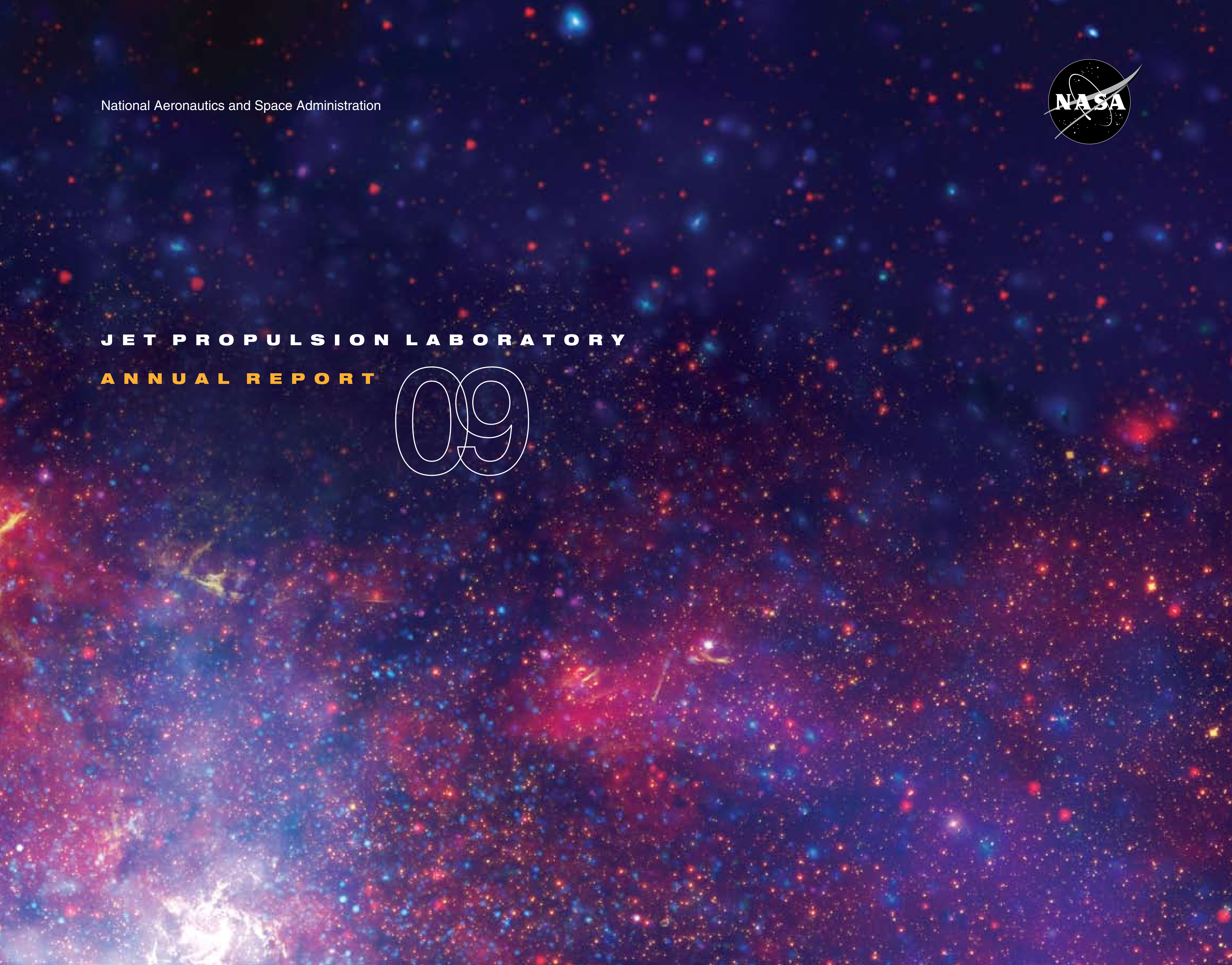
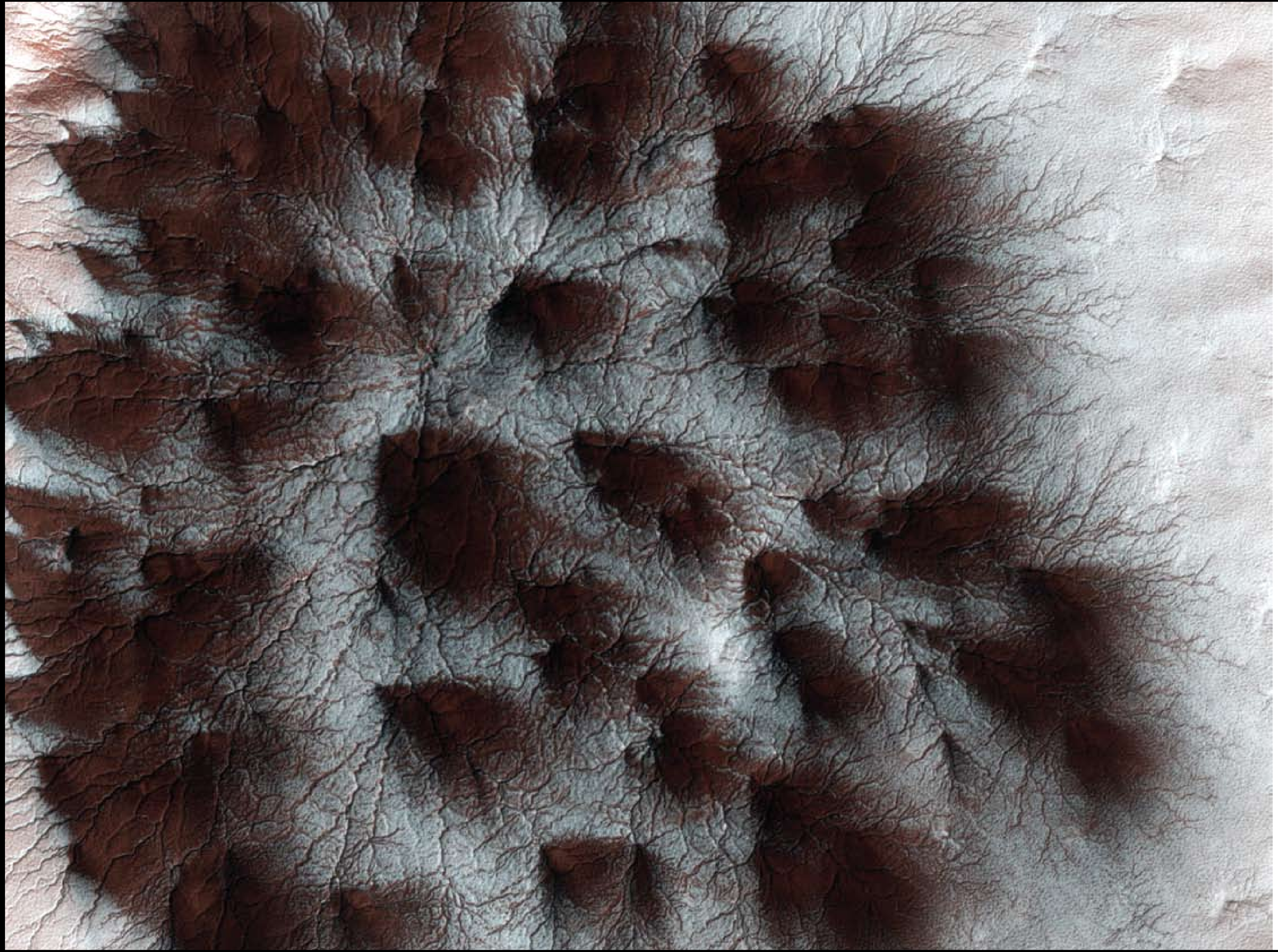


National Aeronautics and Space Administration

JET PROPULSION LABORATORY

ANNUAL REPORT 09



CONTENTS 09

Mars' seasonal cap of carbon dioxide ice erodes the surrounding terrain as it sublimates from ice to vapor every spring. In the region where the High Resolution Imaging Science Experiment camera on NASA's Mars Reconnaissance Orbiter took this image, dusty troughs form a starburst pattern.

Cover: To celebrate the International Year of Astronomy, NASA's Great Observatories — the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory — produced a composite image of the turbulent center region of our Milky Way galaxy.

DIRECTOR'S MESSAGE

2009 was truly the year of astronomy at the Jet Propulsion Laboratory. While the world at large was celebrating the International Year of Astronomy, we were sending more telescopes into space than in any other year, ever. As these missions unfold, the astronomers are sure to change the way we see the universe. One of the newly lofted observatories is on a quest to find planets like our own Earth orbiting other stars. Another is a telescope that gathers infrared light to help discover objects ranging from near-Earth asteroids to galaxies in the deepest universe. We also contributed critical enabling technologies to yet two other telescopes sent into space by our partners in Europe. And astronauts returned to Earth with a JPL-built camera that had captured the Hubble Space Telescope's most memorable pictures over many years.

And while it was an epic time for these missions, we were no less busy in our other research specialties. Earth's moon drew much attention from our scientists and engineers, with two JPL instruments riding on lunar orbiters; previously unseen views of shadowed craters were provided by radar imaging conducted with the giant dish antennas of the Deep Space Network, our worldwide communication portal to spacecraft around the solar system. At Mars, our rovers and orbiters were highly productive, as were missions targeting Saturn, comets and the asteroid belt. Here at our home planet, satellites and instruments continued to serve up important information on global climate change.

The year was not without its challenges and disappointments. In February, we lost a satellite designed to measure carbon dioxide in Earth's atmosphere when the nose cone on its launch vehicle failed to open properly. Another Earth satellite stopped collecting data in the fall after a remarkable 10 years in orbit. For several months, engineers worked hard without success to try to free one of the Mars rovers that had become mired in an interplanetary version of a golfer's nightmare sandtrap. Here on the ground, our staff went above and beyond to protect the laboratory when a fire in the San Gabriel Mountains — the largest blaze ever in Los Angeles County in recorded history — brought flames to within a few hundred feet of our facility.

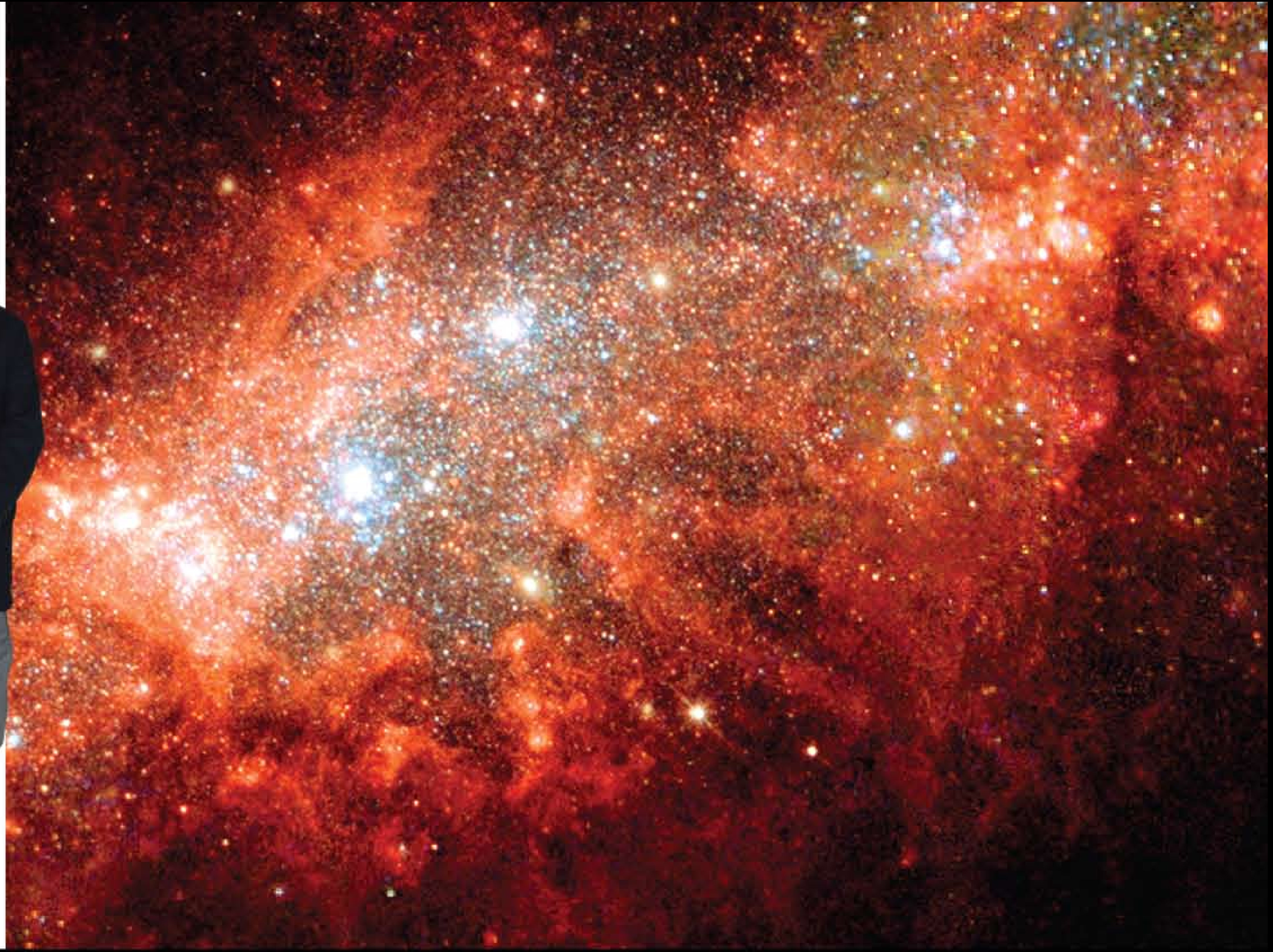
Whether triumphs or setbacks, all of our efforts exploring the world around us demonstrate the many ways in which we can use the laboratory's capabilities to contribute to the interests of our country and the globe. Increasingly, national attention is turning to the topic of global climate change, and the role that NASA can play in helping to understand and address it. For several years JPL has been one of the largest contributors of instruments to NASA's Earth-observing missions. The expertise of our technical community makes this a natural area where we can contribute to national priorities.

There is also increased interest at the federal level in leveraging the keen public fascination with NASA's missions to help promote science, technology, engineering and mathematics education at all levels, from elementary school to university. I'm very proud that JPL is widely recognized for its programs used in classrooms, museums and other educational venues, many of which make innovative uses of new technologies. This too is an important area where we can make a meaningful contribution to national interests.

But our main business is, of course, exploring. Many initiatives will keep us busy for years. In 2009, NASA gave approval to start planning a major flagship mission to Jupiter's moon Europa in search of conditions that could host life, working with our partners in Europe. In addition to our prospective Earth science projects, we have full slates of missions in Mars exploration, planetary exploration and space-based astronomy.

This year's annual report continues our recent direction of recounting the laboratory's accomplishments throughout the year month by month. I hope you will find these outcomes achieved by our people in 2009 meaningful and informative, and look forward to having you join us as we bring to life our explorations yet to come.

Charles Elachi



A hotbed of vigorous star birth activity, the dwarf galaxy NGC 1569 is captured here by JPL's Wide Field and Planetary Camera 2 on the Hubble Space Telescope.

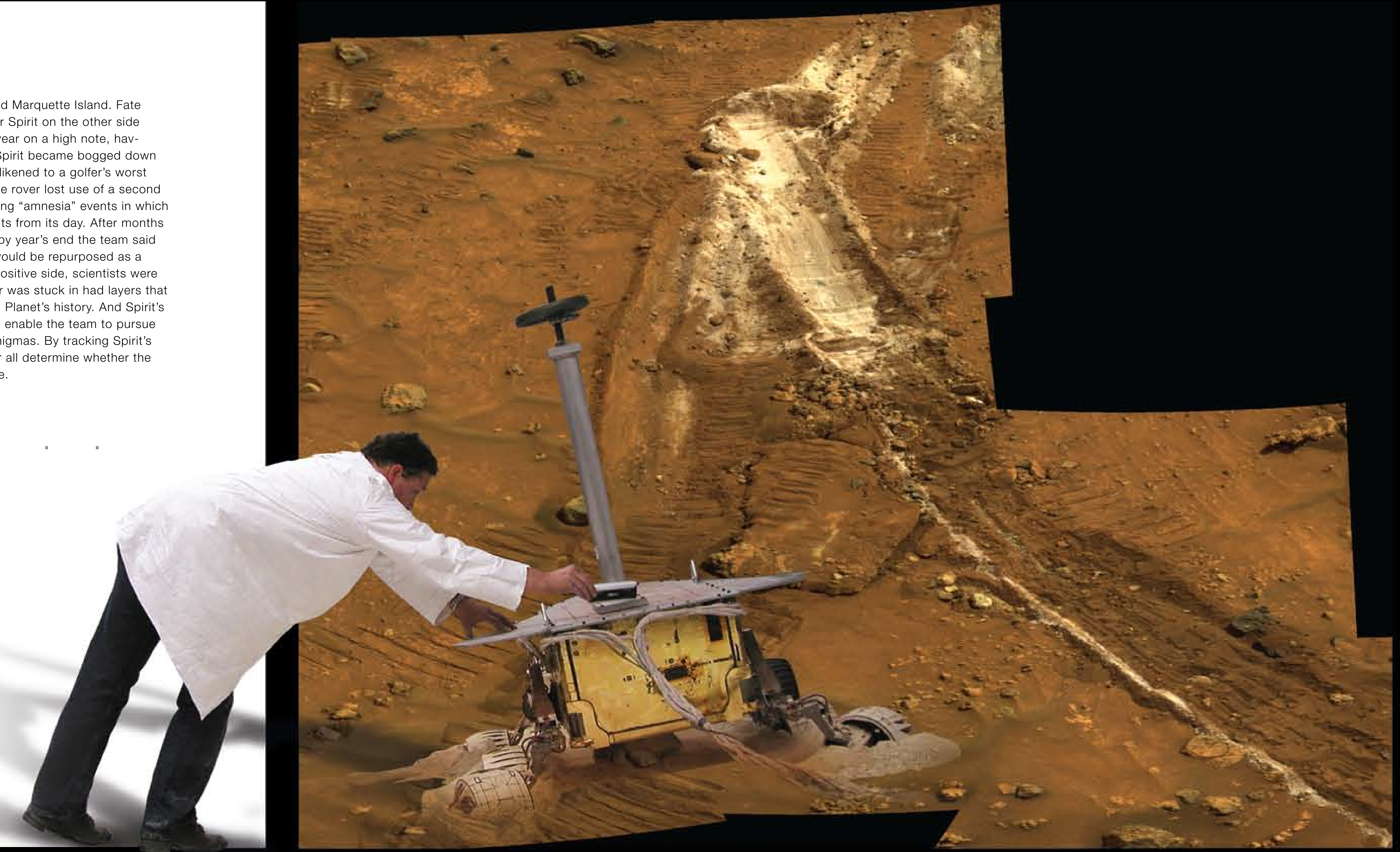
ROAD WARRIORS

It was the mission that wouldn't end. By the time the Mars rovers Spirit and Opportunity logged their fifth anniversary roaming the Red Planet in January 2009, they had outstripped the original 90-day goal by a factor of 20 — in the process collecting tens of thousands of photos and generating hundreds of scientific papers reconstructing the history of now-vanished water on the neighboring world. Year Six proved productive for Opportunity, which continued a lengthy trek across a Martian plain toward a large bowl called Endeavour Crater. In fact it set a driving record, rolling across 5.3 kilometers (3.3 miles) in 2009 — more terrain than it has covered in any other year. In the process Opportunity discovered and scrutinized two new, large meteorites, which scientists christened Block Island and Marquette Island. Fate had a more difficult future in store for Spirit on the other side of the planet. Though it started the year on a high note, having survived a massive dust storm, Spirit became bogged down in loose sand that the mission team likened to a golfer's worst nightmare. To compound matters, the rover lost use of a second of its six wheels, and started exhibiting "amnesia" events in which it neglected to save a record of events from its day. After months of attempting to extricate the rover, by year's end the team said it was increasingly likely that Spirit would be repurposed as a stationary science outpost. On the positive side, scientists were pleased that the deep sand the rover was stuck in had layers that revealed intriguing details of the Red Planet's history. And Spirit's likely future as a stationary lab could enable the team to pursue an answer to one of Mars' central enigmas. By tracking Spirit's radio signal, they might once and for all determine whether the planet has a solid or molten iron core.

JANUARY

LIFE'S COSMIC ORIGINS?

Did comets bring the building blocks of life to the primitive Earth? More evidence that the answer might be yes came from scientists analyzing samples of comet dust delivered to Earth in 2006 by the Stardust spacecraft. They revealed traces of glycine, an amino acid used by living creatures to make proteins — the first time an amino acid has been found in a comet. Stardust itself continued on a new mission to fly by Comet Tempel 1, which had a crater blasted in it by another spacecraft, Deep Impact. In January, Stardust passed within 9,200 kilometers (about 5,720 miles) of Earth to fling it onto a flight path for its final approach to Tempel 1 in 2011.



NO LOOKING BACK

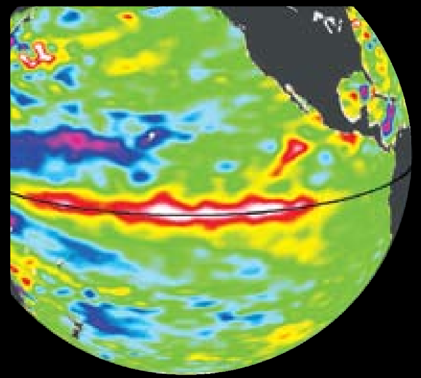
For one JPL mission, 2009 was the point of no return. Propelling itself through the solar system by the whisper-light thrust of an ion engine, the Dawn spacecraft ventured out into the asteroid belt — never to return to the vicinity of inner planets such as Earth. On the way, Dawn sailed past Mars in February, using the opportunity to calibrate its science instruments. Alternating between firing its innovative ion engine and coasting, by the end of the year Dawn had used the high-tech thruster for 11,365 hours, or just over half of its mission time to date. In 2011, Dawn will reach the large asteroid Vesta, which it will orbit for a year before departing to orbit the dwarf planet Ceres. If all goes well, that will make it the first spacecraft to orbit more than one target world in succession.

FEBRUARY

THE CARBON PUZZLE

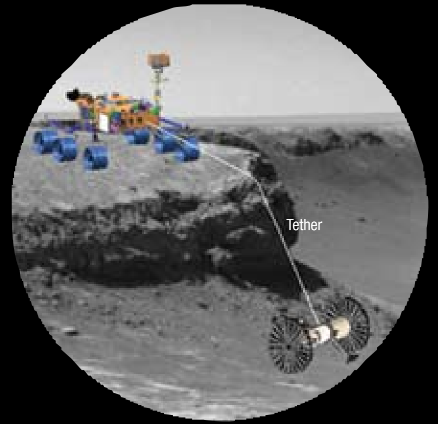
To untangle the complex reactions responsible for global climate change, scientists have long known they need to get a fuller picture of carbon dioxide in the atmosphere — where it is produced, and where it is taken up. Great hopes were thus riding on the Orbiting Carbon Observatory, a satellite designed to provide such a global view of the greenhouse gas. When the satellite was lofted over the Pacific from California's Vandenberg Air Force Base, its clamshell-shaped nose cone, or fairing, failed to open correctly, ending the mission before it began. Later, Congress approved funding to start building a replacement satellite.

QUICK TAKES



After 17 years of cooperation between JPL and the French space agency, the world has enjoyed advance warnings of El Niño currents and hurricanes based on the global view of ocean satellites, most recently Jason 1 and Jason 2. In February, that pair of spacecraft carried out a tango to reposition themselves to provide an even better perspective of Earth's seas. The new orbits allow them to see much smaller ocean features, and to track how rapidly developing ocean currents change over time. During the year, the satellites confirmed that a new El Niño appeared to be brewing in the tropical Pacific.

Like tourists eager to pack as much as possible in on a vacation, scientists find that there are many alluring destinations in the outer solar system. Is there more to discover at the moons of Jupiter, or Saturn? In February, NASA announced its decision that the next major mission to the outer planets will be a flagship-class project to Jupiter and its moons. A joint venture bringing together JPL and the European Space Agency, the plan calls for NASA to send an orbiter to the giant planet's moon Europa, while Europe will dispatch a spacecraft to another moon, Ganymede. Europa is especially tantalizing, scientists say, because they have long suspected that some form of life might be harbored in deep, vast seas believed to lie beneath a frozen outer crust. In fact, they say, there is twice as much water on Europa as in all of Earth's oceans combined. The mission's launches are expected around 2020.



When robots are sent to other planets, the universal byword in selecting landing sites is: be safe. No one wants to lose a complex rover by sending it over the edge of a cliff. But future missions may not be quite so limited, thanks to efforts such as Axel – a small wheeled robot that can rappel off cliffs, travel nimbly over steep and rocky terrain, and explore deep craters. Apart from possible missions in space, the robot — created by a joint team of JPL engineers and Caltech graduate students — might be used in earthly tasks such as search-and-rescue operations. In February the team announced the completion of field tests in JPL's Mars Yard.

MARCH

EYES ON THE EARTH

How soon can you see the data from NASA's fleet of Earth-orbiting satellites? How about now? Thanks to state-of-the-art visualization technologies, a new website, Eyes on the Earth 3D, allows users to fly along with any of the space agency's 15 operating Earth satellites, viewing authentic data maps of ozone, sea level or carbon dioxide levels mapped onto the surface of a globe. The missions constantly monitor our planet's vital signs, such as sea level height, concentration of carbon dioxide in our atmosphere, global temperatures and extent of sea ice in the Arctic. And now the public can keep up to date on those changes, thanks to their new Eyes on the Earth.

NOT TOO BIG, NOT TOO SMALL

You might call it the Goldilocks mission. Astronomers for years have been discovering planets orbiting other stars at a steady clip, but almost all of them are gaseous giants utterly inhospitable to life. Thus the rationale for the Kepler project. Like the fairy tale heroine, the space mission is seeking planets not too big, not too small — but just the right size and distance from their parent stars to possibly host life. The spaceborne telescope accomplishes this by watching for changes in the light from stars as planets pass in front of them. Following launch in March, Kepler took up its orbital station and promptly began sending home its first images from the star-rich portion of sky it will concentrate on in its quest for Earth-like worlds — the region of the constellations Cygnus the Swan and Lyra the Lyre. With the spacecraft deployed, JPL handed off science operations to NASA's Ames Research Center, home of the mission's principal investigator. By the end of the year, the science team was close to announcing its first crop of newly found worlds.

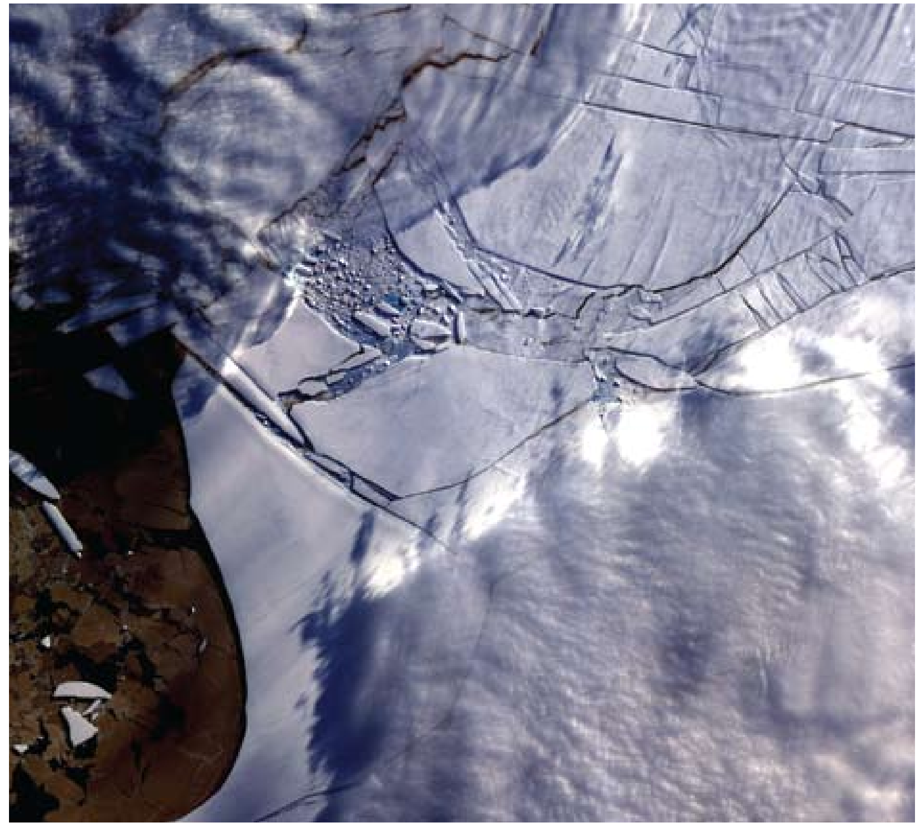
QUICK TAKES

Ladies and gentlemen, the robots are in the building. In fact, they were all over venues at JPL and in Los Angeles as the laboratory hosted robotics competitions for schools in the region. In one, a dozen elementary, middle and high school students came to JPL with tabletop-sized robots made from Lego bricks to face off against each other in contests to rescue pieces of space exploration gear. JPLers staffed and helped judge the Los Angeles region's First Robotics competition, which pitted larger robots against each other in tests of physical prowess. But educational efforts weren't all about fights between mechanical beings. In more of an academic realm, JPL also hosted the region's Science Bowl, a quiz show–like contest that sent winners to nationals sponsored by the U. S. Department of Energy.

APRIL

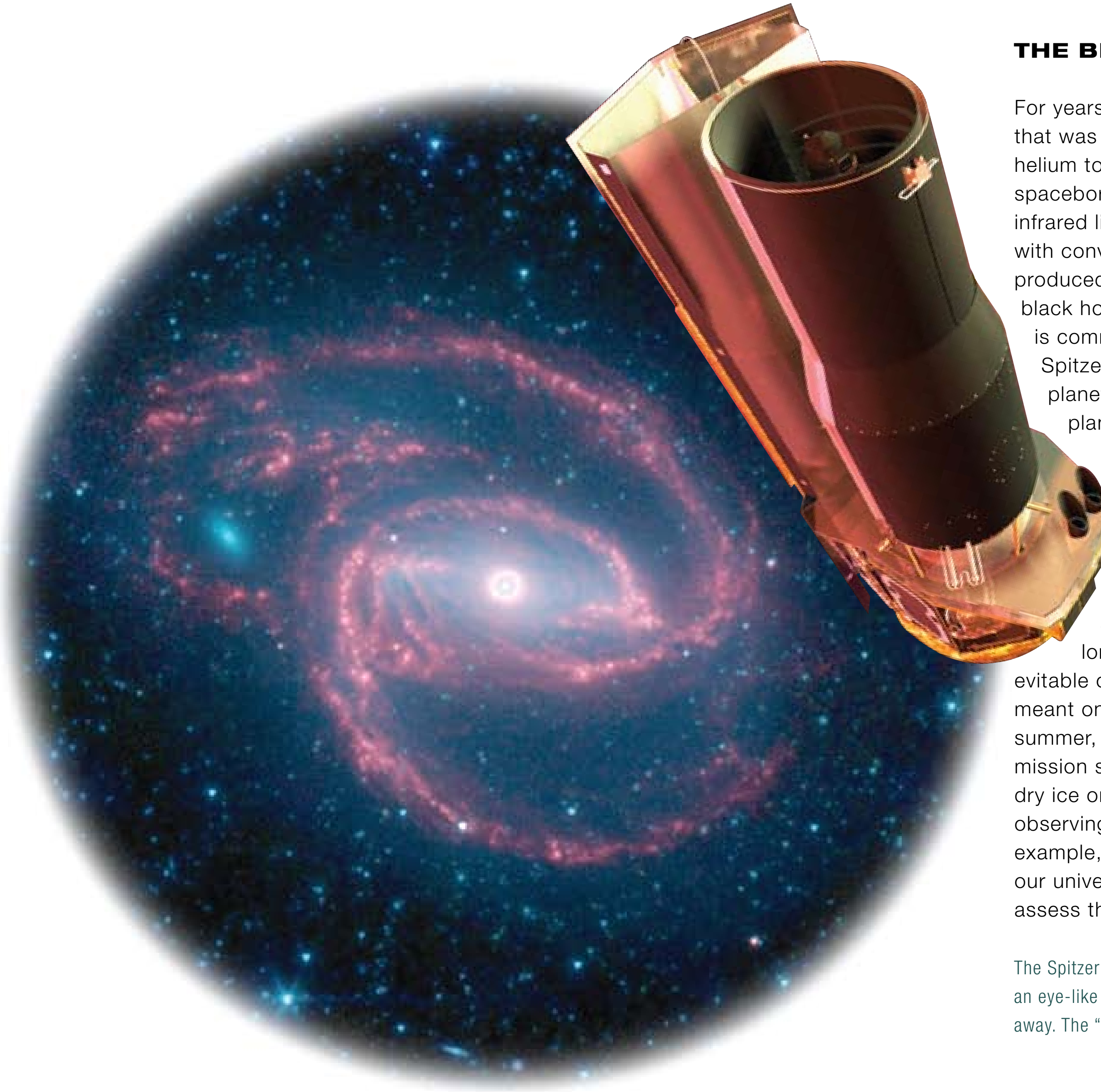
ON THIN ICE

As Earth Day was commemorated around the world, research by JPL scientists continued to demonstrate that the Arctic is on thin ice — literally. Combining readings from a NASA ice-monitoring satellite with historical ice records from U. S. Navy submarines of the Cold War era, researchers say that a decade-long trend of shrinking sea ice cover is continuing. Since 1980, sea ice thickness has declined by more than 50 percent. Between 2004 and 2008, the Arctic sea ice cover shrank by nearly the size of Alaska's land area. The trend is troubling because, as ice is lost, there is more open ocean to absorb heat, leading to still more ice being lost during summer. And it may lead to consequences that impact parts of Earth far beyond the Arctic north. The cooling influence of Arctic sea ice is an important part of long-term patterns of ocean and atmospheric circulation that drive global climates. The loss of sea ice could have the effect of throwing a major climate thermostat out of whack.



The disintegrating Wilkins Ice Shelf, on the western side of the Antarctic Peninsula, was imaged by the Advanced Spaceborne Thermal Emission and Reflection Radiometer on NASA's Terra satellite.

MAY



THE BIG THAW

For years the Spitzer Space Telescope toiled in a deep freeze — and that was just fine with everyone. Chilling its detectors with liquid helium to bring them within three degrees of absolute zero made the spaceborne telescope extraordinarily sensitive to the slight hint of infrared light from objects far, far away in deep space too dark to see with conventional instruments. Following its launch in 2003, Spitzer produced a long string of discoveries, ranging from hordes of missing black holes to the revelation that the stuff that comets are made of is common throughout our galaxy. Perhaps most unexpectedly, Spitzer was the first telescope ever to directly capture light from planets orbiting other stars; previously, astronomers could detect planets only by their effects on their parent stars. In 2009, the observatory continued to produce a steady stream of memorable images of otherworldly sights such as colliding galaxies; it also discovered a new, enormous — but faint — ring around Saturn, much larger than the planet's previously known rings. Thrifty management by Spitzer's human operators enabled them to stretch the telescope's supply of liquid helium, prolonging its mission nearly a year longer than its expected lifetime of five years. In May, the inevitable came when Spitzer's coolant was finally depleted. But that meant only a transition, not an end, for the storied observatory. By summer, Spitzer was busy making observations in its new, "warm" mission state. Even with no coolant, Spitzer remains far colder than dry ice or even liquid nitrogen. The warm Spitzer is continuing many observing programs and is embarking on new explorations — for example, refining estimates of Hubble's constant, or the rate at which our universe is stretching apart. Astronomers also plan to use it to assess the sizes of near-Earth asteroids.

The Spitzer Space Telescope imaged a wild creature of the dark — a coiled galaxy with an eye-like object at its center. The galaxy, NGC 1097, is located 50 million light-years away. The "eye" is actually a monstrous black hole surrounded by a ring of stars.

A VIEW LIKE NO OTHER

When future histories of the space age are written, no collection of photos from the cosmos may match the wondrous output of the Hubble Space Telescope in its early years. And all those amazing images — from a famed "Deep Field" picture revealing an amazing array of galaxies in seemingly blank space, to the iconic "Pillars of Creation" depicting gas columns in the Eagle Nebula — were captured by the telescope's primary instrument, JPL's Wide Field and Planetary Camera 2. Shaped like a baby grand piano installed in a telescope the size of a schoolbus, the camera first achieved fame when it saved Hubble's vision — compensating for a tiny but ruinous fault in the shape of the telescope's main mirror. But then the amazing stream of images began. A few years later, the camera was decommissioned when a replacement was installed on-orbit — but, later, was called back into action when an electronic fault rendered the replacement camera inoperable. Finally, in May 2009 — after collecting more than 135,000 pictures — the JPL camera was removed from Hubble by visiting astronauts, who returned it to Earth in space shuttle Discovery. Plans call for the camera to go on display at the National Air and Space Museum in Washington — but only after taking a victory lap tour around the country, including a stop in 2010 at its birthplace at JPL.

This image of the spiral galaxy Messier 101 is a composite of views in different wavelengths from the Spitzer Space Telescope, the Hubble Space Telescope, and the Chandra X-ray Observatory.

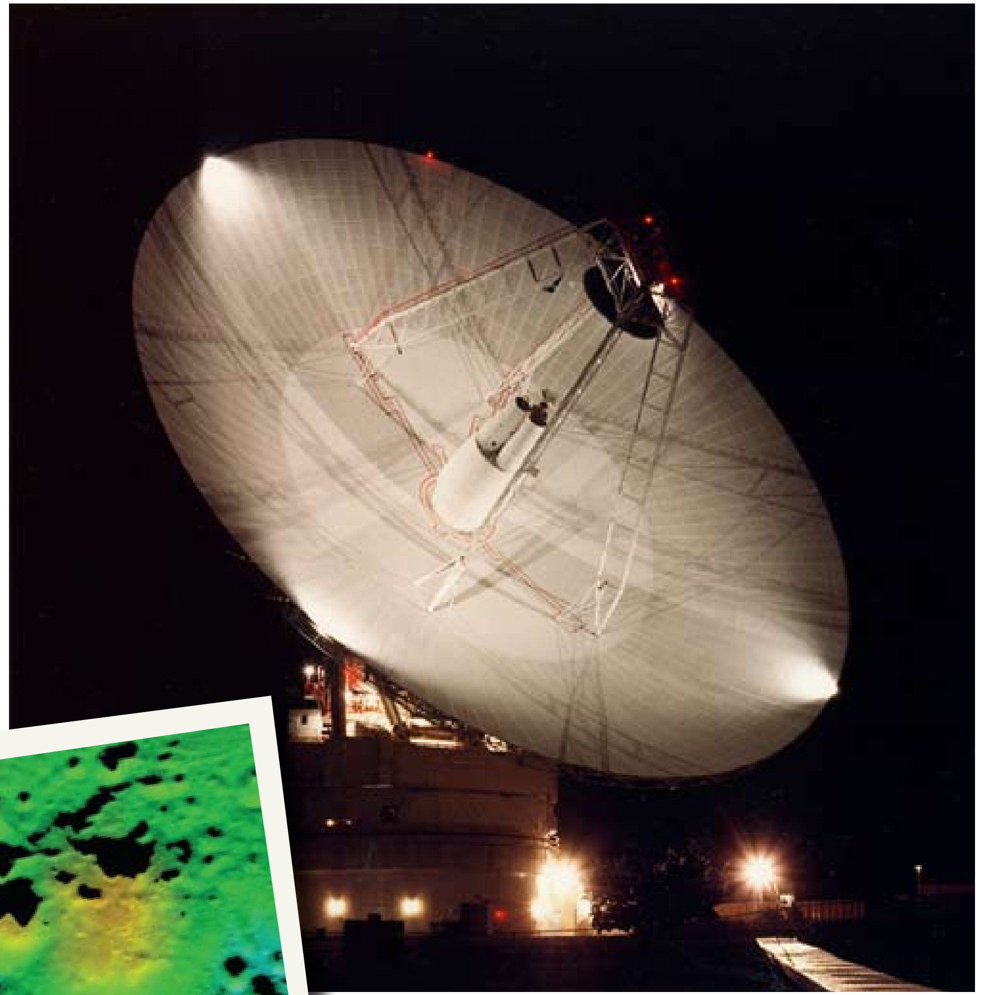
COSMIC TIME MACHINES

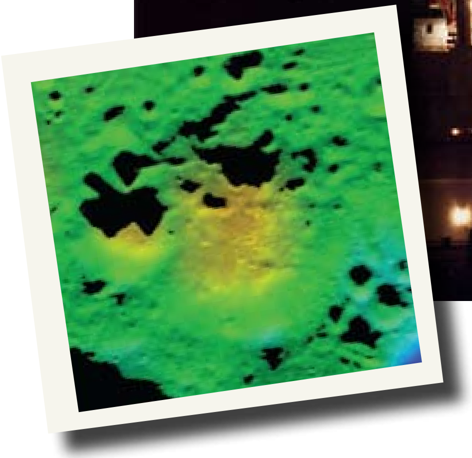
They might be carpool partners, but twins they are not. True, the European Space Agency's Herschel and Planck spacecraft rode together into space on a single rocket following their launch from a rain forest in South America. Both are infrared telescopes, destined to orbit an invisible spot in space called the Lagrange 2 point, four times farther from Earth than the moon. And both take advantage of significant technology contributions from JPL. Beyond that, the two spacecraft — one named for the astronomer who discovered Uranus, the other for the famed quantum physics theorist — were headed on distinctly different missions. Herschel is sifting through star-forming clouds — the "slow cookers" of star ingredients — to trace how life-forming molecules like water form. Planck's gaze is trained on traveling across impossibly long distances with a record of the earliest era of the universe; it is taking the sharpest portrait ever of the residue of the Big Bang, known as the cosmic microwave background. Herschel got down to business soon after launch, sending home cameos of galaxies and dust clouds in space. Scientists reported that the first results from Planck were excellent; by summer it was starting to collect light billions of years old. Its final tapestry of the infant universe will be released toward the end of 2012.

QUICK TAKES

Long-distance, the Bell System used to say in the early days of national phone service, is the next best thing to being there. These days it would be — Twitter and Ustream? That's what social media–savvy JPL staff were willing to bet when they set up Internet feeds from JPL's annual Open House — a two-day event where the public is invited to see the latest developments in space missions and technology. Those not able to join the 30,000 who came through the front gates in person could glean the highlights from the event via pithy dispatches on Twitter and video served on Ustream. Highlights included demos of the latest robots from JPL's workshops and glimpses of the next Mars rover being assembled in the laboratory's clean room.

Two months in the Arctic may not be everyone's idea of a dream getaway, but for engineers and scientists who create imaging radars they couldn't ask for anything better. In May and June, JPL researchers mounted their latest radar imagers in a NASA jet and set off for Greenland and Iceland. During the expedition, they captured extensive views of glaciers and ice steams — revealing how climate change is affecting the Arctic, while gathering experience for designing future radar satellites.



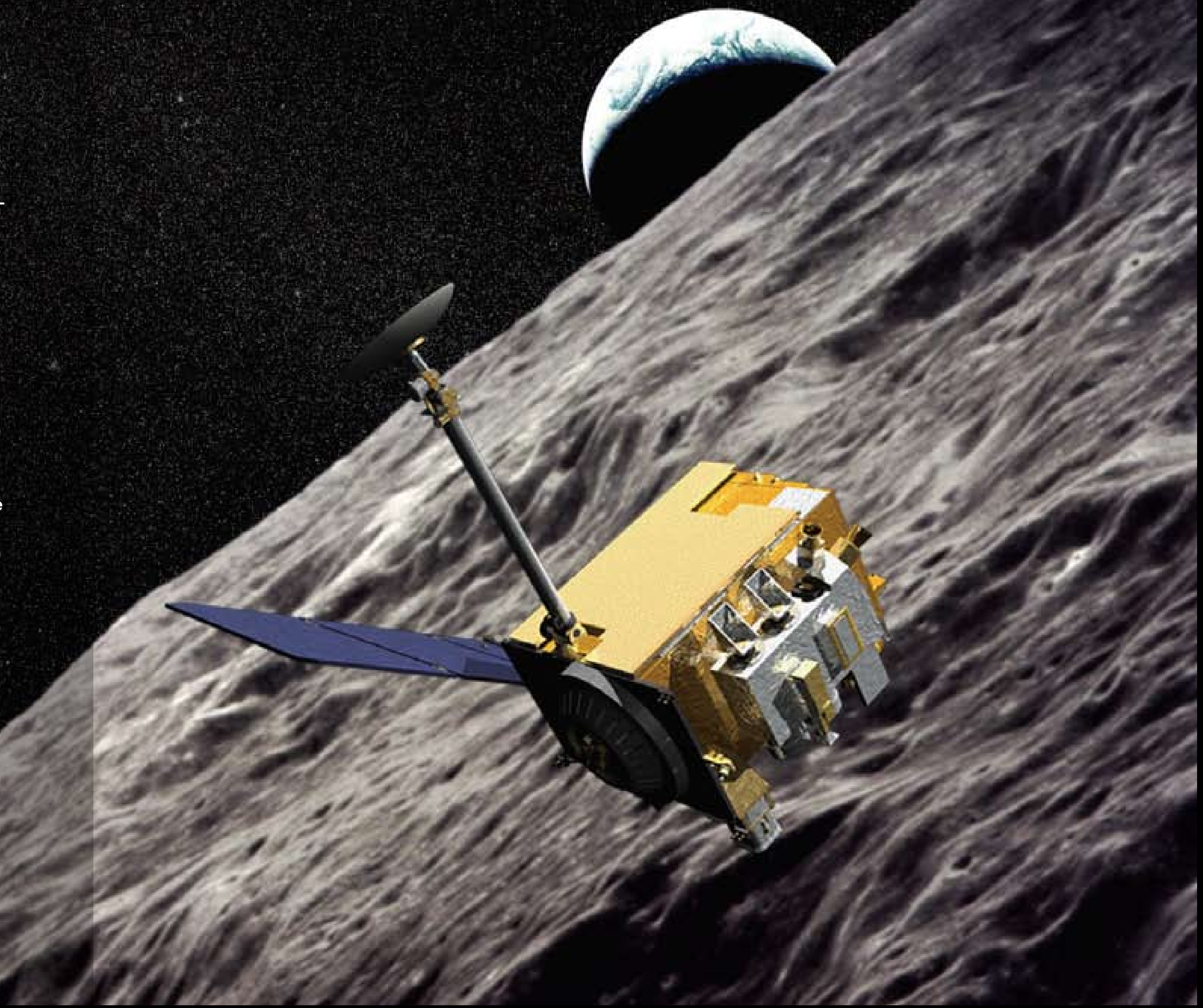


VIEW OF THE DARK SIDE

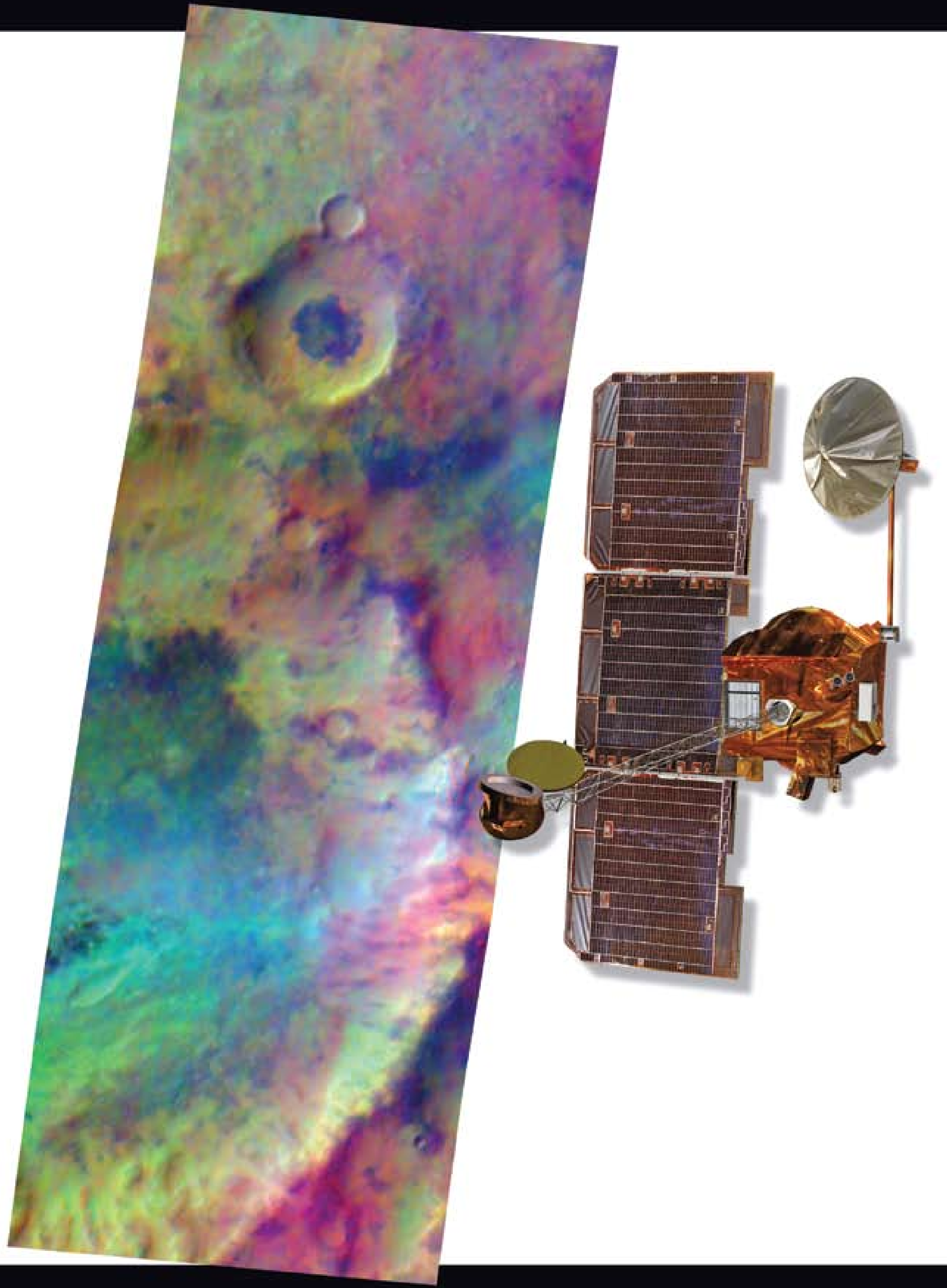
The far side of the moon may be invisible from Earth, but Pink Floyd albums aside, it's not truly the dark side of our natural satellite. The moon's hardest-to-see regions are the eternally shadowed craters near the north and south poles, which never see sunlight. They're of compelling interest to NASA, since the darkness means they could harbor water ice, but the lack of light makes them hard to explore. Enter JPL's Deep Space Network, which has developed a different way to image objects in space. Using the 70-meter (230-foot) dish antenna in California's Mojave Desert like a giant flash gun, researchers bounce radar pulses off the moon to create radar pictures similar to those collected by JPL imaging radar instruments at Venus, Saturn's moon Titan and the Earth itself. Over the summer, a team used an upgraded system to collect fresh, high-resolution radar images of a crater near the moon's south pole that enabled NASA to intentionally crash-land a spacecraft there in the fall. In other technology developments, the Deep Space Network used a higher-than-ever frequency, the Ka-band, for routine communications for the first time ever with the Kepler spaceborne telescope.

DEEP FREEZE

And what's dark, in most habitats around the solar system, is also cold. In June, JPL launched Diviner, an instrument on NASA's Lunar Reconnaissance Orbiter designed to make highly detailed temperature maps of the moon. Before long, Diviner had completed the first-ever global survey of temperatures across the lunar surface. It showed that, at minus 238 Celsius (minus 397 Fahrenheit), the dark craters at the moon's poles are the coldest places on the surface of any body in the solar system, including distant Pluto. Scientists viewed it as good news for the prospect of such craters harboring ancient stockholds of water ice of possible use to future human explorers. Later in the year, another JPL instrument — the Moon Mineralogy Mapper on India's Chandrayaan 1 spacecraft — confirmed the presence of water molecules near the moon's poles.



The Lunar Reconnaissance Orbiter, shown in this artist's rendering, will create a comprehensive, highly detailed map of the lunar surface.

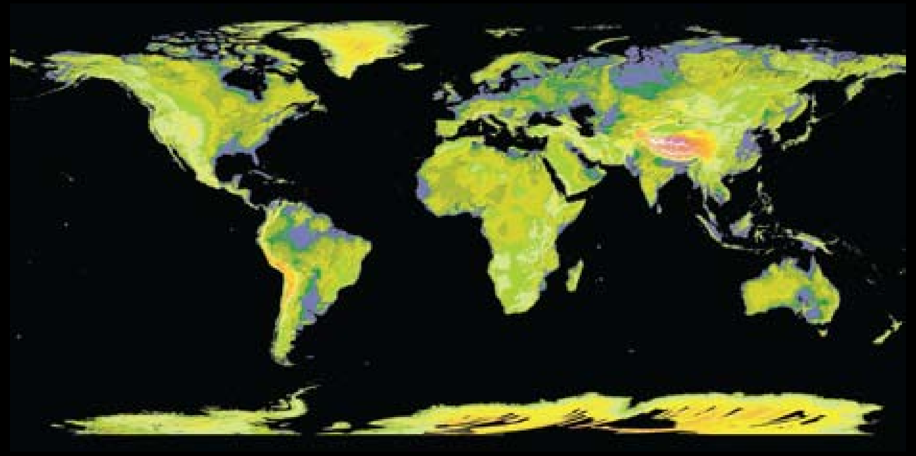


A PLACE IN THE SUN

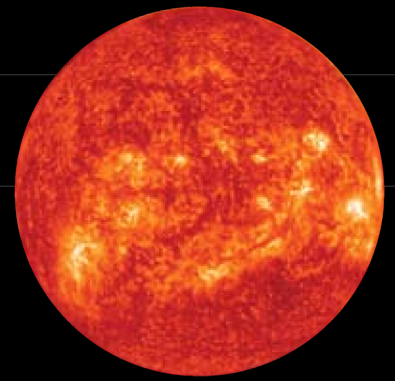
Anyone who has taken a family on vacation knows only too well that you can't please everyone. But you can try to split the difference. One of the major choices that the team controlling the Mars Odyssey mission has to make is just how to position the orbit — by tweaking the flight path one way or another, the orbiter passes over spots on the Red Planet at different times of day. For some science instruments a late-afternoon orbit is better, while for others an overhead passage earlier in the day gives them more to work with. For five years Odyssey plied a later-afternoon route, but in July moved to a mid-afternoon orbit. That will help efforts such as completing a high-resolution temperature map of the entire planet. And after seven years of collecting data with Odyssey's gamma ray spectrometer, scientists released a global map showing the distribution of sulfur across the planet. Sulfur is important, they said, because it is a marker for water cycles on Mars.

Pastel colors swirl across Mars, revealing differences in the composition and nature of the surface in this false-color infrared image taken on May 22, 2009, by the Thermal Emission Imaging System camera on NASA's Mars Odyssey orbiter.

QUICK TAKES



It may be too big to load into your handheld GPS, but there will surely be a lot of uses for the most extensive digital topographic map ever produced of Earth, released by NASA and Japan's government in June. Created from nearly 1.3 million images, the map uses data collected by the JPL-teamed Advanced Spaceborne Thermal Emission and Reflection Radiometer, or Aster, instrument on NASA's Terra satellite. It matches up with and extends the previously most complete topographic map of Earth, which was produced by JPL's Shuttle Radar Topography Mission. Scientists expect it will find a wide range of uses in areas such as energy conservation, firefighting and city planning.



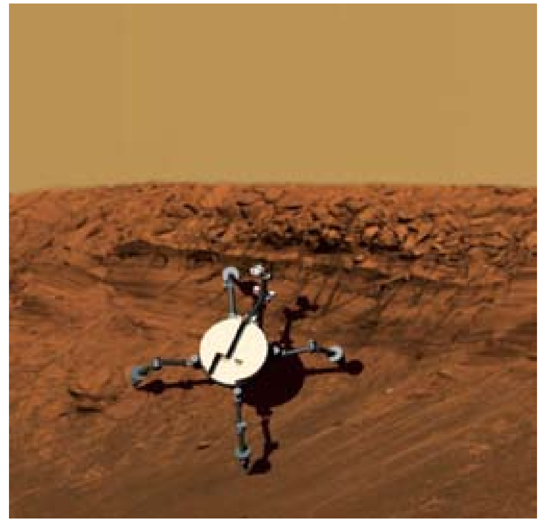
Sometimes it ain't over until it's over. The U. S./European team controlling the Ulysses solar-polar probe were thrilled when the spacecraft kept operating nicely beyond the mid-2008 ending date announced for the mission. Engineers had expected the spacecraft to give up the ghost around then as it ran out of power to keep its onboard propellant from freezing. But they came up with a novel plan to fire Ulysses' thrusters every two hours, allowing the spacecraft to stay alive a full year beyond that date. By the end of June 2009, space agencies declared the mission was finally over. Over the years since its 1990 launch, Ulysses made three orbits of the sun's poles, and serendipitously flew through the tails of three comets.

The original Broadway show came and went eons ago, but the age of Aquarius is still just around the corner. At least that's when a JPL ocean-viewing instrument called Aquarius will be carried into orbit, given a ride on a satellite built and launched by a new international partner, the space agency of Argentina. Once on station above Earth, Aquarius will specialize in measuring how much salt is in the ocean from one region to another. That's important to know, scientists say, because it tells them about how heat is transported and stored in the sea — a crucial part of how global climates work and are changing. In June, JPL shipped the instrument to Argentina in preparation for launch.

ONWARD TO MARS

For JPL's next rover mission, the Mars Science Laboratory, there were two big jobs to accomplish in 2009. First, the team had to resolve issues with the vehicle's many motors, or "actuators," and some of the spacecraft's electronic chips — two vexing problems that contributed to the reset of the mission's launch from 2009 to 2011. Second, to stay apace of the launch schedule it was important to keep up the drumbeat of assembling and testing the many systems and components that make the mission work. Highlights from the year included testing of the entire flight system in JPL's space simulator, as well as wind-tunnel testing of the lander's parachute (the largest ever for use beyond Earth) and completion of its heat shield in July. By year's end, mission managers were confident they had a handle on the actuator and chip issues. And the rover had gained a name. Twelve-year-old Clara Ma of Kansas won a nationwide contest with her proposal to call the robotic emissary "Curiosity." "Curiosity is an everlasting flame that burns in everyone's mind," Clara wrote. "Without it, we wouldn't be who we are today."

JULY

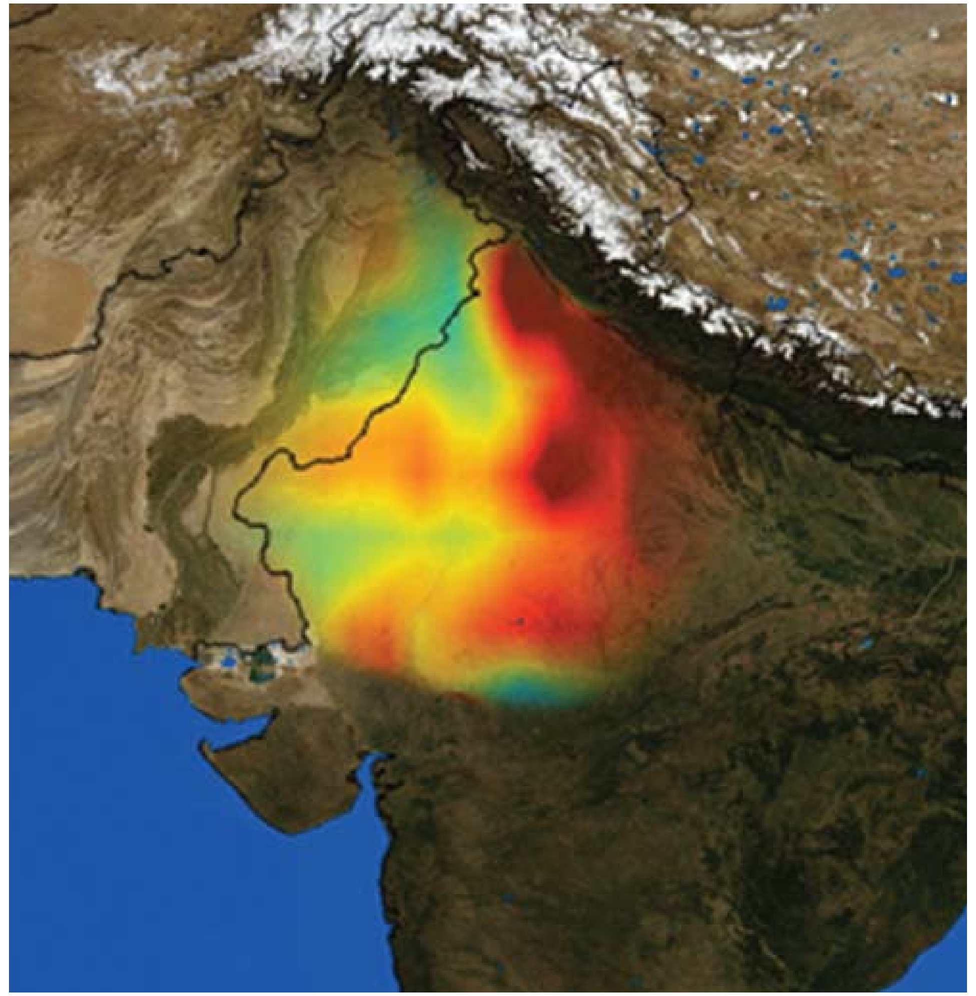


NEXT ON DECK

What's on the drawing board for missions to the Red Planet after Mars Science Laboratory launches in 2011? More missions with an international flavor, according to an announcement in July by NASA and the European Space Agency. The two agencies said they agreed to work together on joint missions in 2016, 2018 and 2020, leading up to sample return in the 2020s. With Mars launch opportunities occurring every 26 months, the 2013 window will be devoted to an orbiter managed by NASA's Goddard Space Flight Center that will focus on the Red Planet's atmosphere. For 2016 and 2018, plans call for NASA/ESA joint efforts that will include an orbiter and new rovers, with NASA's involvement managed by JPL.

QUICK TAKES

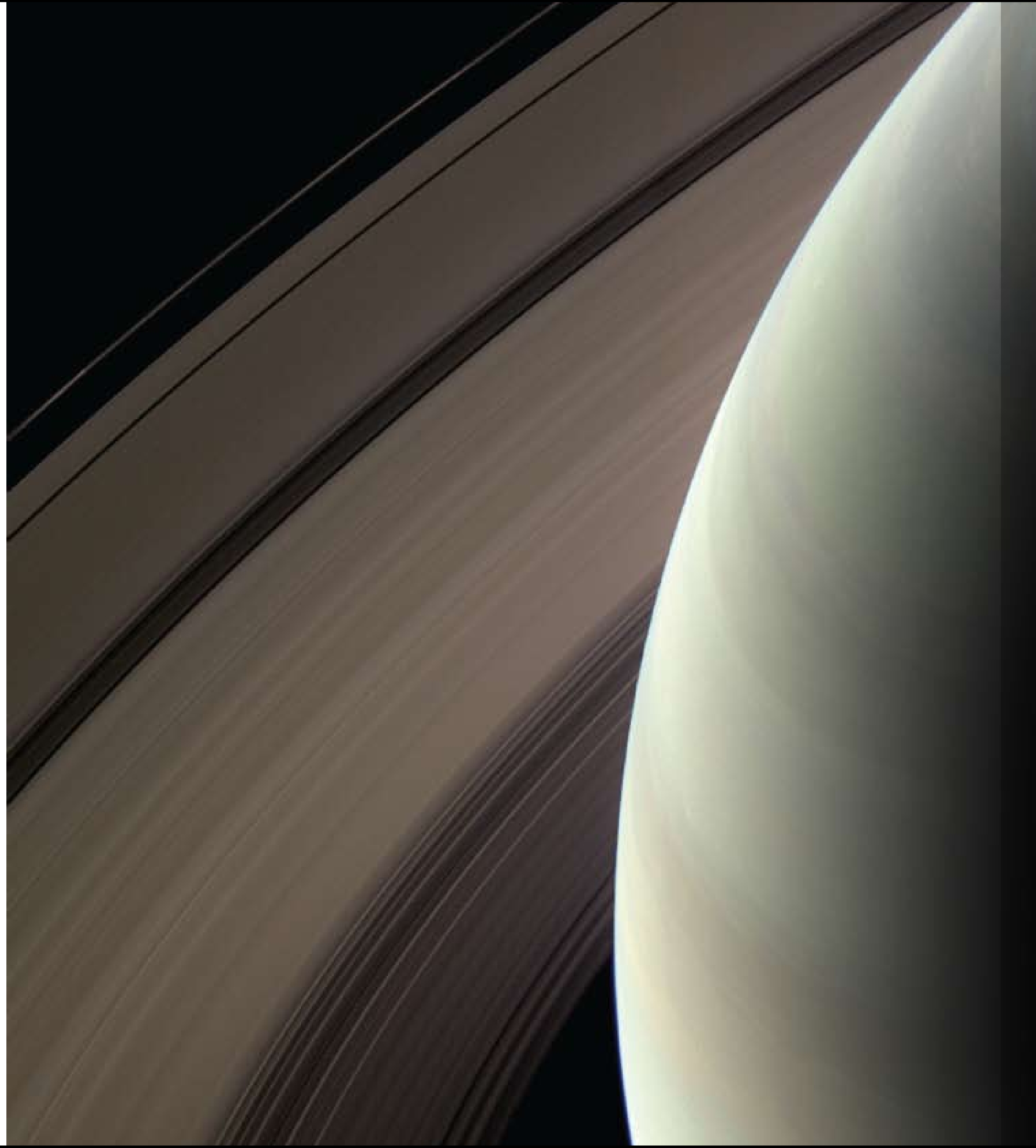
Is serving up clean electricity and water rocket science? The City of Los Angeles is betting that it could be — or at least it wouldn't hurt to have a few rocket scientists in the room. The city's Department of Water and Power — with more than 3.8 million residential and business customers, it's the largest municipal utility in the world — signed an agreement with JPL and Caltech to work on developing green technologies. As one of the first projects off the drawing boards, the U. S. Department of Energy agreed to fund an effort to make Los Angeles' energy grid smarter and more efficient.



WHAT LIES BENEATH

JPL missions have a reputation for revealing the unseen, using sophisticated technologies like imaging radar and infrared sensors. One mission takes it to another level. Based on extremely sensitive measurements of how Earth's gravity affects their orbits, the twin Gravity Recovery and Climate Experiment, or Grace, satellites can detect things on and within Earth that no imaging system can perceive. In August, for example, scientists announced the satellites had found that groundwater under the soil of northern India had dropped by as much as 33 centimeters (one foot) a year over the past decade — signaled only by how the vanishing water had subtly affected the intensity of gravity in that region. Later in the year, scientists announced Grace had found a similar groundwater loss under California's Central Valley, the state's primary agricultural region.

AUGUST



THE RAZOR'S EDGE

Even after years of study by the Cassini spacecraft, Saturn and its moons continue to surprise. Scientists on the mission were looking forward to 2009 because it would offer a unique view of the stately planet that comes only once every 15 years — Saturn's equinox, when sunlight hits its rings edge-on and they nearly disappear. Just as shadows elongate near sunset on Earth, this would allow Cassini's cameras to detect subtle features that normally are washed-out by the rings' brightness. And detect they did. Perhaps most surprisingly, scientists found that the rings — long thought to be about 10 meters (about 30 feet) thick — have previously unknown mountain-like zones of icy particles that are up to three kilometers (about two miles) thick. Other parts of the rings, long thought to be flat, are actually corrugated, like the roof of a Quonset hut. Another surprise was in store on Titan, Saturn's largest moon. As Cassini flew by the haze-shrouded moon, it caught a glint of light reflected off the largest of what are believed to be many lakes in Titan's north — proving that they in fact are filled with liquid. It is far too cold for a swim, though, as that would not be water but rather liquid methane. Yet another key find came on Saturn's moon Enceladus, home of geysers spewing icy water particles into space. Flying through the plumes, Cassini detected ammonia — a substance that can act as an antifreeze, keeping water liquid at low temperatures. That could lend credence to the theory that the geysers are powered by subsurface reservoirs of water. Other memorable findings by Cassini included the first-ever video of ghostly "northern lights" — the tallest ever seen in the solar system — dancing far above the planet. The spacecraft also caught a fresh look at Saturn's "Hexagon," an odd six-sided pattern in the planet's northern hemisphere that was first detected by the Voyagers in the 1980s. The new views capture the most detailed images yet of the intriguing shape crowning the planet, revealing concentric circles, curlicues, walls and streamers not seen in previous images.

THE MOUNTAINS ABLAZE

As the summer of 2009 wound to a close in California, many were apprehensive about the prospect for major fires, as dozens had already burned tens of thousands of acres across the state. For the region surrounding JPL, the worst was yet to come. In the last few days of August, a blaze started in the San Gabriel Mountains that would soon grow into the largest and deadliest of the summer fires – not to mention the largest wildfire in modern history in Los Angeles County. Named the Station Fire — for its point of origin near a ranger station — the blaze burned 64,983 hectares (160,577 acres), killed two firefighters and threatened 12,000 structures in foothill communities including La Cañada Flintridge and Altadena adjacent to JPL. The laboratory closed for four days as the fire approached within about 200 meters (one-eighth of a mile); flames also climbed the slopes of Mount Wilson, threatening the century-old observatory where Edwin Hubble had discovered that the universe was expanding. JPL satellite instruments that documented the fire included the Multi-angle Imaging SpectroRadiometer and the Advanced Spaceborne Thermal Emission and Reflection Radiometer on NASA's Terra satellite. JPL staff returned to work September 1, while the fire lingered on in pockets; it was not 100-percent contained until rain fell in mid-October.

SEPTEMBER

You might think of it as a smoke detector on steroids. For six months in 2009, JPL's shoebox-sized Electronic Nose was deployed on the International Space Station, working around the clock to sniff out 10 contaminants in the air breathed by astronauts. The device identified formaldehyde, Freon, methanol and ethanol, but all were at harmless levels, researchers reported. In September, the instrument was brought back to Earth along with other gear transported by the space shuttle. In the future, the device could be used in other astronaut missions, as well as on Earth to sniff for unexploded land mines or monitor work areas for chemical spills.

QUICK TAKES

X-ray vision may be the stuff of 1950s pulp science fiction, but to current-day astronomers, it's a valuable way of seeing the universe. Many objects such as black holes and supernovas throw terrific amounts of high-energy X-ray radiation into space, and will be the quarry for a mission approved by NASA in September. Led by a Caltech professor, the Nuclear Spectroscopic Telescope Array, or NuStar, will launch in 2011 on a quest to survey the universe in a part of the energy spectrum little studied until now.

GOING GREEN, IN STYLE

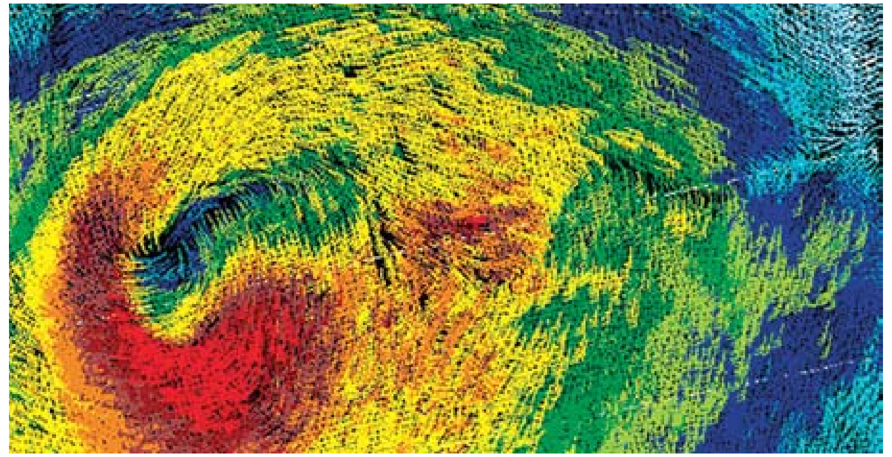
Designers of spacecraft that venture across space for years are used to making resources stretch a long way. In October, that philosophy came home to the laboratory itself when JPL dedicated its newest building, the Flight Projects Center. From a garden of drought-resistant plants on the roof (it cools the building in summer, warms it in winter) to the use of woods from sustainable forests, the structure is designed to be as green as possible. So much, in fact, that it won Gold Leadership in Energy and Environmental Design certification from the U. S. Green Building Council — the first building anywhere in NASA to achieve that distinction. Besides its environmental features, the center fulfills a very pressing need, providing about 17,930 square meters (193,000 square feet) that will house one-eighth of JPL's workforce at a time when space at the laboratory is at a premium.

OCTOBER

QUICK TAKES

Mr. Clean doesn't cut it. When missions are being dispatched to any planet where life could potentially take hold, engineers go through many steps to clean all the parts of the spacecraft to minimize any microbes that could hitch an interplanetary ride. To help keep spacecraft gear pristine, JPL researchers developed a new microscope-based technology to rapidly scan for any sign of microbial life. The new method may help the military test for disease-causing bacteria such as anthrax, and might also be useful in medical, pharmaceutical and other fields.

NOVEMBER



CHASING HURRICANES

For an understudy called to take on a starring role in record-breaking time, it was a remarkable run in the limelight. In 1997, NASA lost a radar instrument designed to monitor winds across the world's seas when the Japanese satellite it rode on failed. Thus was a new star born — the Quick Scatterometer, or QuikScat, a replacement satellite designed, built and launched in a remarkably short year and a half. Sent into orbit in 1999, QuikScat used two radar beams and a spinning antenna to capture winds over 90 percent of the ocean every day. Hurricane forecasters hailed it as a major advancement, allowing them to detect the formation of tropical cyclones faster than previously possible. QuikScat completed its original mission — plans called for it to operate for two years — and just kept on going. But after a decade in orbit, time eventually began to take its toll; as is often the case on spacecraft, the issue was a moving part. Over the 10 years of the mission the antenna had rotated nearly 100 million times, and eventually the bearings gave out. How to replace the satellite originally planned as a quick-fix replacement itself? NASA was studying options, which could include building a freeflying satellite or putting an instrument on an international partner's satellite, sometime around the middle of the next decade.

QUICK TAKES

For Europe's comet-bound Rosetta spacecraft, 2009 marked a final goodbye to Earth. The mission actually launched in 2004, but it has taken several loops around the sun — along with three Earth flybys — to build up the energy to fling the spacecraft out into the environs of comet 67P/Churyumov–Gerasimenko, its ultimate destination. Following a final Earth flyby in November, Rosetta will visit Earth no more. After an asteroid flyby in 2010, the spacecraft will go on to its comet rendezvous in 2014. JPL contributed a microwave instrument, called Miro, that will look for substances important to life such as water, ammonia and carbon dioxide.

Mars may be millions of miles away, but new partnerships are helping JPL make it real for members of the public around the world. In November, JPL and Microsoft unveiled Be A Martian, a website where users can participate as citizen scientists to improve Martian maps, take part in research tasks, and assist Mars science teams studying data about the Red Planet. JPL also collaborated with Google to announce an update to Mars in Google Earth, a three-dimensional mapping tool for the Red Planet. The new features allow users to travel back in time to see Mars through the eyes of science pioneers by exploring antique maps by astronomers Giovanni Schiaparelli, Percival Lowell and others.

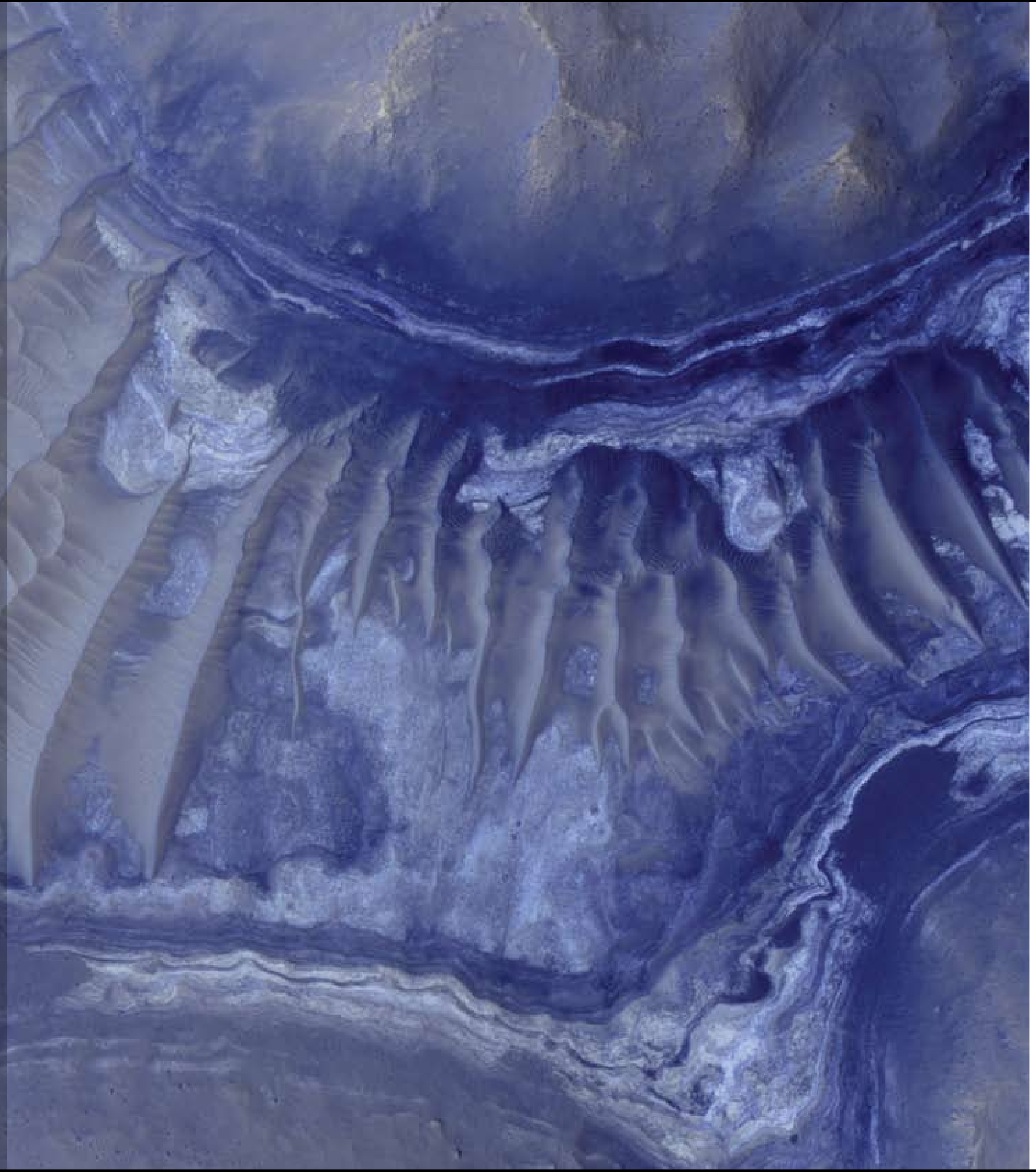
DECEMBER

PLUMBING THE UNSEEN

The vastness of space may not be as empty as you think. Between and beyond all the stars we can see, there are countless more — not to mention asteroids and nebula and other manner of space objects — that don't give off enough visible light for our eyes or normal telescopes to see them. Many glow brightly, though, in the infrared spectrum, and that is just the niche that JPL's new spaceborne telescope is designed to mine. A Swiss Army knife for infrared astronomers, the Wide-field Infrared Survey Explorer, or WISE, will detect hundreds of millions of objects from asteroids to distant galaxies as it maps the entire sky following its December launch. Hundreds of times more sensitive than JPL's celebrated Infrared Astronomical Satellite of the 1980s, WISE will snap millions of images — one every 11 seconds — and map the sky one and a half times during its 10-month mission. Among the tens of thousands of new asteroids that WISE is expected to discover, up to 200 are expected to fall in the category of rocks that pass relatively close to Earth. So, in addition to turning up exotic new objects such as brown dwarfs and infrared galaxies, WISE quite possibly could help save the home planet.

RETURN OF THE GREAT GALACTIC GHOUL

It may be no more real than Bigfoot, but in the mythology of space exploration, the Great Galactic Ghoul holds a place of distinction. That's the name that mission managers of yesteryear gave to the elusive gremlin assumed to be responsible whenever a spacecraft would misbehave for no apparent reason. And while the flight controllers of today may have better tricks to minimize his influence, the Ghoul has never completely exited the stage. In the first few months of 2009, Mars Reconnaissance Orbiter's highly successful mission was interrupted several times when the spacecraft's computer inexplicably reset itself. After the fourth event in August, the flight team left the spacecraft in a protective mode for several months while they worked on diagnosing the problem. Though they didn't find what caused the resets, they did send up a software patch to prevent a possibly fatal scenario if two resets happened in rapid succession. In December, the orbiter was brought back into normal operation and finished off the year with yet more stunning observations of the Red Planet. Were the resets caused by cosmic particles hitting the spacecraft's computers? Or the handiwork of a cosmic wraith? No one can say for sure, but the team was glad to have the orbiter back in top form. The resets aside, science results from the orbiter included a fresh look at Deimos, the smaller of Mars' two moons, as well as a shot of the Phoenix lander covered with frost in the Martian arctic. Scientists were also excited when the orbiter showed the existence of a new kind of clay in the vicinity of Endeavour Crater — the destination for the rover Opportunity. The clay, which must have formed in very wet conditions, has never yet been encountered on the ground on Mars.

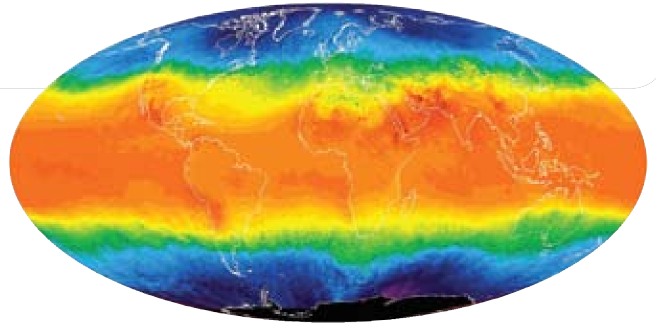


Exposed layers and sand dunes converge in the Noctis Labyrinthus formation on Mars. The image was taken by the High Resolution Imaging Science Experiment camera aboard NASA's Mars Reconnaissance Orbiter.

QUICK TAKES

Astronomers would love to be able to see the inner regions of young solar systems to find how worlds like Earth form, but not a single telescope in the world is up to the task. Yet in December, astronomers using the W. M. Keck Observatory in Hawaii announced they were able to measure the properties of a young solar system at distances closer to the star than Venus is to our sun. To achieve the feat, the team used the JPL-built Keck Interferometer to combine infrared light gathered by both of the observatory's twin 10-meter (33-foot) telescopes. The double-barreled approach gives astronomers the effective resolution of a single 85-meter (280-foot) telescope — several times larger than any now planned.

One place that climatologists look for evidence of climate change is in the temperature of large lakes, but traditionally they have been hampered by the lack of long-term records. Using instruments on NASA and European satellites, JPL scientists announced they were able to quantify changes in the temperature of six large lakes in California and Nevada between 1992 and 2008. Water temperature at the surface of the lakes — which included Lake Tahoe and Mono Lake — rose twice as fast as air temperature. Such rapid warming is expected to have a significant impact on the lakes' ecosystems.



For years carbon dioxide has been fingered as a chemical culprit of global climate change. But how does it move around in the atmosphere? One JPL instrument, the Atmospheric Infrared Sounder on NASA's Aqua satellite, is able to help answer that. In December, the science team unveiled an extensive, seven-year data set revealing how the elusive, long-lived greenhouse gas moves around in parts of the atmosphere. One surprise: pockets of carbon dioxide are unexpectedly "lumpy," not as evenly dispersed as scientists had predicted.

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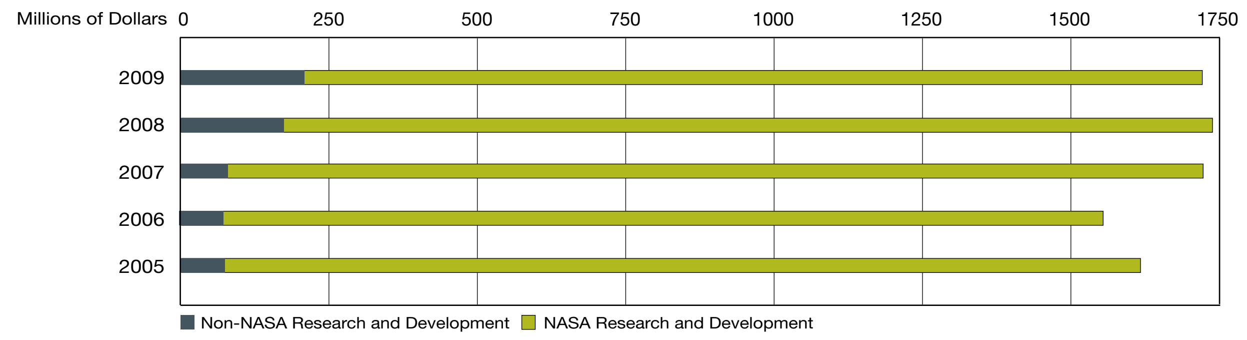
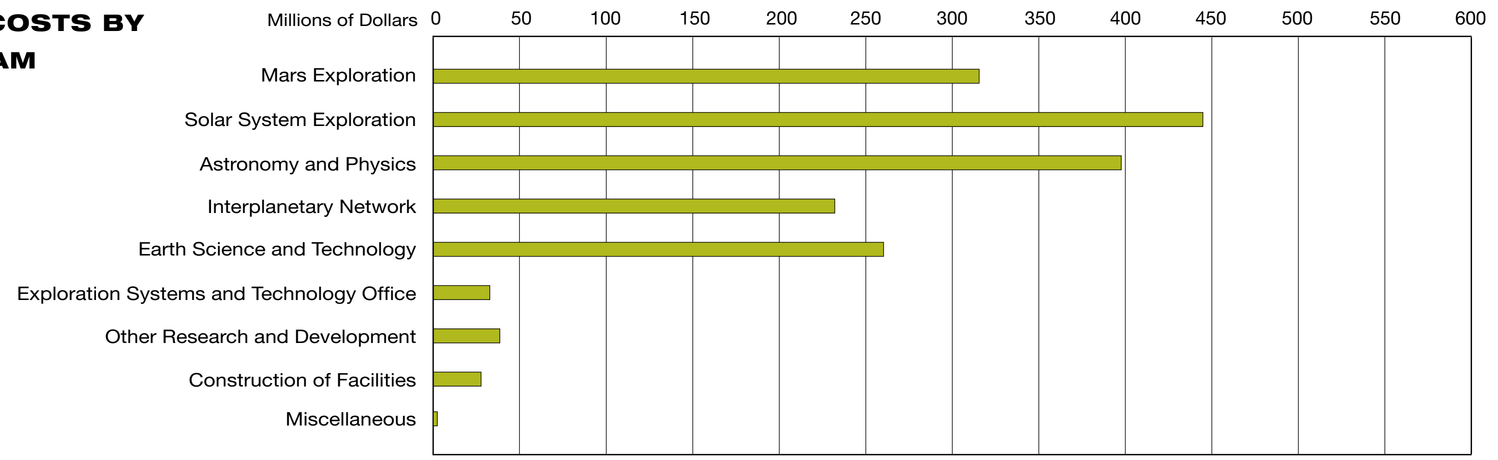
Right, this simulated natural color image of the Station Fire burning in the San Gabriel Mountains was captured by the Advanced Spaceborne Thermal Emission and Reflection Radiometer on NASA's Terra satellite. The large dark gray area is evidence of forest and chaparral destruction. Left, JPL ocean scientist Josh Willis.

BUDGET AND WORKFORCE

TOTAL COSTS



TOTAL COSTS BY PROGRAM



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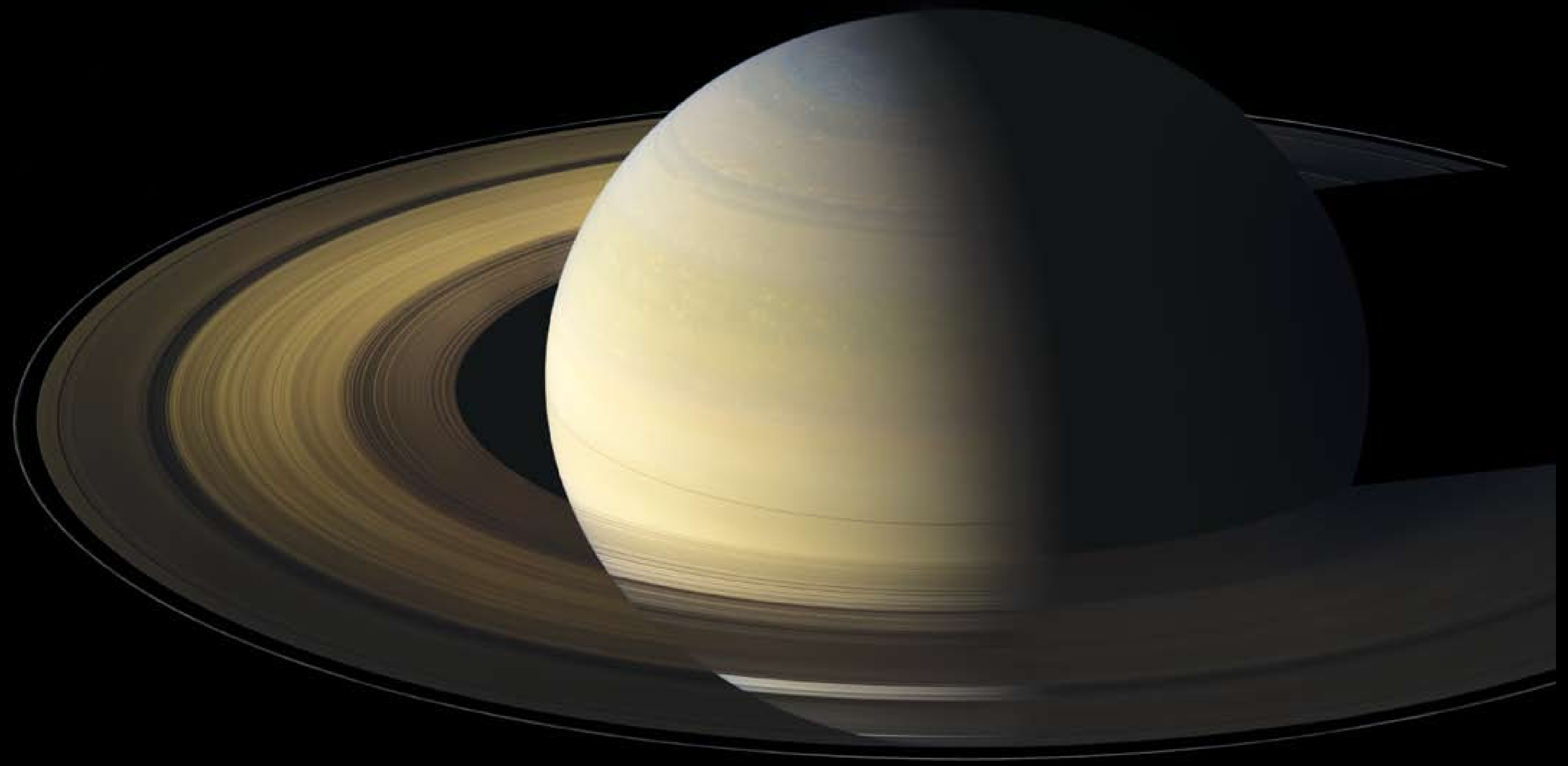
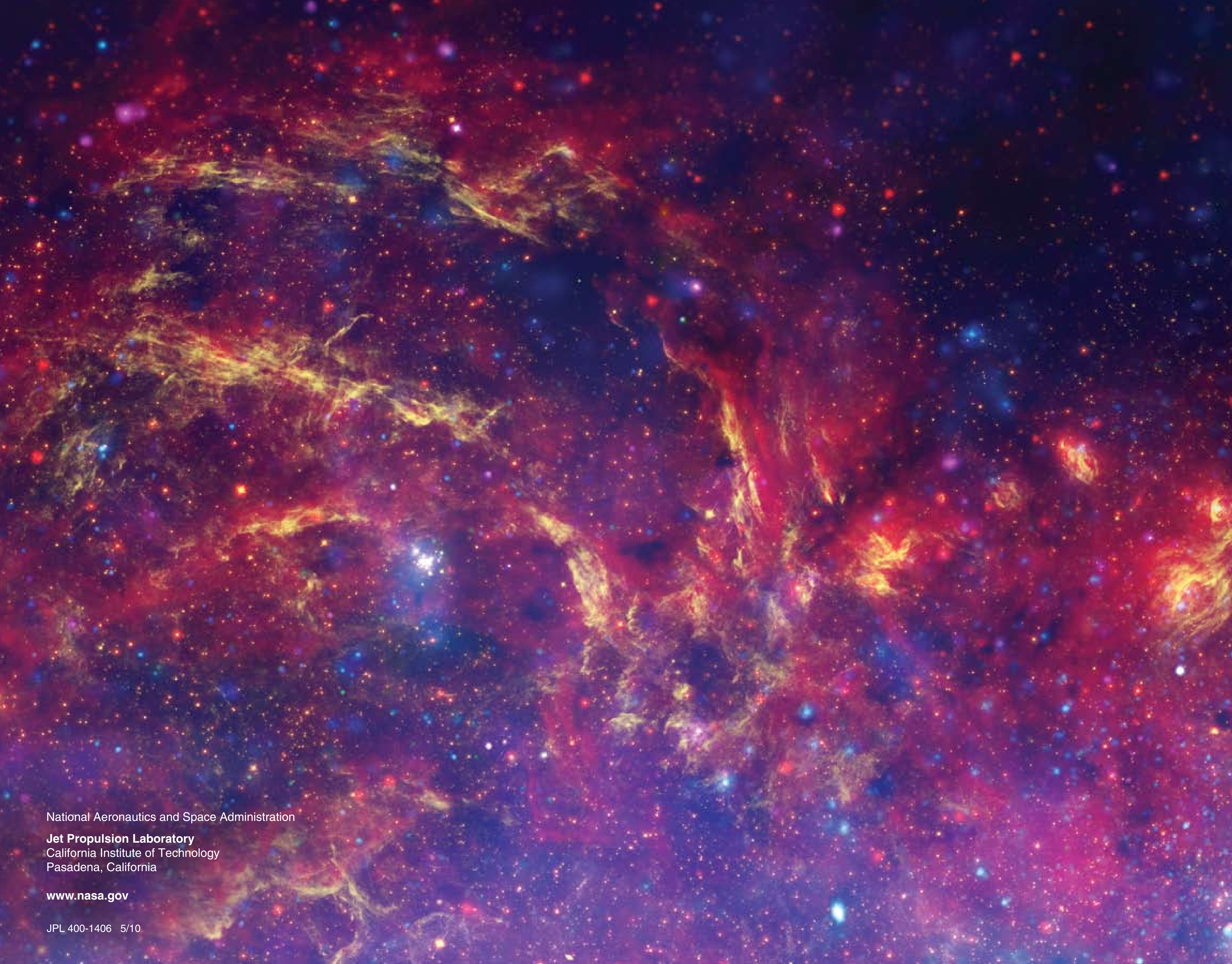


This composite image of 75 successive exposures taken from above the ring plane shows Saturn just a day and a half after equinox, when the sun was exactly overhead at the equator.



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