as the width of an office desk. Another camera will expand the present area of high-resolution coverage by a factor of 10. A third will provide global maps of Martian weather.

Also on the spacecraft are a ground-penetrating radar, supplied by the Italian Space Agency, to peer beneath the surface for layers of rock, ice and possibly liquid water; a spectrometer to find water-related minerals in patches as small as a baseball infield; and a radiometer to monitor atmospheric dust, water vapor and temperature. Two other science efforts will analyze the motion of the spacecraft in orbit to study the structure of the upper atmosphere and the Martian gravity field.

The spacecraft it will join at Mars include the long-lived Mars Exploration Rovers, Spirit and Opportunity. Both far surpassed their original 90-day design lifetime by spending two Earth years — or one Martian year — so far on the red planet. The longer they have explored, the more evidence they have found for water in the planet's past.

Spirit spent the first eight months of the year trekking into a range of hills to the summit of Husband Hill — a climb roughly equivalent to the height of the Statue of Liberty. It then continued on over the other side into a basin between two sets of hills. "As Spirit went up and down the hill, we kept encountering new kinds of rocks," said Dr. Joy Crisp, the rovers' project scientist at JPL. Many appear to be affected by groundwater. In addition, Spirit analyzed soils that have a chemistry consistent with clay minerals, a sign that a lot of water soaked the ground at one time. From its vantage point in the hills, the rover also spied several whirling dust devils.



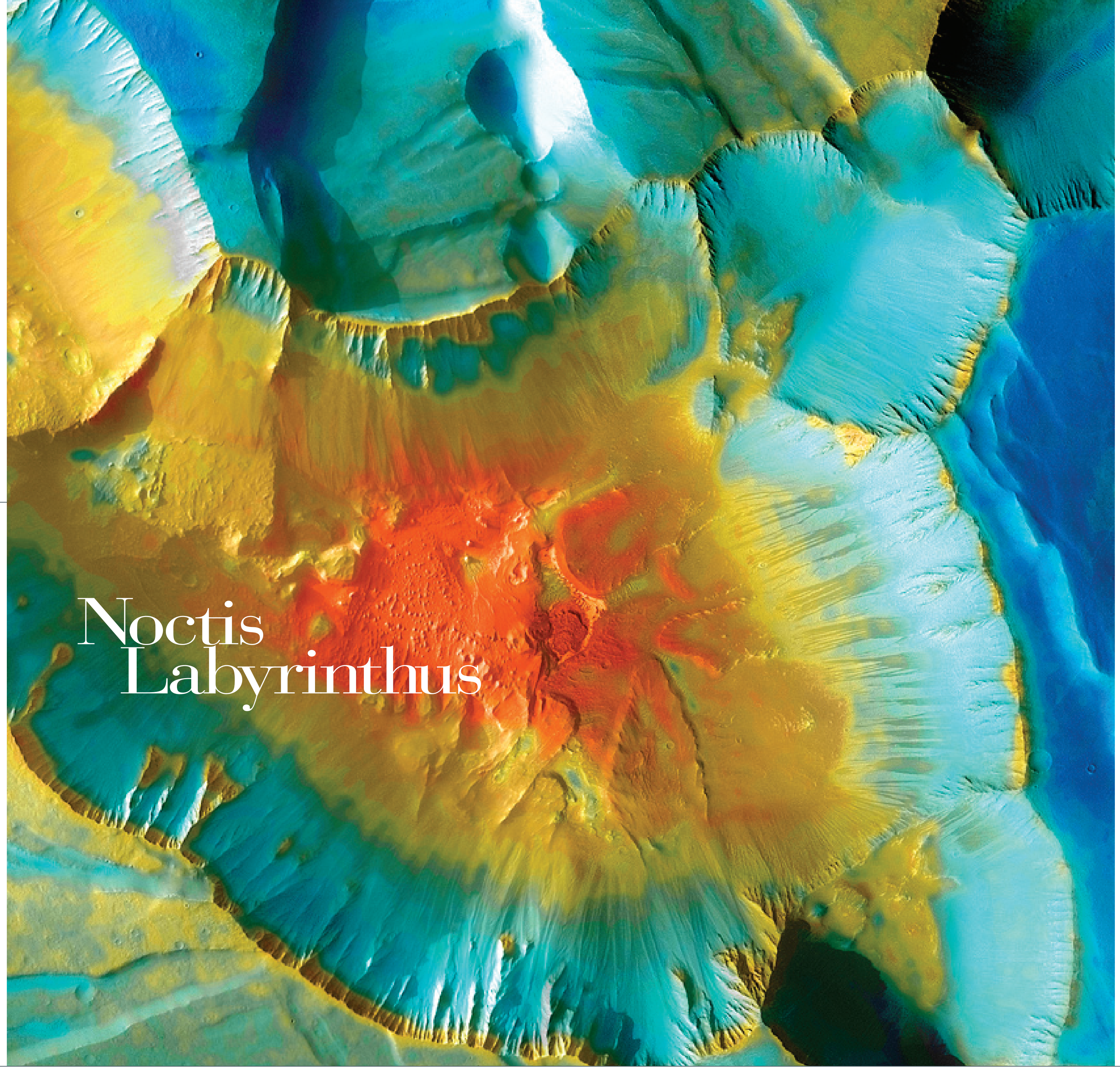
Opportunity spent part of the year overcoming challenges, first when it became stuck in a sand trap for five weeks, and later when its instrument arm proved balky. The rover encountered rocks of considerable beauty, many with cross-ripples that suggest they were sculpted in flowing water. In other rocks, the rover found equal levels of sodium and chlorine suggesting the presence of table salt — which can only form in water.

The picture that has emerged is that Opportunity's landing site, Meridiani Planum, indeed must have been quite wet — though it was also a very acidic environment. Scientists conclude that this part of Mars would not have been a hospitable birthing-place for life to form — though if once established it's possible life could have persisted there, as it has in equally challenging environments on Earth.

One of the biggest pieces of science news from Mars in 2005 was from a radar instrument co-managed by JPL that is flying on a European orbiter. The Mars Advanced Radar for Subsurface and Ionosphere Sounding, a collaboration with Italy's space agency, used its ground-penetrating ability to detect a previously unknown layer of craters beneath the planet's relatively flat northern hemisphere. Scientists had always assumed the northern plains were younger than Mars' southern highlands, so they looked to the south for niches where life might have taken hold billions of years ago. "Seeing these underlying craters tells us that the northern plains are much older than we thought, perhaps even as old as the southern highlands," said Dr. Dan McCleese, program scientist for Mars exploration at JPL. This opens up the possibility of exploration by radar in the north to find possible footholds of life from long ago. A similar radar on Mars Reconnaissance Orbiter will help continue this search.

Volcanoes and *lava flows in Mars' Syrtis Major region, imaged in false color by Mars Odyssey (above left).*

A surprisingly *terrestrial-seeming sunset on Mars (below left), memorialized by Mars Exploration Rover Spirit.*



Noctis Labyrinthus

Two other JPL orbiters were equally busy at Mars. Mars Global Surveyor celebrated its eighth year orbiting the planet, finding intriguing changes over time. New gullies that did not exist three years before were discovered on a Martian sand dune; boulders tumbling down a Martian slope left tracks that weren't there two years ago. And for three Mars summers in a row, deposits of frozen carbon dioxide near Mars' south pole have shrunk from the previous year's size, suggesting a climate change in progress. Many of Global Surveyor's most important findings have come, in fact, since its primary mission ended in 2001.

During four years in orbit, Mars Odyssey has completed a global map of the planet showing the abundance of elements in various regions. Apart from its own scientific studies, Odyssey played a crucial role enabling the success of the Mars Exploration Rovers. Ninety percent of the data from the two rovers reached Earth by way of being relayed by Odyssey.

The ruptured *landscape of Noctis Labyrinthus at the western end of the sprawling Valles Marineris canyon (left), imaged by Mars Odyssey.*

A self-portrait *in false color by Mars Exploration Rover Opportunity (upper right) as it worked to free itself from a sand dune.*

BETH DEWELL *probably wasn't the only athlete to get a call on her cell phone as a 10K race was about to get started along the Southern California coast last year. But she was almost certainly the only one to get a call from another planet. Dewell is one of four mission managers who oversee the health and welfare of the two Mars Exploration Rovers, working two-weeks-on, one-week-off shifts to keep operations running smoothly. While the team is no longer living on "Mars time" — middle-of-the-night sessions have become rare, and weekend operations are worked out for the most part on Fridays — issues can crop up that occasionally intrude on leisure-time activities.*

"At one time I thought I wanted to be a rover planner — everyone wants to be a rover planner and drive the rover," says Dewell, who joined JPL as a "fresh out" from college in 2002 after receiving a bachelor's degree in mechanical engineering from MIT. "But I really enjoy the mission manager job. I'm there to look at whether there are conflicts, if anything is unsafe, and so on. When we're planning to do something with the rover, I'm the final person who says, yes, let's go."

Her favorite memory in an as-yet-still-beginning career? "That would have to be when Spirit reached the summit in the Columbia Hills," says Dewell. "It was great to get there and see the valley and everything below. It was a great feeling of accomplishment."

"YES, LET'S GO . . ."

DeepSpacenetwork

One of the new *work-horses of the network, a 34-meter (110-foot) antenna at Goldstone, California (far right) features updated equipment called a beam waveguide.*

Ground systems *(inset) are being reorganized into Internet-like architectures.*

The highest volume of information ever received in a single day was achieved during sessions with the Mars Reconnaissance Orbiter as it made its way to Mars.

THE TEAMS RESPONSIBLE FOR NASA'S SPACE COMMUNICATION GATEWAYS on three continents were very active on several fronts in 2005. Like the year before, the giant dishes of the JPL-managed Deep Space Network were exceptionally busy supporting more than 38 spacecraft from various space organizations; thirteen mission-critical events required extra attention. At the same time, the network's stewards had eyes on the future.

With the launch of Mars Reconnaissance Orbiter, the Deep Space Network began to communicate with a spacecraft on a regular basis in a new radio band. Called Ka-band, this zone of the frequency spectrum is above the X-band, the more typical frequency range for spacecraft of recent vintage. Going to the new band allows the network to communicate at four times the data rates for equivalent spacecraft and ground receiving configurations. This will push link data rates into the millions of bits per second. The highest volume of information ever received in a single day was achieved during sessions with the Mars Reconnaissance Orbiter as it made its way to Mars.

One cautionary note about the new Ka-band communication is that it is more susceptible to interference from poor weather — the "rain in Spain" that has sometimes bedeviled spacecraft missions since the Voyager era. "Even considering these types of atmospheric conditions, we're seeing that we can transfer four times as much information as before," said Dr. William Rafferty, deputy director of JPL's Interplanetary Network Directorate. "That gives you flexibility in different ways. In some situations you might choose to use one-fourth the power, but keep the same bit rate, to save spacecraft resources."

Engineers were very engaged with improvements to the venerable, but aging, global network. While carrying out upgrades to antennas and power systems, they worked on overhauling the network's software architecture to require fewer one-of-a-kind building blocks, making it more like modern distributed computer networks that

Engineers continue *to evaluate arrays of many antennas as a way to pick up faint spacecraft signals.*

The flagship *antennas of the network are the 70-meter (230-foot) dishes, including this one in the California desert (far right).*

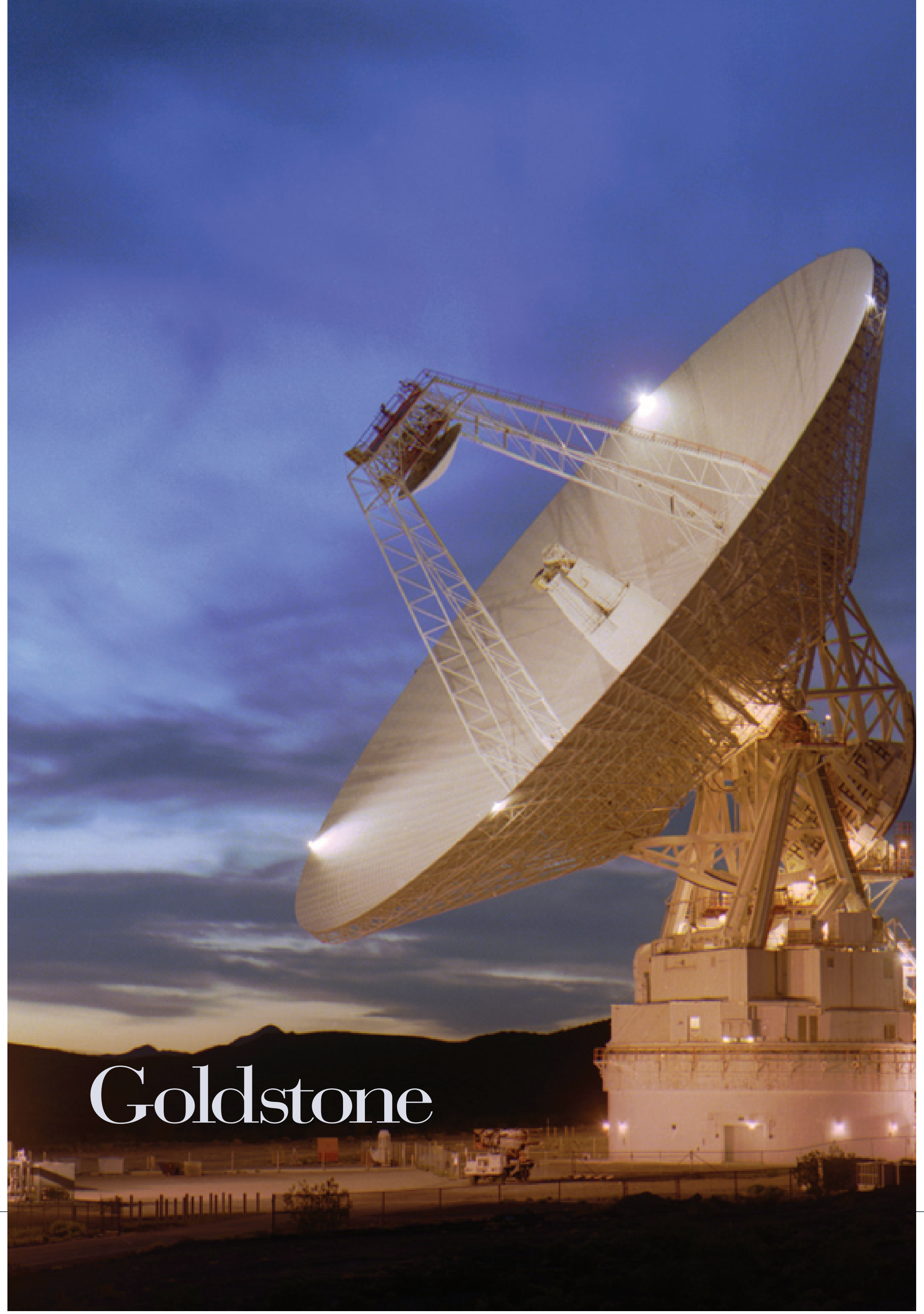
Can JPL take a page from the banking world — or the dot-coms? **THOM McVITTIE** *thinks so.*

As NASA missions carry more sophisticated instruments and push data rates higher, the Deep Space Network is exploring how the technologies that have enabled e-commerce and global exchange of information can be applied to meeting mission needs.

The Internet is powered by a small set of capabilities such as Web browsers, addressing systems and transfer protocols that enable the e-mail, Web browsing and electronic banking applications that we use every day. "We're working with NASA and the international community to evolve the current space links into an interplanetary network where science data can be moved around the solar system as easily as you e-mail pictures to your friends or share them on a Web site," says McVittie.

McVittie, who joined JPL 10 years ago after working at Los Alamos National Laboratory, believes that taking an Internet-like approach makes sense. "We're handling many more missions, much richer data, and the science teams are more geographically distributed," he says. "Using these approaches will allow us to take advantage of what industry has to offer, and give us the flexibility to apply more of our resources on providing the rocket-science capabilities that missions need."

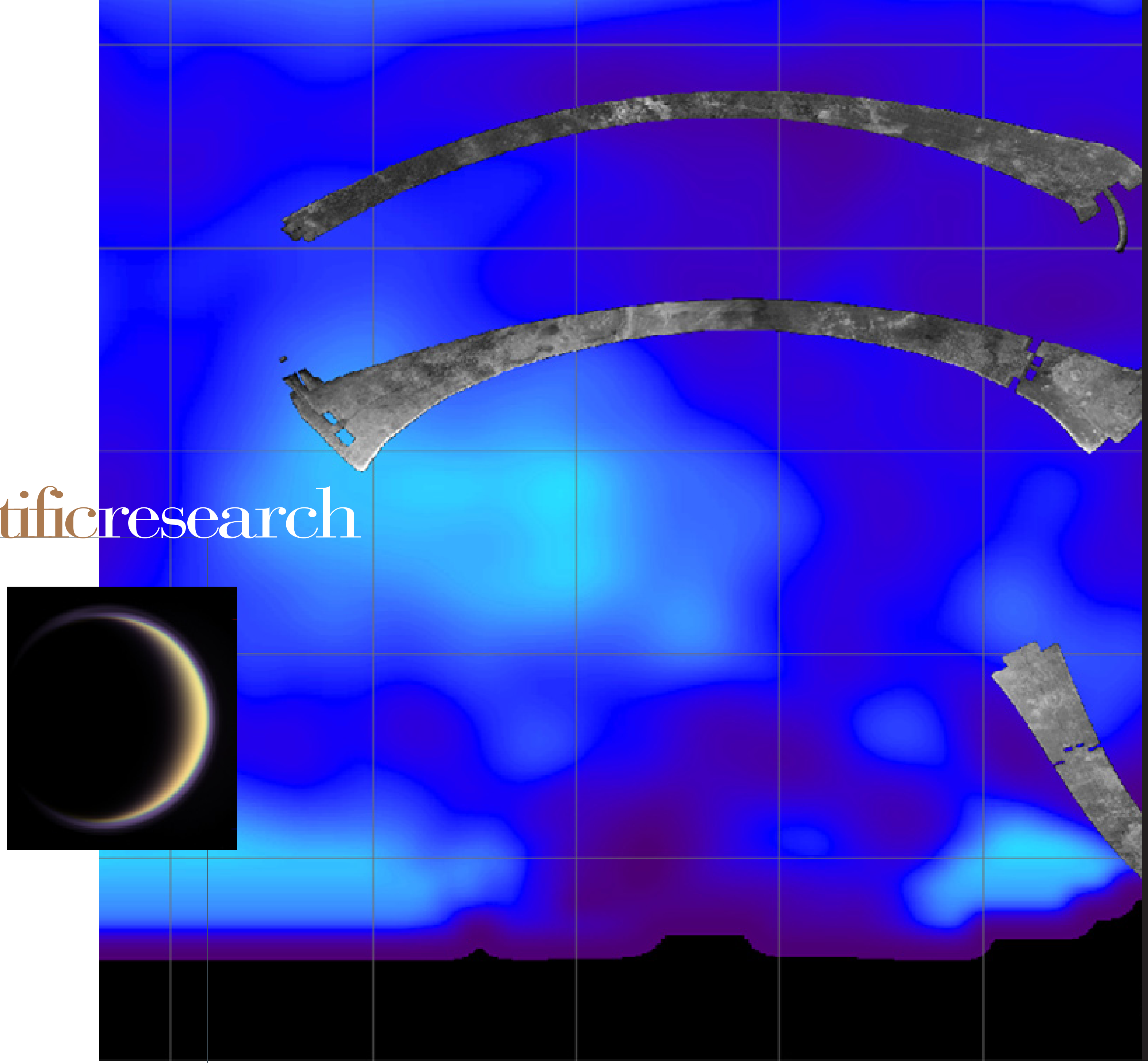
"AS EASILY AS YOU E-MAIL PICTURES . . ."



can use cost-effective, off-the-shelf systems. As an example of networking improvements, two spacecraft — Mars Reconnaissance Orbiter and Deep Impact — sent data to the ground using a space equivalent of the Internet file transfer protocol. In this way, if some data drops out for any reason it will be automatically retransmitted.

Also looking to the future, researchers experimented with the idea of using arrays of smaller antennas, rather than a single giant antenna, to capture the almost vanishingly faint signals of spacecraft many millions of kilometers away. Following the 2004 deployment at JPL of two 6-meter-diameter (20-foot) antennas, an additional 6-meter antenna was installed at Caltech and a 12-meter (39-foot) antenna at JPL in 2005. In the summer and fall of 2005, radio electronics were added to the 6-meter antennas at JPL. Testing showed the antennas performed as expected in the X and Ka bands; arraying was successfully demonstrated using natural radio sources and the signal from Mars Reconnaissance Orbiter. Initial evaluation of the 12-meter antenna was started.

Scientific research



***JPL scientists** are making extensive use of images of Saturn's moon Titan from Cassini's radar mapper. Here the radar strips are placed over a Hubble Space Telescope image of Titan (far right). In optical light, the moon is shrouded by perpetual haze (inset).*

> JPL is home to more than 300 scientists working in planetary science and life detection, Earth sciences, astrophysics and space sciences.

BUILDING AND FLYING SPACECRAFT ARE ONLY PART OF THE EQUATION that contributes to JPL's successful history of exploration. The true heart of discovery lies within the scientific questions that these spacecraft are sent to answer — and within the scientists who pose and attempt to answer those questions.

While JPL frequently teams with scientists at many universities and other institutions, the Laboratory itself benefits from a cadre of on-staff scientists. JPL is home to more than 300 scientists working in planetary science and life detection, Earth sciences, astrophysics and space sciences. These broad fields take in diverse specialties ranging from how galaxies form and the nature of atmospheres on Earth and other planets to understanding oceans and earthquakes. Nearly all of JPL's scientists do work connected with the Laboratory's flight projects or pursue basic research of their own by applying for and winning NASA awards. Their basic research makes use of NASA-collected data, or aids in the formulation of new missions for the future.

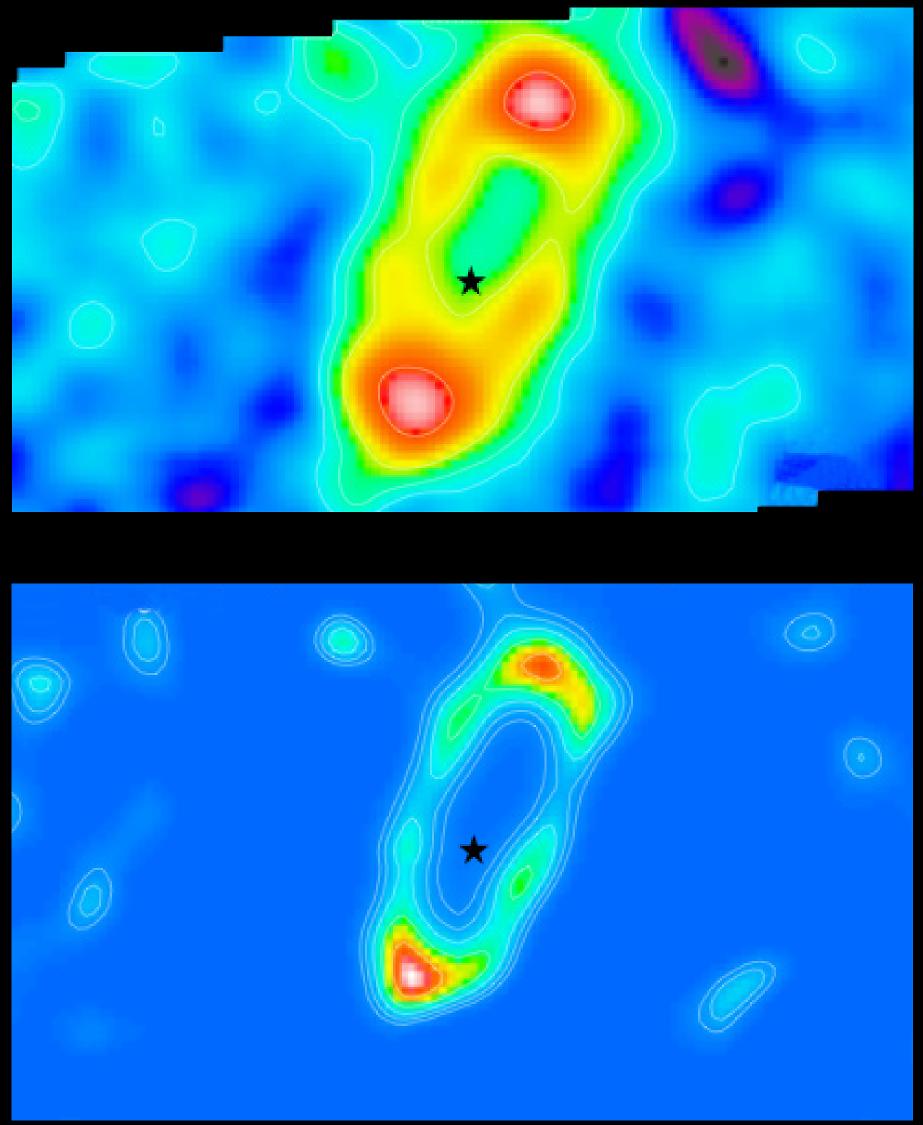
In 2005, after a 28-year journey, the Voyager 1 spacecraft crossed a boundary of the solar system on its journey into interstellar space. This boundary, called the termination shock, is where the solar wind transitions from supersonic to subsonic flow. Voyager 1 crossed this shock at a distance of 94 times the distance from the Sun to Earth. Contrary to expectations, Voyager 1 observed that energetic particles accelerated at the termination shock well before crossing it. JPL scientist Dr. Paulett Liewer and her colleagues used three-dimensional computer simulations of the solar wind and its interaction with the interstellar material to explain that the shock-accelerated particles were caused by the interstellar magnetic field.

Under the science leadership of Dr. Charles Elachi, the Cassini spacecraft's radar instrument began its observing campaign of Titan's surface in late 2004, revealing a landscape that was geologically complex and young. One large circular feature and numerous flows may be signs of icy volcanoes forming in extremely low-temperature areas. Sinuous channels are a telltale indication that liquids have flowed on the surface.

Besides their roles on JPL missions, many scientists conduct research with other tools. JPL work studying the December 2004 tsunami in the Indian Ocean included a key insight by Dr. Tony Song and his colleagues. They suggested that new kinds of data such as digital seismometry and satellite radar altimetry can help in understanding where and how tsunamis form. They created a model based on fault slip motion that accurately corresponded to the tsunami event, proposing that such models, together with fresh earthquake data, can be used to provide earlier warning to coastal communities at risk.

JPL oceanographer Dr. Paul DiGiacomo led a study of marine pollution in Southern California using data from a European imaging radar satellite. His team found that such radar data can be an effective way of monitoring pollution from storm water runoff, wastewater discharge and natural seepage of hydrocarbons.

Meanwhile, JPL astronomer Dr. Ken Marsh and a team used the Caltech Submillimeter Observatory on Mauna Kea, Hawaii, to image a dust ring around the star Fomalhaut, in the process discovering possible evidence for an unseen planet. Fomalhaut is one of the 20 brightest stars in the sky, located in the constellation Piscis Austrinus (or "Southern Fish") some 25 light-years away. Using a JPL-developed software tool, the team enhanced the image's resolution by a factor of three. This allowed them to show that the center of the dust ring is displaced from the star by about eight times the distance of Earth to the Sun. In addition, the density of planet-building material is highest at the portion of the ring farthest from the star. The team attributes both of these findings to the gravity effects of an unseen planet.



Fomalhaut

A dust ring *around the star Fomalhaut showing signs of an unseen planet (left) was captured by JPL scientists using the Caltech Submillimeter Observatory in Hawaii.*

Titan is not the kind of place you'd want to take a deep breath of air — for one thing, you would be frozen instantly. Nevertheless, it's just those deep-freeze conditions that have allowed the Saturn moon to preserve relics of chemistry that could tell us how life formed on Earth. And that is Titan's draw for scientists like **ERIC WILSON**.

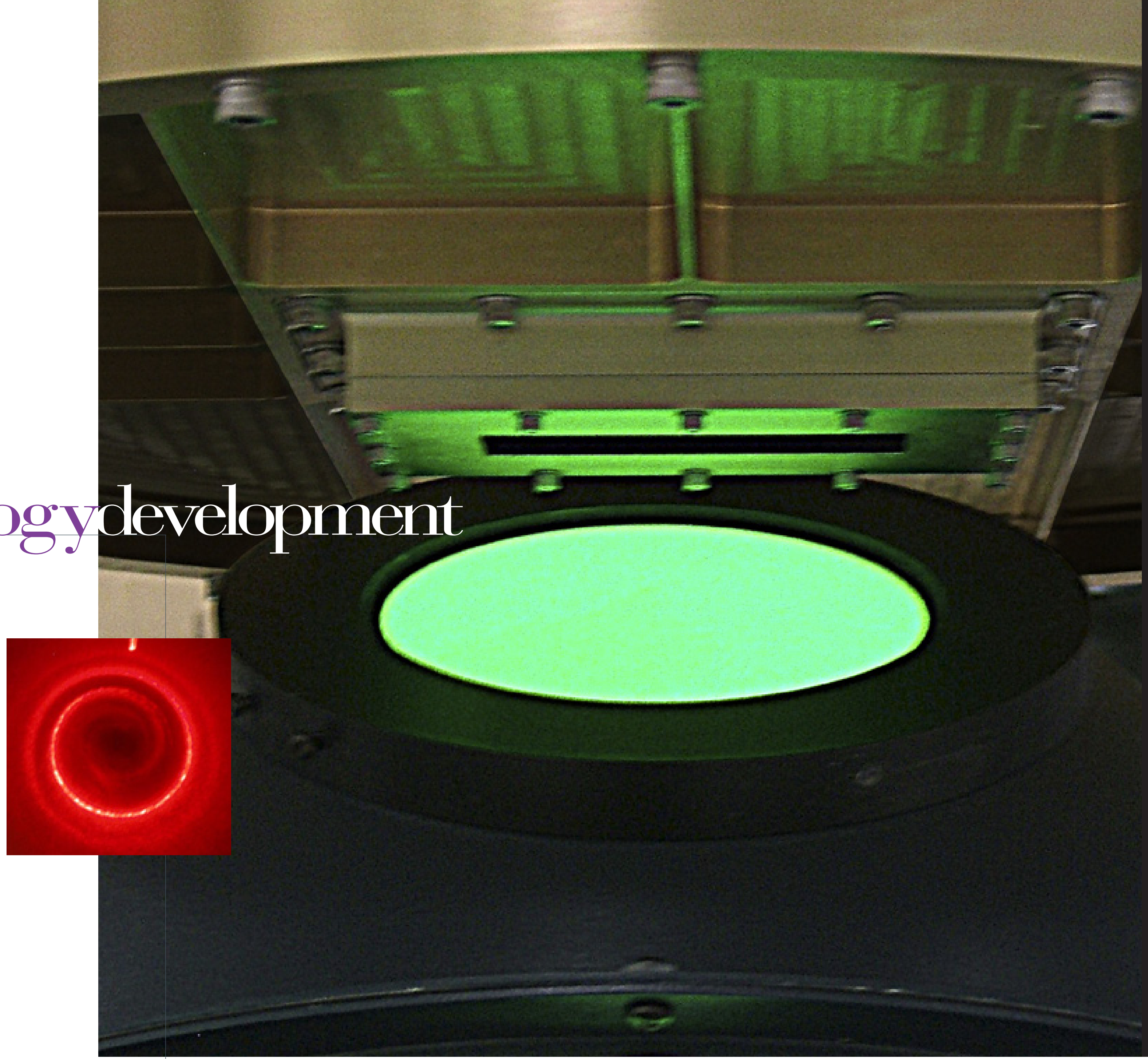
A Los Angeles native, Wilson was drawn to astronomy when, as a seven-year-old, he was fascinated by images of Saturn sent to Earth by Voyager 2. Later, as a math and astronomy double major at USC, he took a class in planetary atmospheres — and concluded he'd found his future. After earning a doctorate at the University of Michigan, he was awarded a National Research Council associateship to conduct research at JPL. In 2004, he became a permanent member of JPL's staff.

Wilson is trying to understand how Titan's atmosphere has evolved, and the role it played in the development of our solar system. "Titan has organic material and a nitrogen-based atmosphere similar to Earth — and this combination might produce compounds that serve as the building blocks of life," he says.

"Science research is not just about what we are finding now, it is also about what we should look for in future missions," Wilson added. "We are working with engineers to define what capabilities are necessary for future spacecraft that will explore Titan and answer the questions that we cannot answer today."

"WHAT WE SHOULD LOOK FOR IN FUTURE MISSIONS . . ."

Technology development



***Acid rain** and other chemicals can be detected by the Mapping Reflected Energy Spectrometer (far right) created by JPL for the National Geospatial-Intelligence Agency.*

***A light vortex** (inset) is created by a JPL research project for the Department of Defense that could be used in phased array antennas.*

In order to keep the Laboratory's technological edge, in 2005 JPL created for the first time a strategic technology plan.

IF THERE IS ONE ESSENTIAL INGREDIENT IN MAKING JPL'S MISSIONS A SUCCESS, it is technology. Far from relying on the state of the art in any of the technologies that come together to make projects fly, researchers continually pushed to develop new ways of doing things.

And JPL technologists were a busy group in 2005. The Laboratory won a record dollar amount of NASA Space Act Awards which the agency bestows on innovators — 45 percent, in fact, of all the total awards to all NASA centers. More than 1,300 individual awards were received by JPL's staff; overall, 51 patents were issued to Caltech or NASA based on JPL technologies.

In order to keep the Laboratory's technological edge, in 2005 JPL created for the first time a strategic technology plan. This blueprint singles out a dozen technologies critically important to JPL to advance NASA's exploration goals. In addition, the Laboratory continued a program instituted three years ago of investing in research and technology development. In 2005, this program funded more than 165 tasks.

About five percent of JPL's budget is accounted for by work the Laboratory performs for sponsors other than NASA, either in the Department of Defense or for other federal or industry customers. Several key projects moved forward during the year.

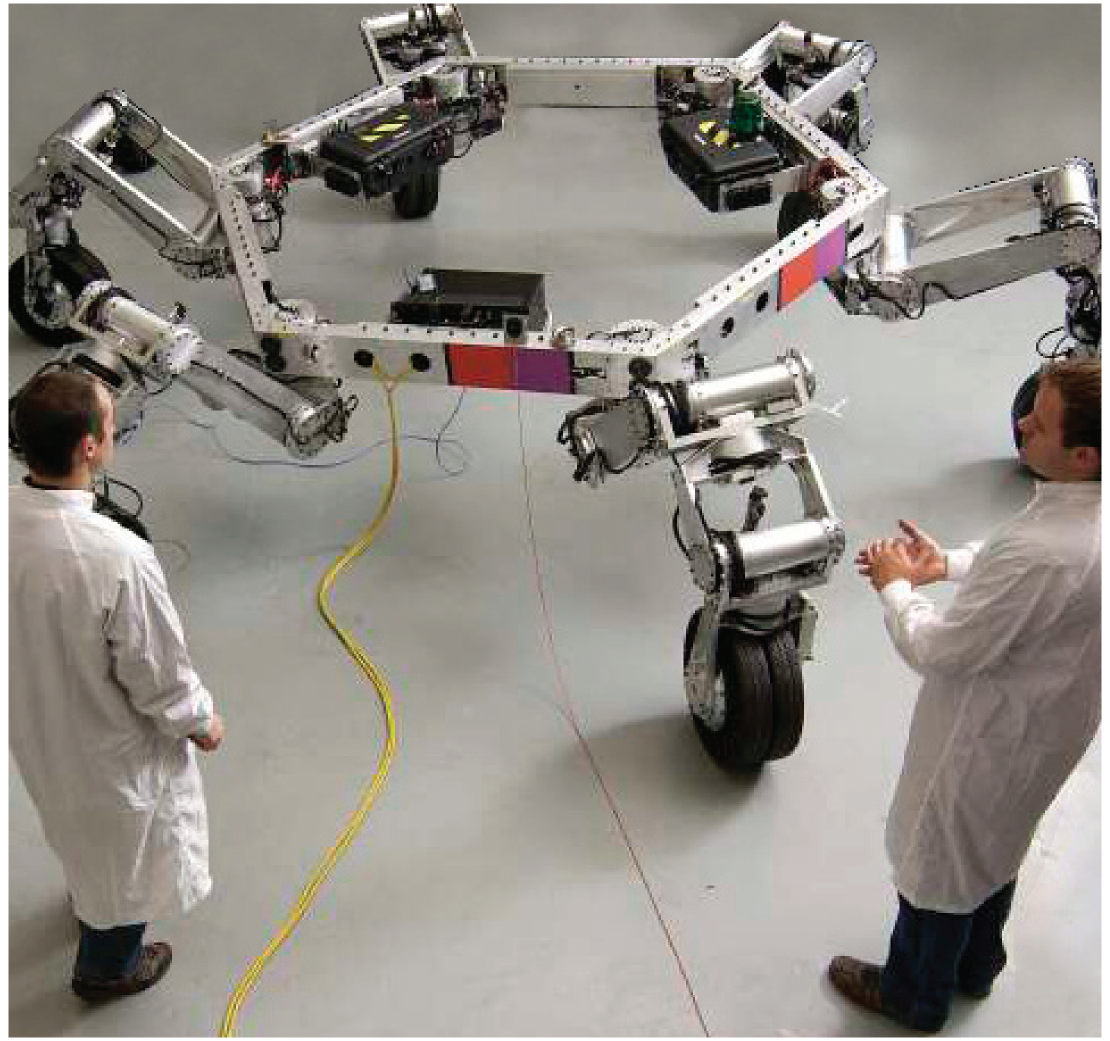
Among them were the Advanced Mirror Telescope, built around the lightest mirror ever designed for space. The system actively controls the shape of the mirror to compensate for atmospheric distortion or any issues in the remainder of the optical path. It is a project for the Department of Defense.

JPL completed and delivered an instrument called the Mapping Reflected Energy Spectrometer for the National Geospatial-Intelligence Agency. Flown on airplanes, the device can be used to monitor many types of chemicals such as emissions from factories or acid rain, with potential uses for public safety.

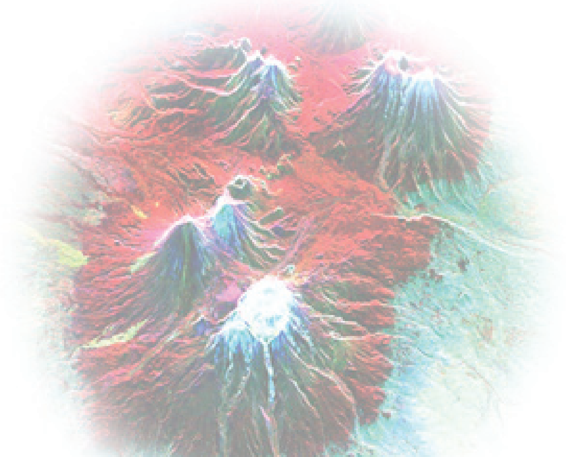
The Laboratory continued to work with NASA and the Department of Defense on joint development of an L-band synthetic-aperture radar. Optimized to detect centimeter-sized movements in Earth's crust, the system might eventually be a tool to help predict earthquakes.

Earthquakes and tsunamis were also the focus of a network of instruments envisaged for the United States' Pacific Northwest through JPL's participation in the Neptune Project. JPL won a competition among federal labs from the Joint Oceanographic Institutions, a consortium of universities and other organizations, to help architect a system of ocean observatories.

JPL's program of licensing technology, meanwhile, had a record year, acknowledged when the National Academy of Public Administration singled out JPL for managing the most sophisticated effort under NASA's Innovative Technology Transfer program. The E-Tongue, a sensor originally created as a water-quality monitor for the International Space Station, was transferred to a company that is working to develop it as a general-purpose lab instrument, with possible homeland security applications. JPL's Blackjack Global Positioning System receiver, which achieves about ten times better accuracy than typical GPS receivers on the market, was transferred to a company that is developing it commercially.



One of JPL's *newest robots, a six-wheeled vehicle called Athlete, might one day haul payloads on the surface of the moon or Mars.*



James Bond may have been saved from many an adventure by gadgets from his research-and-development man, Q. The imaging radar people of JPL have **WENDY EDELSTEIN**.

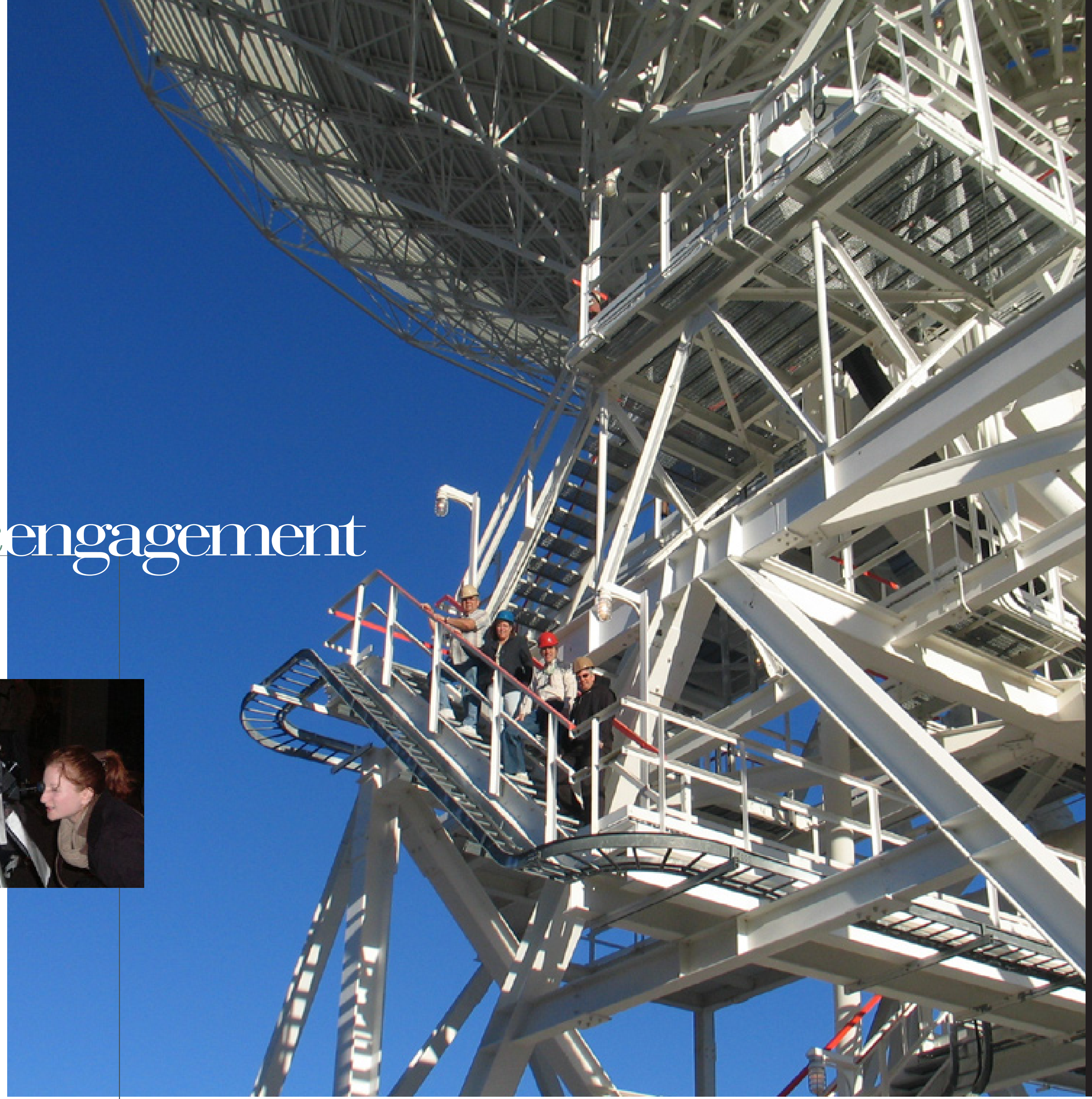
Not that Edelstein and her colleagues are dreaming up ejector seats or submersible sports cars. Their job is to provide the technology to enable future imaging radar instruments to study Earth or the surfaces of other planets. Right now she is working on advanced lightweight antennas and miniaturized, low-power electronics for an L-band radar that is being developed in partnership with the National Reconnaissance Office.

"We're trying to use L-band radar to answer important science questions as well as issues of national security," says Edelstein. Such an instrument, for example, could measure centimeter-level motions in Earth's crust, making it a good way to study tectonics and earthquakes. It could also reveal subsurface features like buried drainage channels on Mars.

Edelstein, who joined JPL in 1988 after receiving a bachelor's degree in electrical engineering from the University of California at San Diego, thinks of that as a near-term project; some of her and her colleagues' work has been on long-term technologies such as antennas made of flexible membranes. How long-term? "Some of those," she says, "are probably 20 to 30 years away."

"20 TO 30 YEARS AWAY . . ."

Public engagement



***Middle-school** and high-school teachers participating in a JPL-teamed educational program get a unique view from an antenna stairway at Goldstone, California (far right).*

***A JPL program** brought together members of the public in Ireland (inset) to view the moon and Mars through telescopes (photo by D. Kelleghan).*

JPL-managed content attracted 4.32 million visits to NASA's Web portal during the Deep Impact encounter, the highest draw of any space agency event during the year.

COMPELLING EVENTS IN SPACE SUCH AS DEEP IMPACT'S COMET ENCOUNTER AND CASSINI'S delivery of the Huygens probe to Titan continued to spark enormous public interest in JPL and its programs. The Laboratory, in turn, found many ways to communicate its stories to that eager public.

A JPL float honoring nine Earth and space exploration missions from the Laboratory made a colorful addition to Pasadena's Rose Parade on January 1, 2005. Eighteen million U.S. households viewed the parade, in addition to millions more in 89 countries. And "Spirit of Exploration," a 30-minute high-definition documentary created by JPL for a special National Air and Space Museum event in 2004, debuted on television with several airings on Discovery HD Theater.

The Web proved to be one of the most effective ways to bring missions to the outside world. JPL-managed content attracted 4.32 million visits to NASA's Web portal during the Deep Impact encounter, the highest draw of any space agency event during the year. JPL was also responsible for two of the five most-viewed sections on NASA's portal, on Deep Impact and Cassini. In the process, the Laboratory was honored by several Macromedia Site of the Day awards for multimedia content. JPL also capitalized on new technologies such as delivering stories to the public by audio podcasts.

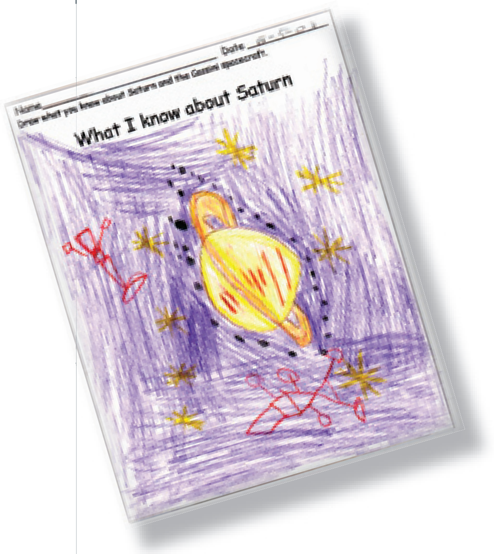
While the Internet was highly effective, the traditional news media were also a potent communication channel. During 2005, JPL issued hundreds of news releases and video products, and supported media visits to the Laboratory and news operations during major flight events. Together, these resulted in at least 3,500 news stories with a reach of 1.2 billion impressions.

A variety of partnerships in informal education created opportunities for public access that proved to be very popular. Seventy-eight museums and science centers across the country used JPL television programming, for example, during the Deep Impact event. To celebrate the success of the comet encounter, JPL hosted a performance of the early rock and roll band The Comets.

The Solar System Ambassadors, a program that works with volunteers who organize presentations and activities on NASA missions in their hometowns, had a total of 459 community activists on its rolls from all 50 states and

JPL's acclaimed *"Reading, Writing and Rings" program promotes literacy with content related to Cassini and Saturn (near right).*

A montage *of JPL spacecraft joined together as a towering robot made for a memorable float in the 2005 Rose Parade (far right).*



Puerto Rico. JPL's Night Sky Network, a coalition of more than 200 amateur astronomy clubs in all 50 states, reached more than 240,000 people with some 3,000 events since its inception just two years ago.

Several special events provided venues for the public to get a taste of space. JPL staffed and supported Los Angeles' First Robotic contest, which drew teams of high school students whose robots competed against each other, as well as the National Ocean Bowl, which included more than 100 student contestants from 17 high schools. JPL was the site for regional competition for the National Science Bowl, which involved 100 students from 24 schools. And JPL served as the finish line for the Dell-Winston solar car competitions, in which 180 students from high schools in seven states raced solar-powered vehicles 2,575 kilometers (1,600 miles) over a week from Texas to the Laboratory's front gate.

"DIFFERENT PLACES, DIFFERENT LANGUAGES . . ."

CAROLINA MARTINEZ *will be the first to admit that she had no science or engineering background when she came to JPL as a media relations representative five years ago. "But this isn't necessarily a weakness," says Martinez, who supports the Cassini mission. "I've tried to make it an advantage."*

How does that work? "Sometimes the science and technical topics that we are trying to share with the public are difficult to explain to a layperson," she says. "So, I can be the stand-in as the target audience that JPL is trying to reach. If I don't understand something, chances are that the person in the street isn't going to either."

A native of El Salvador, Martinez came to Southern California when she was eight years old, and graduated from Cal State Fullerton. In addition to her work with Cassini, she has used her Spanish language skills to help broaden the Lab's audience with Hispanic news media.

But Cassini remains her first love. "It's wonderful, working with such a diverse international team, with people from different places, different languages," she says. And though the Saturn mission is expected to be long-lived, can she imagine life eventually after Cassini? "No, I can't!" she says emphatically. "I can't even think about it."

With such a variety of colorful events, JPL was no less active in the classroom in the realm of formal education. During 2005, JPL's educational programs reached an estimated 150,000 teachers and nearly 500,000 students.

Applications to JPL's minority education initiatives increased by about 20 percent during the year, including a significant jump in the number of applications to a program that serves students with disabilities. An all–African American female robotics team from Spelman College that had received initial funding and proposal support from JPL and NASA was one of only five U.S. teams that competed in RoboCup 2005 in Japan. High-school students participating in a JPL summer program won a NASA-wide competition on designing space missions.

A record 500 students from high school to post-doctoral level participated in summer programs at JPL. That included, for the first time, several sight-impaired students who spent the summer interning at JPL under a collaboration between NASA and the National Federation for the Blind.

In new initiatives, JPL established a partnership with California State Polytechnic University, Pomona, which leads the Collaborative After School Project serving hundreds of thousands of children at 800 sites. The Laboratory hosted a professional development workshop attended by 47 after-school site directors who work with 305,000 students. Also, NASA announced the addition of five Southern California schools to the agency's Explorer Schools program, bringing to 15 the total of regional campuses to which JPL brings enriched space-related content and activities.

There were new developments with JPL's acclaimed "Reading, Writing and Rings," a literacy program about the Cassini mission to Saturn for children in first through fourth grades that has helped children make significant and sometimes stunning progress in language arts. Teacher evaluations showed that 97.6 to 99.6 percent of participating educators found the materials useful in their classrooms, especially for children learning English. In collaboration with JPL, a book publisher has begun adapting the project into a product line for children in middle school who read below grade level.

Institutional activities

A rare view *of nighttime building reflections was created when heavy rains at the beginning of the year caused a temporary lake in the Arroyo Seco.*

JPL continued to implement what the business world calls a system of earned value management, which evaluates and analyzes the progress of a project by assigning monetary value to the work accomplished, the time taken and costs incurred.

IN 2005, EFFORTS WERE AFOOT ON MANY FRONTS IN THE LABORATORY'S BUSINESS AND institutional communities to refine JPL's processes, tools and work environment.

The Laboratory strengthened its management with key personnel appointments, including the creation of two new senior positions. A post of associate director for programs, project formulation and strategy was established to enhance JPL's strategic planning and development of new flight projects. The Laboratory also created a chief information officer position to lead the Laboratory's information technology effort. Other initiatives in information technology included upgrades to prevent spam electronic mail messages and computer virus infections, as well as improvements in such areas as online storage, password synchronizations, help desk support and wireless networks.

Elsewhere, a major Laboratory-wide review was undertaken to examine all base operations, nonscientific general operations and technical support for potential areas of consolidation. This led to increased efficiencies and the freeing up of resources for other purposes.

JPL's Institutional Business Systems — the online environment responsible for functions ranging from purchasing to timecards — were expanded and upgraded in 2005. An integrated inventory system was put in place, enabling staff throughout JPL's fabrication and business groups to share information on materials on-hand. Another online system called the Data Warehouse debuted, offering a storehouse of data for many different kinds of business reporting.

To support more rigorous cost estimating and the conduct of pricing reviews on major proposals, a formal Pricing Office was established. JPL continued to implement what the business world calls a system of earned value management, which evaluates and analyzes the progress of a project by assigning monetary value to the work accomplished, the time taken and costs incurred. This year the system was adopted by a number of major flight projects, including the Advanced Mirror Telescope, Kepler, the Phoenix Mars lander, Aquarius and the Orbiting Carbon Observatory. The capability is currently being evaluated by a NASA assessment team, and it is expected JPL will receive full validation in 2006 — becoming the first NASA center to achieve this milestone.

JPL began operation of a compressed natural gas fueling station, reducing fossil fuel dependence among fleet vehicles. JPL's plant protection and security personnel continued a mutual assistance program, providing training and use of Laboratory facilities to Los Angeles County, the City of Pasadena and Los Angeles City helicopters.

Two significant construction projects moved forward. As the year ended, JPL was preparing to issue a design contract for construction of a Flight Projects Center, while preliminary design was expected to begin on a dual-use Educational Center and Administration Building.

JPL successfully coordinated its 17th High Tech Conference, attended by 300 individuals from prime contractors and government agencies, and 700 small business owners, as well as its 7th annual Small Business Round Table and a semi-annual Science Forum, both with an attendance of 200. Other activities for small businesses JPL supported included an annual mentor–protégé program conference in Washington and a small business solutions conference in New York.

In human resources, an online manager's information processing center went live that offers supervisors improved access to workforce information, thus making their own time more efficient. JPL established a diversity and inclusion committee made up of a cross-section of employees to improve the working environment for all of the Laboratory's staff.

In addition, an employee survey was conducted that drew a response rate of 65 percent, regarded as a very enviable showing. The survey showed that employees put high marks on their satisfaction with working at JPL; they also gave very favorable grades to the Laboratory's efforts in such areas as safety, diversity, ethics and integrity.

A backup childcare program was rolled out that allows employees to get backup care on an as-needed basis with an outside service. Vacation rates were enhanced for employees with fewer than 15 years of service to help make JPL's benefits as competitive as possible.

JPL's facility *master plan calls for gradual renewal of the Laboratory's buildings.*

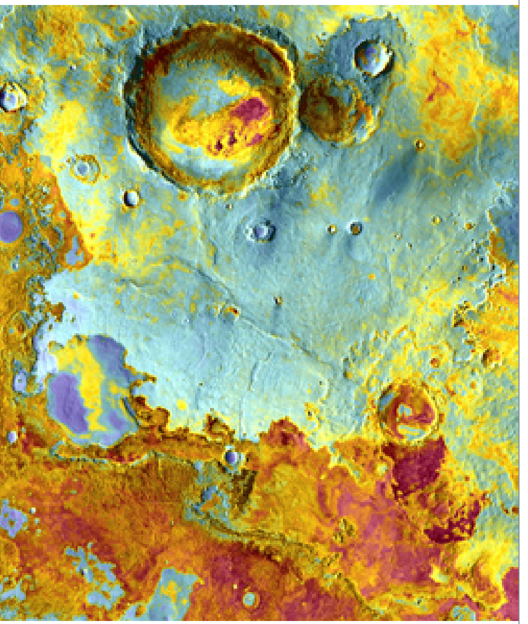
As a fashion merchandising major in college, **JENNY COON** *imagined a future as a buyer in Paris. Instead, she now spends her time tracking down the most razor-sharp minds in science and engineering around the world to bring them to JPL's staff.*

Oscar de la Renta it's not, but to Coon her position as a human resources recruiter for JPL is her "dream job." "The transition isn't as improbable as it might seem," she explains. "Early in my career I moved toward human resources, for example working as an H.R. manager in a small firm. In part it comes down to being a people-oriented person."

Coon points to many recent innovations in JPL recruiting, such as a new applicant tracking system and new strategies to find talent. Sometimes that means taking advantage of outside resources that didn't exist a decade ago, such as the proliferation of job-hunting Web sites.

"We've been working hard to make staffing as responsive to the Lab as possible," she says. "It's extremely important to us that JPL's business practices keep pace with the reputation of its technical work. I'm really proud to see what we've been able to do."

"BUSINESS PRACTICES KEEP PACE . . ."



Mars Odyssey *view of Meridiani Planum, the region in which the Mars Exploration Rover Opportunity landed.*

Mark Adler
Engineer of the Year, Drexel University

Yoseph Bar-Cohen
Research Council Award for Sustained Excellence, American Society for Nondestructive Testing

Smart Materials and Structures Lifetime Award, International Society for Optical Engineering

John Casani
Goddard Astronautics Award, American Institute of Aeronautics and Astronautics

Vint Cerf
Presidential Medal of Freedom

Tien-Bsin Chao
Elected Fellow, International Society for Optical Engineering

Joy Crisp
Women in Science and Technology Award, California State Senate and Assembly

Christopher Clavius, S.J. Award, Saint Joseph's University

Charles Elachi
Bob Hope Distinguished Citizen Award, National Defense Industrial Association

Laurel Award, Aviation Week & Space Technology

Evolvable Computation Group
Silver Medal, Human Competitive Competition, Genetic and Evolutionary Computation Conference

Lucien Froidevaux
Editor's Citation for Refereeing, Journal of Geophysical Research-Atmospheres

Lee Fu
Editor's Award, Journal of Atmospheric and Oceanic Technology

Fred Hadaegh
Elected Fellow, American Institute of Aeronautics and Astronautics

Gerard Holzmann
Elected Fellow, National Academy of Engineering

Robert Kwok
Elected Fellow, Institute of Electrical and Electronics Engineers

Wayne Lee
Mark Bingham Award for Excellence in Achievement, University of California at Berkeley

Rosaly Lopes
Carl Sagan Medal, American Astronomical Society Division for Planetary Sciences

Lute Maleki
Elected Fellow, American Physical Society and Optical Society of America

MAJOR EXTERNAL AWARDS

Mars Exploration Rover Team
Leonardo da Vinci Award, American Society of Mechanical Engineers Design Division

Laureates Hall of Fame Award, Aviation Week & Space Technology

Trophy for Current Achievement, National Air and Space Museum

Goddard Memorial Trophy, National Space Club

Best of What's New Grand Award, Popular Science

Firouz Naderi
Ellis Island Medal of Honor, National Ethnic Coalition of Organizations

Edward Smith
Arctowski Medal for Solar Physics, National Academy of Sciences

Space Very Long Baseline Interferometry Project
Laurels for Team Achievement Award, International Academy of Astronautics

Linda Spilker
Distinguished Alumni Award, California State University Fullerton

Stardust Team
Laurel Award, Aviation Week & Space Technology

Nancy Van Wickle
Medal of Excellence Award, Women At Work

Paul Weissman
Elected Fellow, American Association for the Advancement of Science

James Williams
Brouwer Award, American Astronomical Society Division of Dynamical Astronomy

MAJOR CONTRACTOR PARTNERS

Lockheed Martin Space Systems
Mars Global Surveyor, Mars Odyssey, Mars Reconnaissance Orbiter, Spitzer Space Telescope, Stardust

ITT Industries
Deep Space Network Operations

Northrop Grumman Space & Mission Systems Corp.
Prometheus

Ball Aerospace & Technologies Corp.
CloudSat, Deep Impact, Kepler, Quick Scatterometer, Spitzer Space Telescope

Lockheed Martin Information Technologies
Desktop Computer Support

Orbital Sciences Corp.
Active Cavity Radiometer Irradiance Monitor Satellite, Dawn, Galaxy Evolution Explorer

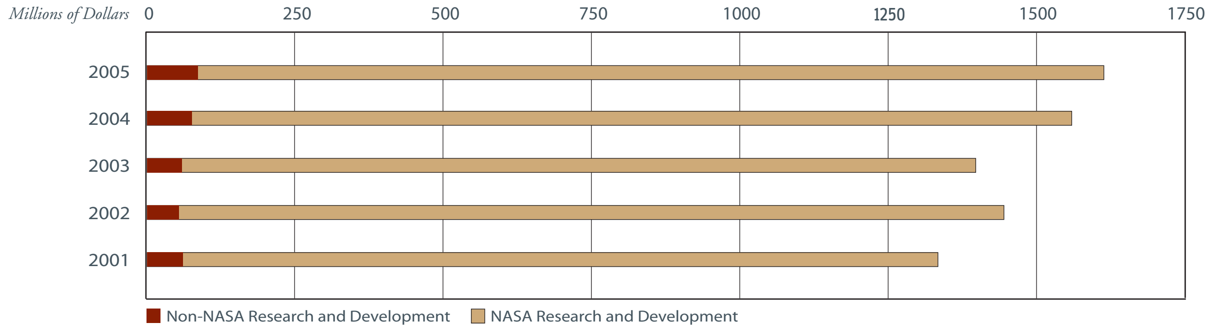
Raytheon
Science Data Systems Implementation and Operations

Computer Sciences Corp.
Institutional Services, Information Technology Infrastructure

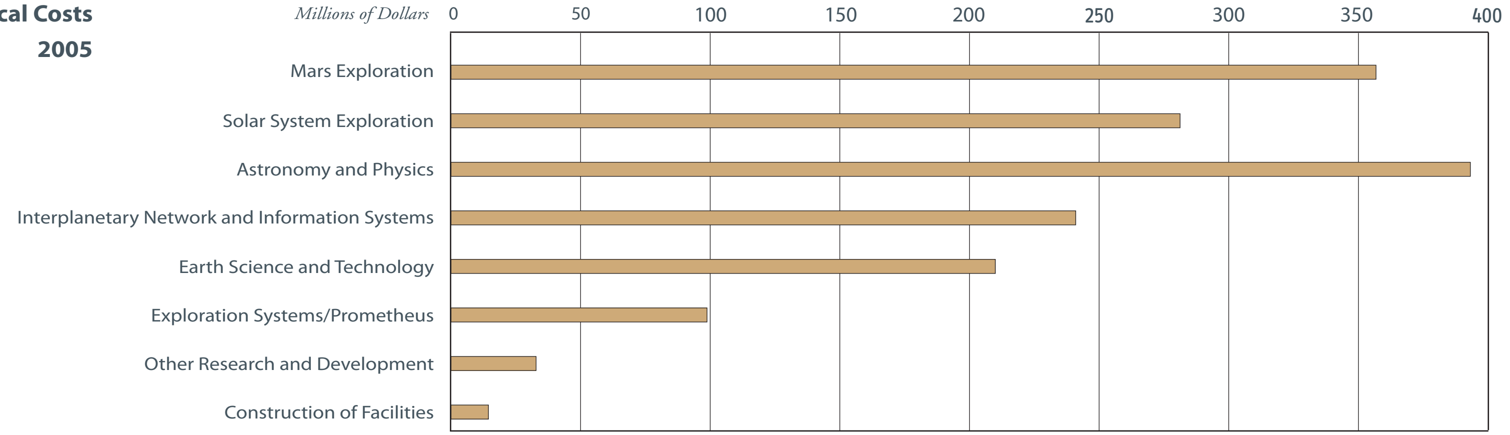
All Star Services Corp.
Facilities Maintenance

General Dynamics Decision Systems
Small Deep Space Transponders

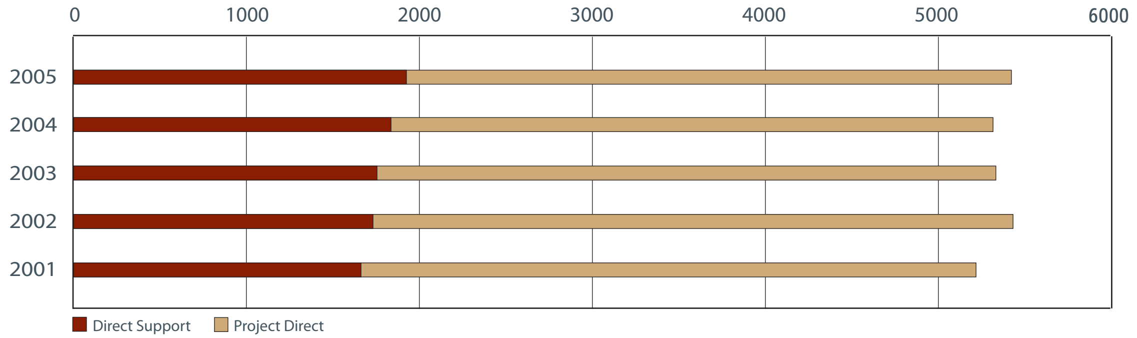
Total Costs



Fiscal Costs
2005



Total
Personnel



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An isolated *water cloud extending more than 30 kilometers (18 miles) above the surface of Mars, imaged by Mars Global Surveyor.*

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