

National Aeronautics and Space Administration

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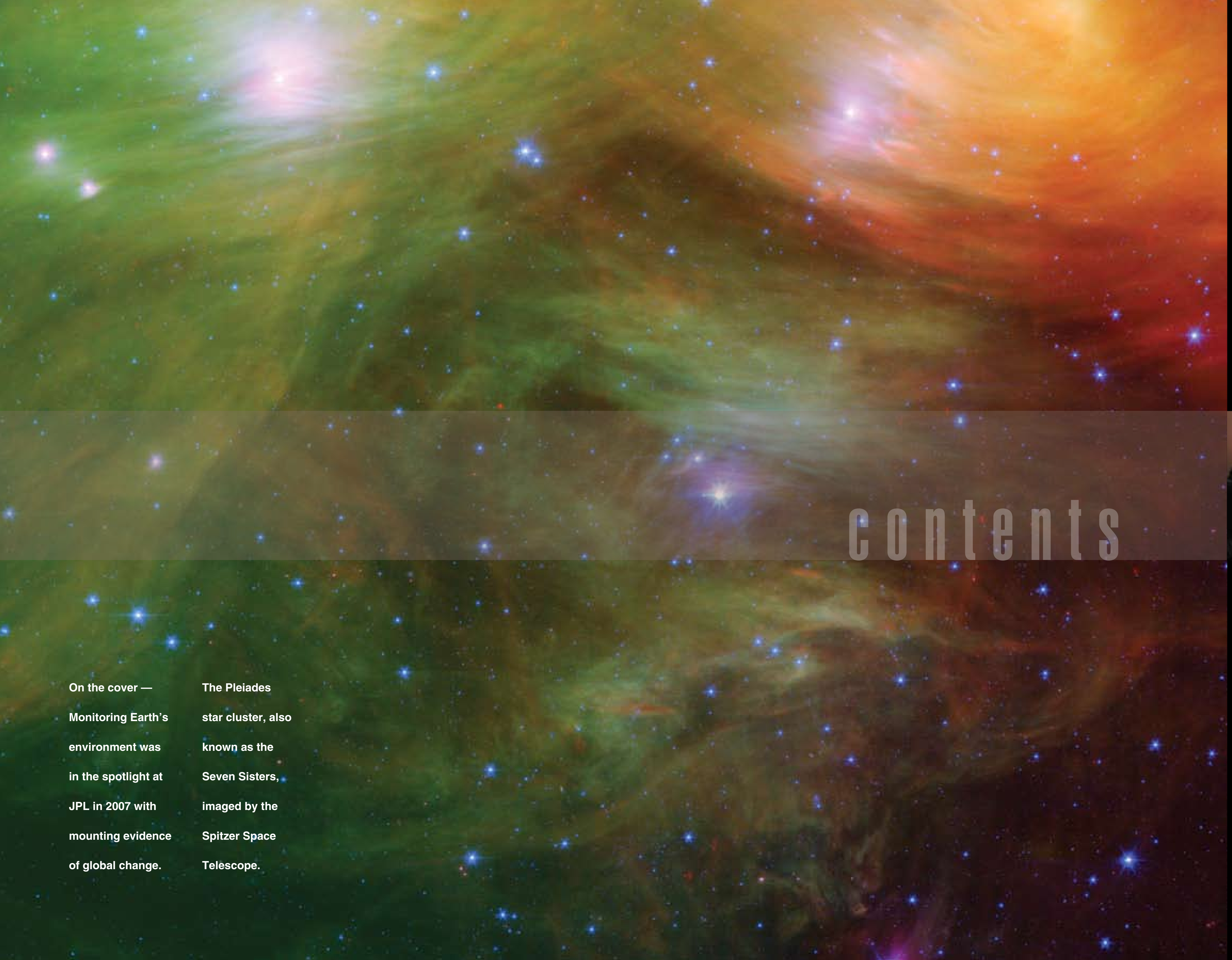
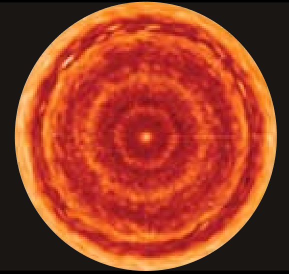
2007 Jet Propulsion Laboratory Annual Report

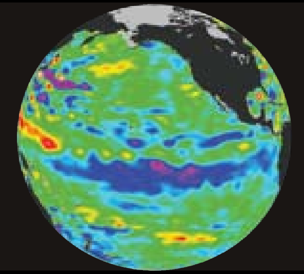


contents

On the cover — Monitoring Earth's environment was in the spotlight at JPL in 2007 with mounting evidence of global change.

The Pleiades star cluster, also known as the Seven Sisters, imaged by the Spitzer Space Telescope.



Many milestones are celebrated in the business of space exploration, but one of them that arrived this year has particular meaning for us. Half a century ago — on January 31, 1958 — the Jet Propulsion Laboratory was responsible for creating America's first satellite, Explorer 1, and joined with the Army to launch it into orbit. That makes 2007 the 50th year we have been sending robotic craft from Earth to explore space. No other event before or since has had such a profound effect on JPL's basic identity — setting it on the path to become the world's leader in robotic solar system exploration.

It isn't lost on historians that Explorer 1, besides being America's first satellite, was also the first spacecraft from any country to deliver scientific results — in its case, the discovery of the Van Allen Radiation Belts that surround Earth. Science, of course, has been the prime motivator for all the dozens of missions that we have lofted into space in the half-century since then. JPL has sent spacecraft to every planet in the solar system from Mercury to Neptune — some of them very sophisticated machines. But in one way or another, they all owe their heritage to the 31-pound bullet-shaped probe JPL shot into space in 1958.

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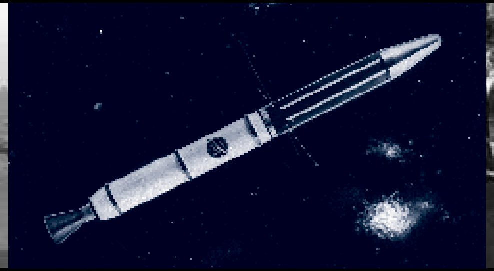
I'm also very pleased that, although we have ranged far and wide across the solar system, we have a very strong contingent of satellites and instruments dedicated, like Explorer, to the environment of our home planet. As you will read

Director's Message

As rich and varied as our programs are now — and our plans are for the near future — it's amazing to consider for a moment that it all began with a simple machine, rustic by today's technology, thrown into orbit on an Army missile.

Key engineers regard JPL's Explorer 1 satellite in 1958 (left). Explorer 1 (center) opened the American space age. A modern-day reunion brought together Explorer alumni (above).

in this report, JPL missions have been providing much of the data to establish the facts of global warming — most especially, the melting of ice sheets in Greenland and Antarctica. During the past year, JPL and our parent organization, the California Institute of Technology, have created a task force to focus the special capabilities of the Laboratory and campus on ways to better understand the physics of global change. While Earth is a chaotic and dynamic system capable of large natural variations, evidence is mounting that human activities are playing an increasingly important role. A central piece of this effort is a search for novel energy sources to replace fossil fuels, the combustion of which adds carbon dioxide to our atmosphere.

All the while, of course, we remain very busy with the other core elements of our exploration activities. We have a very robust Mars program, with two aging but persistent rovers ranging across the surface, a pair of orbiters surveying the planet from overhead and a new lander en route to arrival in May 2008. In our solar system program, we have a newly launched spacecraft that will use inventive ion propulsion to orbit two asteroids in succession, as well as a flagship craft delivering an unflagging series of discoveries at Saturn. Two space telescopes, one observing in the infrared and the other in the ultraviolet, peer into the universe beyond our solar system. Their output includes intriguing findings about exoplanets — worlds that orbit other stars. In all, we are managing 19 JPL spacecraft and seven instruments across the solar system.

All of this is supported by our worldwide Deep Space Network, which provides the communication link between spacecraft and the ground. In addition, missions are infused with technologies developed by researchers working on projects for non-NASA sponsors as well as on pure research.

There are many other exciting missions in the pipeline. Teams will soon begin the final assembly of a highly capable rover — much larger than the pair currently on Mars — that will be sent to the Red Planet in 2009. New Earth science missions will be launched in coming months, to be joined by astrophysics observatories. Our planners are also analyzing plans for major new missions to the outer solar system, and spacecraft that can help us find Earth-like planets around other stars.

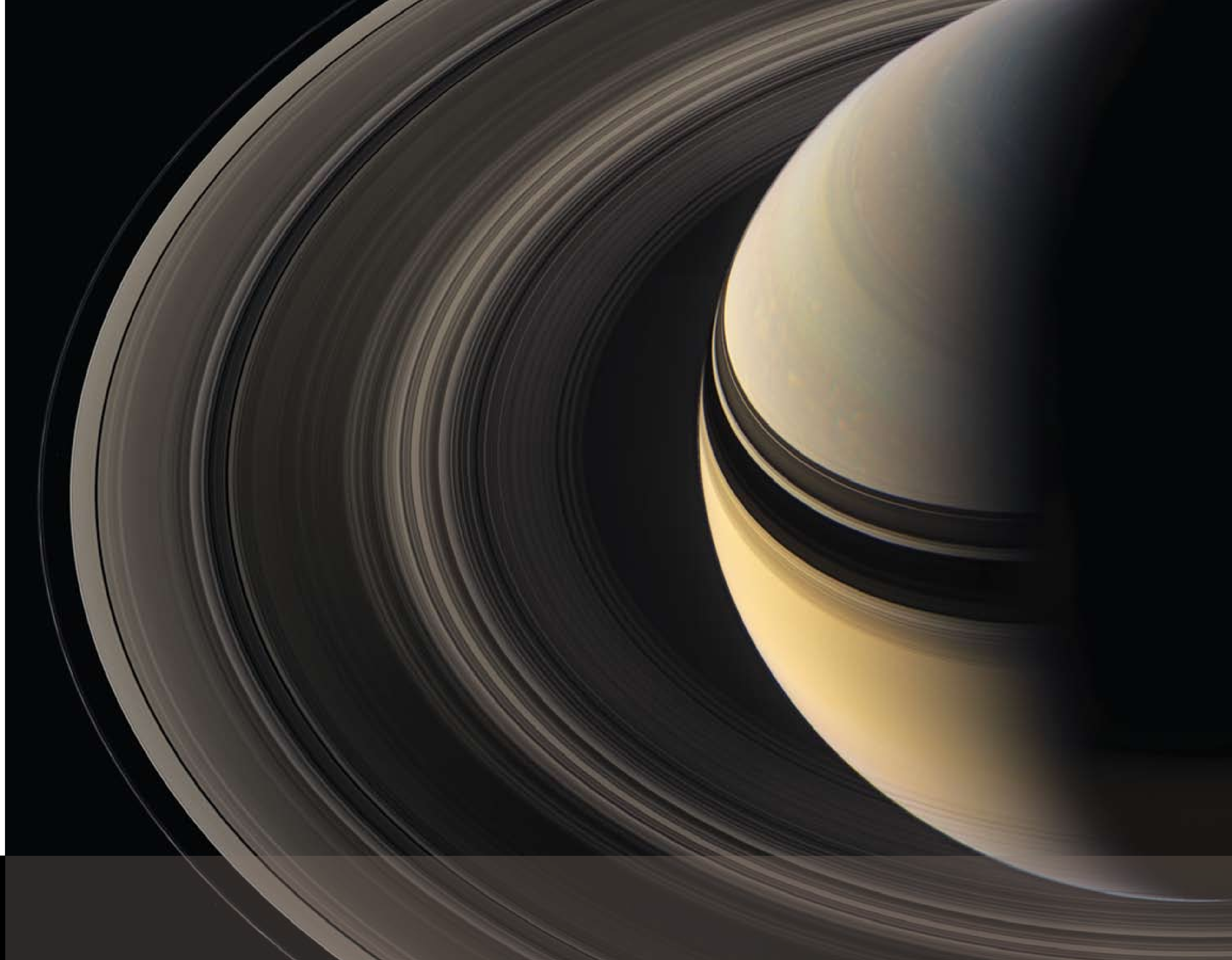
As rich and varied as our programs are now — and our plans are for the near future — it's amazing to consider for a moment that it all began with a simple machine, rustic by today's technology, thrown into orbit on an Army missile. I hope you will join me in honoring the JPL men and women who created that piece of history that was so responsible for what we've become today. And I hope as well that like me you will savor the amazing new missions to come.

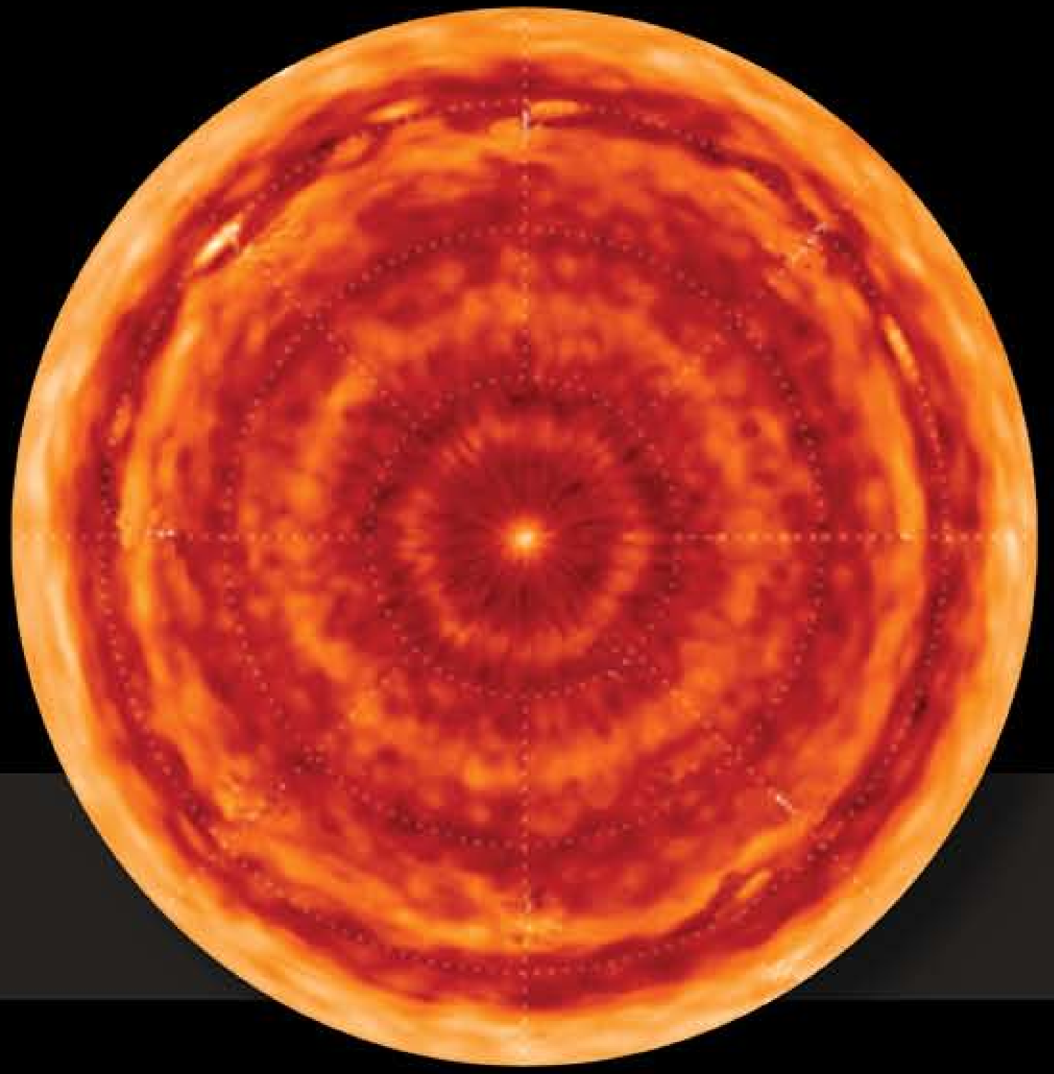
Soaring far above the plane of Saturn's elaborate system of rings, Cassini captured a portrait of the giant planet from a unique perspective. The flagship orbiter delivered a variety of findings during its tour in 2007.

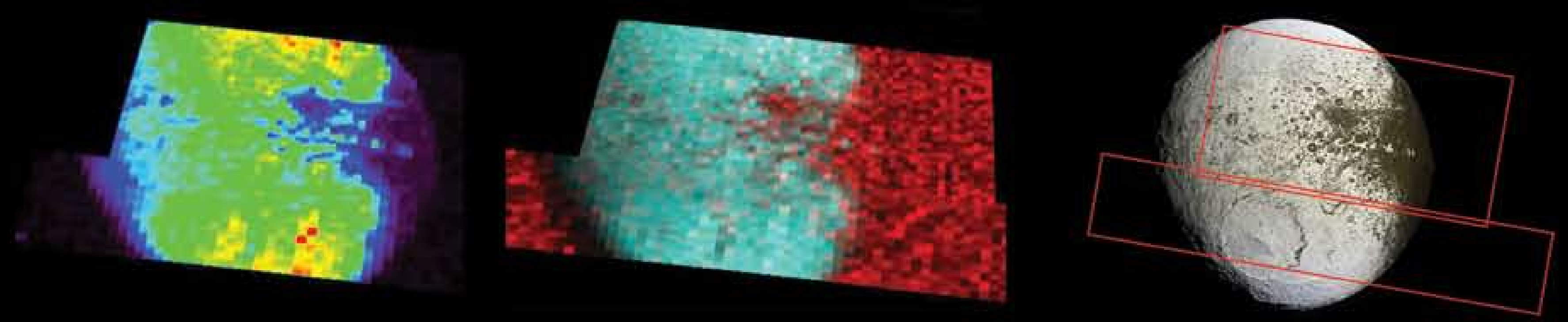
Solar system explorers were active on a number of fronts in 2007, targeting bodies from modest-sized asteroids and comets to the second largest gas giant planet circling the sun. The ongoing missions demonstrated that, as much as we believe we have come to know the solar system, it continues to offer surprises.

With the Dawn mission, JPL is again turning to ion propulsion, a technology used to great effect on the Deep Space 1 spacecraft of nearly a decade ago. Dawn uses a larger ensemble of ion thrusters to help it achieve a space exploration first — traveling to one body, orbiting it, then leaving to travel to and orbit a second body. In Dawn's case, the targets are the asteroid Vesta and the dwarf planet Ceres, which it will reach in 2011 and 2015, respectively. Though the amount of thrust from the ion system is seemingly slight — at most it produces about the amount of force involved in holding a single sheet of notebook paper in your hand — over the course of the mission it will change the spacecraft's speed as much as its Delta rocket did during its launch in late September. Dawn's ion thrusters were powered up in December; its next stop will be a flyby of Mars in early 2009.

Cassini — which marked a decade in space since its 1997 launch — spent an exceedingly productive year at Saturn, producing a wide array of discoveries in its explorations of the giant planet, its rings, moons and energy environment. The flagship spacecraft's imaging radar pierced the perpetual haze enshrouding Saturn's largest moon, Titan, to reveal seas and lakes of liquid methane or ethane. Titan's







An unexpected hotspot is revealed at Saturn's north pole by Cassini's infrared spectrometer (left) — girdled by an uncannily hexagon-shaped band. Saturn's strange two-toned moon Iapetus is rendered in ultraviolet light (below left and center), disclosing features such as mountain ranges. An image in visible light (right) is marked to show the regions of the ultra-violet observations.

far north, where it was winter, was shown to be pitted with giant lakes and seas — at least one of them larger than North America's Lake Superior. Lakes were also found near Titan's south pole. Cassini's mapping spectrometer, meanwhile, took a picture of an enormous cloud half the size of the United States in Titan's north.

Turning its spectrometer on Saturn itself, Cassini caught a portrait of a highly odd, hexagon-shaped feature in the giant planet's butterscotch atmosphere circling its north pole. The strange geometric feature was first seen by the Voyager 1 and 2 spacecraft a quarter century ago. Scientists said it is similar to the winds of Earth's polar vortex, except that in the case of Saturn the winds follow an uncanny six-sided path. Cassini's ultraviolet imager, meanwhile, found the particles that make up the planet's haunting rings to be unusually diverse. Scientists previously thought that the rings were probably formed when a comet shattered a Saturnian moon perhaps a hundred million years ago, but the new view suggests they may have been around since the earliest era of the solar system when the planets formed.

One of the highlights of Cassini's studies of Saturn's moons came when it made its sole close flyby of Iapetus. The strange world, first discovered by the Italian–French astronomer Giovanni Cassini more than 400 years ago, has two faces — one bright as snow, the other as black as tar. A few months after arriving at Saturn in 2004, Cassini took a picture of Iapetus from a distance that showed its equator to be girded by an immense ridge of mountains —

a midriff bulge that lends the moon a walnut shape. In its close flyby in September, Cassini showed the moon to be heavily cratered across both its bright and dark sides. Elsewhere on Saturn's moons, Cassini made observations of geysers on Enceladus and detected hydrocarbons on Hyperion. The spacecraft found that Tethys and Dione are flinging great streams of particles into space — possibly the result of geological activity.

Other missions found second lives in 2007. Deep Impact made headlines in 2005 when it released a projectile that blasted a crater in the nucleus of Comet Tempel 1. After two years in electronic sleep as it silently orbited the sun, Deep Impact was awakened this year to prepare it for a flyby of a second comet — Hartley 2, which it will reach in 2010.

The comet that Deep Impact originally blasted with its impactor, meanwhile, will have a visit by yet another spacecraft in a bit of extraterrestrial teamwork. In 2011, Comet Tempel 1 will be visited by Stardust, a spacecraft that, like Deep Impact, is being reprogrammed for a new lease on life following its prime mission. Stardust flew by Comet Wild 2 in 2004 and returned to Earth two years later, dispatching a capsule bearing comet dust samples that landed on the salt flats of the Utah desert. The main Stardust spacecraft, however, passed Earth and continued on in orbit around the sun. Its flyby of Tempel 1 in 2011 will allow it to see the changes wrought when the comet nucleus was blasted by Deep Impact.

Powtawche Williams

Growing up on a Choctaw reservation in rural Mississippi, Powtawche Williams recalls that it was the vivid night skies that first triggered her interest in space.

"Later, after we moved to New Orleans, we had a unit on space and working in the space industry in sixth grade," says Williams. "The culmination of the unit was to watch the space shuttle Challenger launch. Seeing the tragedy made a huge impression on me."

But it didn't deter her interest, and after science-oriented summer camps and a high school internship at the Stennis Space Center, Williams ended up as a mechanical engineering major at Stanford. That was followed by a master's and doctorate at Rice University in Texas, and an internship at Johnson Space Center.

In grad school she got involved in plotting spacecraft trajectories for planetary missions, and after getting her Ph.D. she found herself hired by JPL to work on the Jupiter Icy Moons Orbiter. When that was cancelled, she moved over to Cassini as a maneuver analyst, the position she holds today.

Williams' arrival at JPL was rocky on one front. A month after she started, Hurricane Katrina descended on New Orleans; she had to do her best to help from afar while her family evacuated. She notes that at the end of 2007 they were finally able to get back into their home that had flooded.

"I was drawn to mechanical engineering because I enjoy building things, working with my hands," says Williams, who also plays cello. "Now I'm very much at home in navigation. One of the things I like about JPL is that you can get variety in your career by moving from one project to another. But I would see myself continuing in navigation."

Yet another comet is on the itinerary for a JPL instrument riding aboard a European spacecraft. In 2004, the Rosetta orbiter was launched from French Guiana carrying a microwave instrument built by the Laboratory, and is slated to reach Comet 67P/Churyumov-Gerasimenko in 2014. JPL's microwave instrument will study, among other things, how different comet materials change from ice to gas. In 2007, Rosetta executed flybys of Mars and Earth to shape its flight path.

Among the elder statesmen of space missions, Voyager 2 followed its twin, Voyager 1, into the solar system's final frontier, a vast region at the edge of the solar system where the solar wind flowing outward from the sun runs up against the thin gases between the stars. Based on where Voyager 2 encountered this zone, scientists concluded that the energy bubble surrounding the solar system, called the heliosphere, is not perfectly symmetrical in shape but rather shows a dent where it is pushed in closer to the sun by the magnetic field between the stars.

Among new missions, in December NASA announced the approval of Grail, a JPL-managed mission that will peer deep inside Earth's moon to reveal its anatomy and history. Modeled on a highly successful JPL Earth mission called Grace, Grail will use a pair of satellites to measure the moon's gravity field in unprecedented detail. Grail is scheduled for launch in 2011.

Teams at JPL also spent much of 2007 conducting studies of concepts for a new flagship mission to the outer solar system. Working with Johns Hopkins University's Applied Physics Laboratory and other NASA centers, JPL analyzed concepts including an orbiter at Saturn's moon Titan, an orbiter at Jupiter's moon Europa and a spacecraft that would study the Jupiter system. In December, NASA approved the three concepts to move forward for further study, including discussions with European and Japanese partners on how to bring in international collaboration.

The cold, cratered landscape of Saturn's moon Tethys glows in stark relief in this crescent view (background) captured by Cassini. Ice particles, water vapor and trace organics were found to be spurting from Saturn's moon Enceladus (right inset). The Dawn spacecraft (left inset) embarked on a four-year flight to the asteroid Vesta, which it will orbit before continuing on to the dwarf planet Ceres.

Fire and smoke of a nighttime launch initiated the mission of the Phoenix Mars lander, which will excavate frozen soil near the planet's north pole to understand the history of water there.

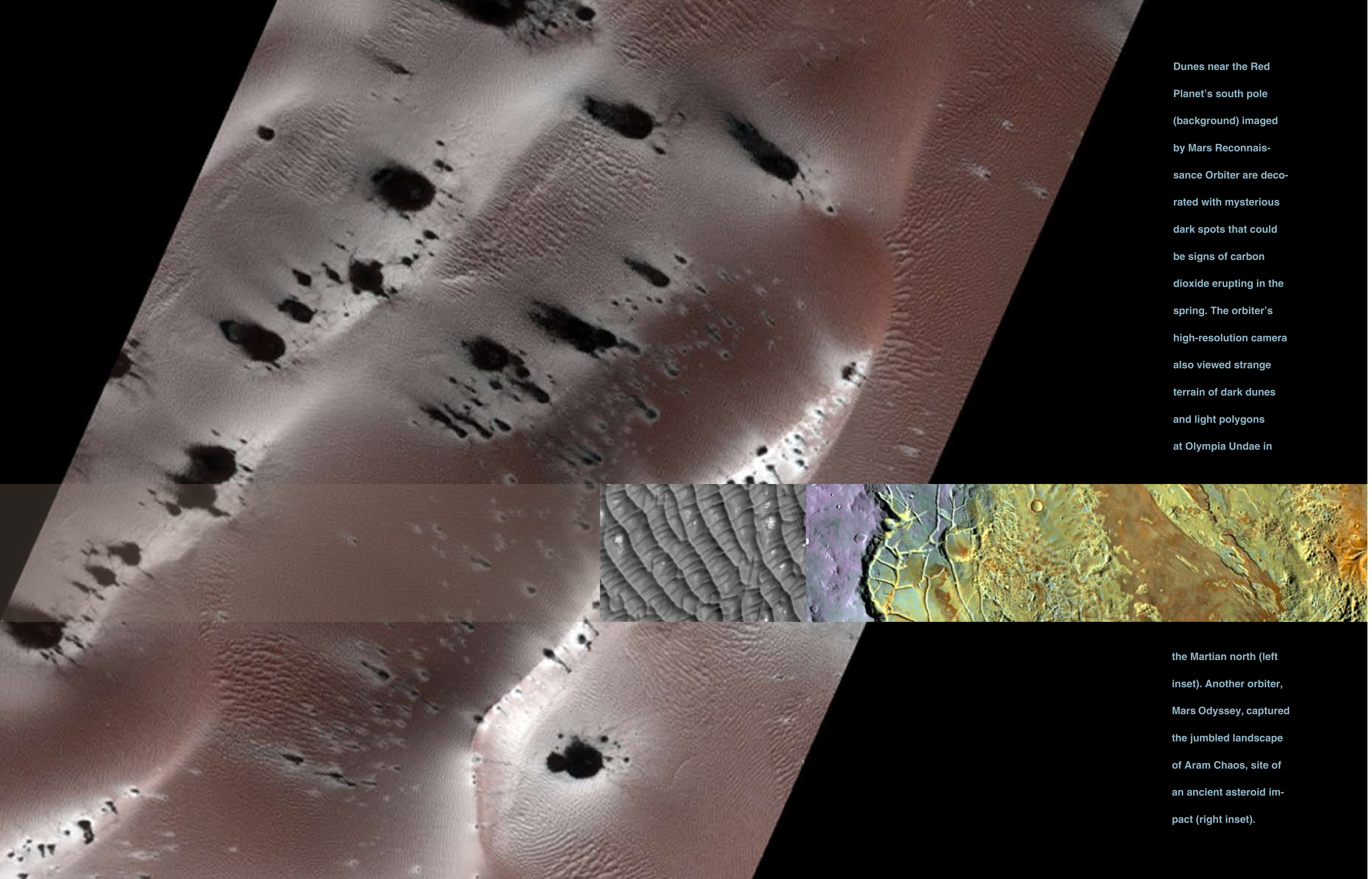
Earth's planetary neighbor is proving to be more intensively studied than ever, with a pair of NASA rovers on the surface, two orbiters overhead, a new lander speeding from Earth to Mars, a new rover under construction and key JPL science involvement in a European orbiter.

A flawless launch in August dispatched Phoenix, a lander destined to settle down near Mars' north pole where it will use a robotic arm to dig into the frozen soil. What it finds, scientists believe, may tell them much about the history of water there and whether microbial life could have existed in that environment at any time in Mars' history. The mission will recoup much of the science intended for Mars Polar Lander, which was lost during its descent eight years ago.

Through the balance of 2007, all of Phoenix's in-flight events proceeded smoothly in preparation for landing on Memorial Day weekend in May 2008.

It was an eventful year for JPL's twin rovers, Spirit and Opportunity, which were nearing their fourth anniversary of prospecting on the Martian surface — remarkable longevity given that the mission was only designed to last for 90 days. Both rovers were considerably impacted when a planet-wide dust storm swept across Mars in June, but managed to survive to carry on their respective studies.

At the height of the storm — the most intense by far to beset the rovers since their arrival — that outcome was not assured. Dust darkened



Dunes near the Red Planet's south pole (background) imaged by Mars Reconnaissance Orbiter are decorated with mysterious dark spots that could be signs of carbon dioxide erupting in the spring. The orbiter's high-resolution camera also viewed strange terrain of dark dunes and light polygons at Olympia Undae in the Martian north (left inset). Another orbiter, Mars Odyssey, captured the jumbled landscape of Aram Chaos, site of an ancient asteroid impact (right inset).

the sky so much that it blocked 99 percent of the direct sunlight reaching Opportunity's solar panels. Ground controllers switched off as many systems as possible on both rovers to conserve power and help them wait out the storm. In August the skies cleared slightly, and by the following month the rovers were in good enough shape to carry on with their explorations.

Opportunity spent much of early 2007 circling the rim of Victoria Crater, as ground teams contemplated where and when to send it down inside the 800-meter-diameter (half-mile) crater, named after Ferdinand Magellan's 16th-century ship that circumnavigated the globe. After enduring the dust storm, Opportunity rolled down the crater's slope, inspecting three bathtub-ring-like layers that circle the crater under the rim as it descended. On the way it also ran communication tests that will help prepare for the arrival of the Phoenix lander.

On the other side of the planet, Spirit continued its exploration of the less water-shaped landscape of the ancient, 170-kilometer-diameter (roughly 100-mile) Gusev Crater, named in honor of a 19th-century Russian astronomer. For much of 2007, Spirit was on the move examining rocks near an outcropping called Home Plate. Scientists were

Leslie Tamppari

When one door closes, so the old expression goes, sometimes another one opens. In Leslie Tamppari's case, the doorways may have been planets.

After earning her bachelor's degree in applied math from the University of Arizona in 1990, Tamppari joined JPL on the Galileo mission to Jupiter. Pursuing grad school at UCLA, she expected to write a thesis about the giant planet's volcanic moon Io. Just before the critical Io flyby that Tamppari expected to yield the essential data that would busy her for years, she learned that the spacecraft had developed tape recorder problems. The observations were cancelled.

Goodbye, Io. Hello — Mars? After casting around among colleagues for ideas, Tamppari connected with Rich Zurek, a JPL senior scientist whose specialty was study of the atmosphere of the Red Planet. Before long, she had a new thesis topic.

A master's degree and Ph.D. later (both from UCLA in planetary science), Tamppari served as science lead for many mission proposals. Then she was invited to join the science team for Phoenix, a proposed lander that would sample the frozen terrain near Mars' north pole. When the mission received final approval, the principal investigator asked Tamppari to step into the role of project scientist — the first-line interface between the science team and engineers at JPL. Phoenix launched in 2007 and will land near the planet's north pole in 2008.

Ironically, Tamppari says math was the subject she got her lowest grades in during elementary school. "And then when I became a math major in college, I wasn't sure what I wanted to do — I knew I didn't want to teach or be a programmer," says Tamppari, who has played clarinet and tenor sax with JPL's big band ensemble and who is expecting her first child in 2008.

"But then I came to JPL for a student job during Voyager's Neptune flyby. There were discoveries every day — it was exciting to feel that I was one of the first people in the world to see what Voyager was showing us. I still feel that way about the job — I feel like an explorer, just like the people from history who went to new continents for the first time."

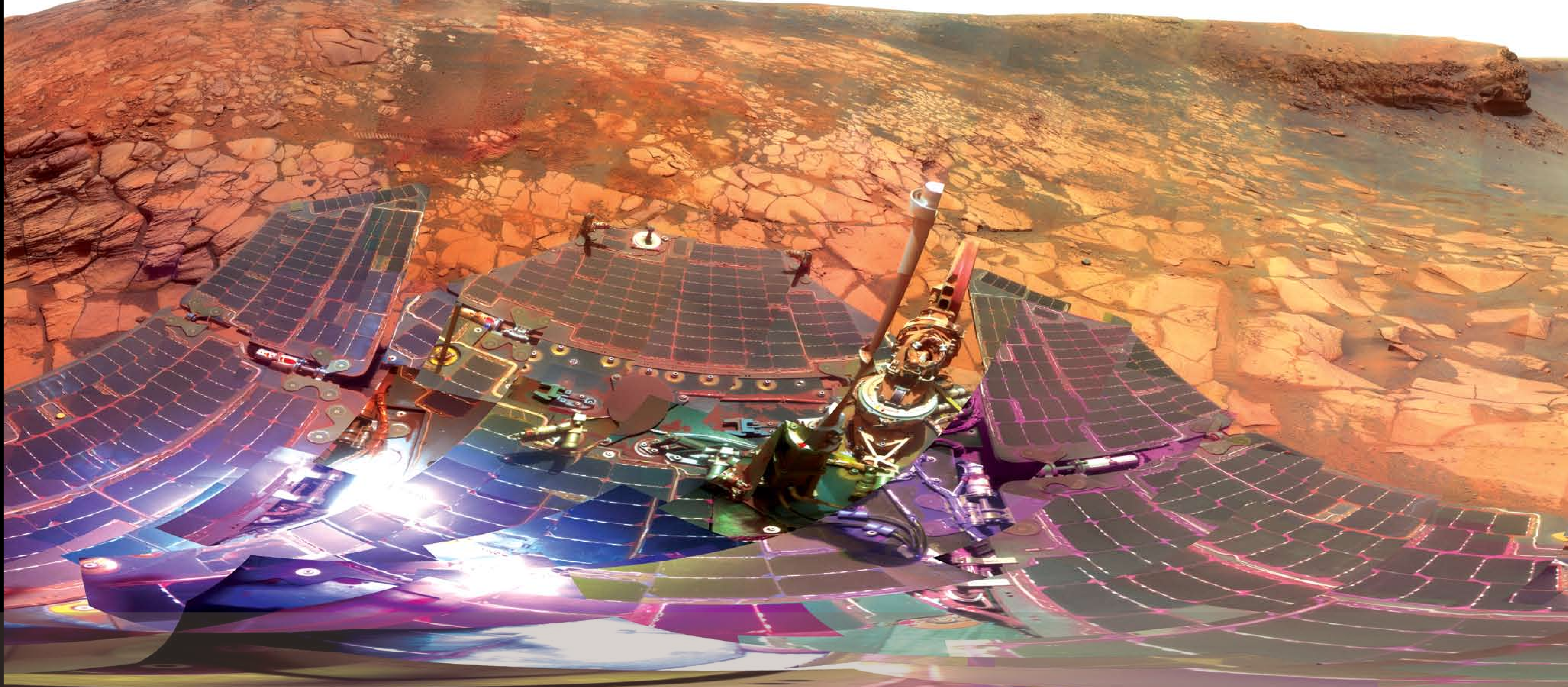
ecstatic when, in May, a dragging wheel on the aging rover uncovered a patch of nearly pure silica, the chief ingredient of window glass. The bright stuff could have been formed in either of two processes, but either way, the locale would almost certainly have been perfect for microbial life in the past. The science team said it could be Spirit's most important discovery from the entire mission.

Keeping watch overhead, Mars Reconnaissance Orbiter and the Mars Odyssey orbiter yielded important science findings. It was the first full year of science operations for Mars Reconnaissance Orbiter, which used its high-resolution camera to assess the landing site for Phoenix and consider sites for the next major rover mission, Mars Science Laboratory. The spacecraft also turned its camera and imaging spectrometer on spidery markings near Mars' south pole. Both instruments turned up evidence bolstering the theory that the markings are signs of carbon dioxide erupting as the area warms in the spring.

Mars Odyssey's thermal camera found signs of roof vents in underground caverns, which Mars Reconnaissance Orbiter confirmed. The latter orbiter's imaging spectrometer discovered deposits of claylike materials that point to Mars being wetter earlier than previously thought. Those could be tempting landing sites for Mars Science Laboratory.

Remarkable Longevity

Mars Exploration Rover Opportunity spent four months prospecting for rocks in an alcove called Duck Bay in the western portion of Victoria Crater. Over 47 Martian days, its panoramic camera collected images that were combined to create this mosaic, in which colors are stretched to bring out subtle differences in the scene.



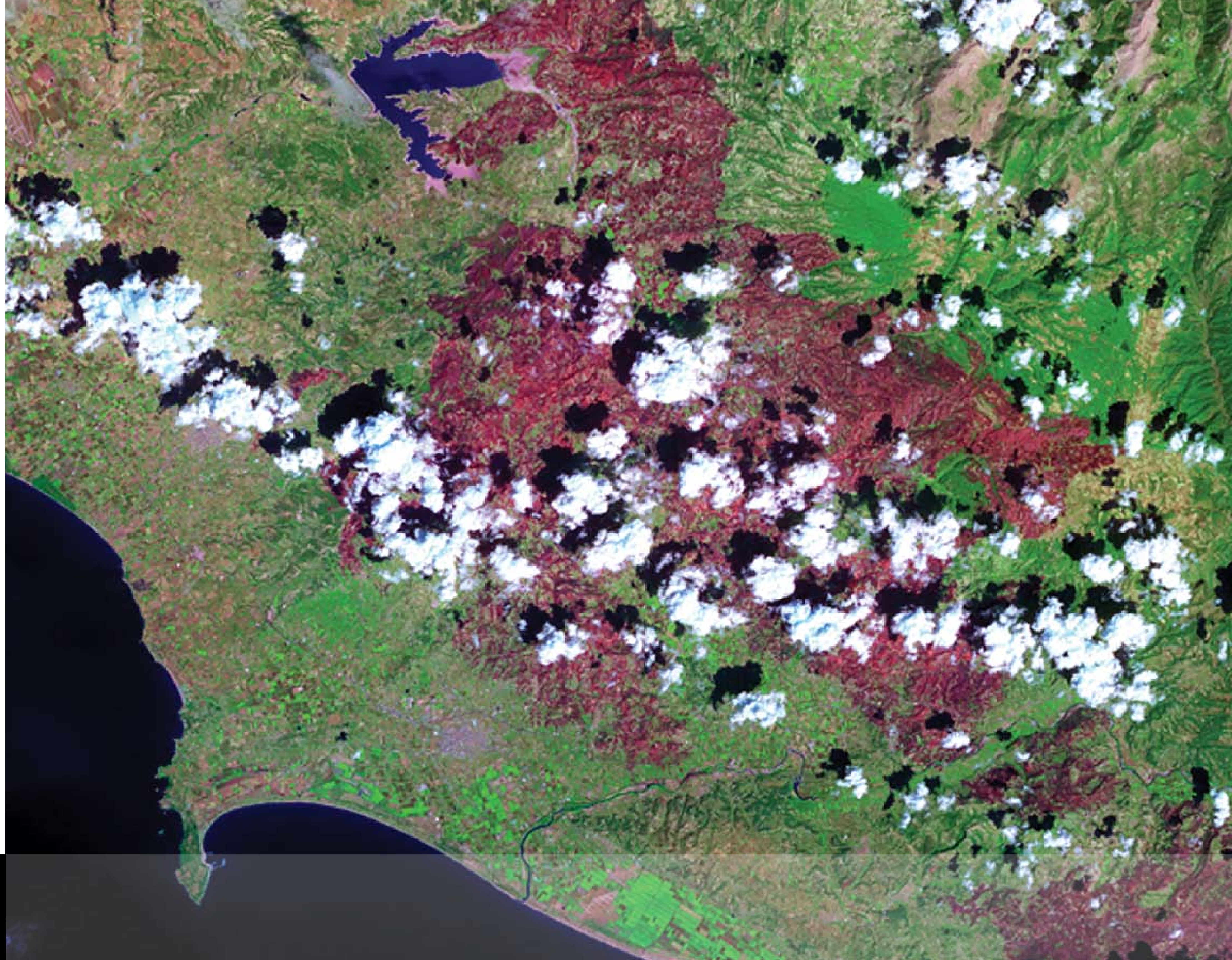
JPL was also responsible for a NASA imaging radar instrument carried by the European Space Agency's orbiter Mars Express. Capable of seeing under the planet's surface, that instrument measured the depth of water ice deposits in the layered terrain near Mars' poles. It found those regions to be very rich in water — in fact, the south polar region has enough frozen water to cover the entire planet to a depth of 11 meters (36 feet).

Back on Earth, teams were busy making and testing hardware for Mars Science Laboratory for its launch in the fall of 2009. Twice as long and three times as heavy as Spirit or Opportunity, the next-generation rover will use a sophisticated suite of instruments to analyze samples of soil and rock for organic compounds or environmental conditions that could have supported microbial life. Some of the hardware work in 2007 included tests of science instruments and parachutes, as well as drop-testing of a model of the rover dubbed Scarecrow (named for the Wizard of Oz character, as the test model has no onboard computer, or brains).

Possible ancient salt deposits in an unnamed crater in the Terra Cimmeria region are shown in an image taken by Mars Reconnaissance Orbiter's high-resolution camera.

The clay-rich Nili Fossae region (below left, imaged by Mars Reconnaissance Orbiter's high-resolution camera) was a candidate landing site for Mars Science Laboratory (below center), JPL's next rover mission. The European Space Agency's Mars Express (below right) features a JPL-teamed radar instrument.

A major fire in southern Greece near the ancient site of the Olympic games left burn areas, colored red in this view by the Advanced Spaceborne Thermal Emission and Reflection Radiometer.



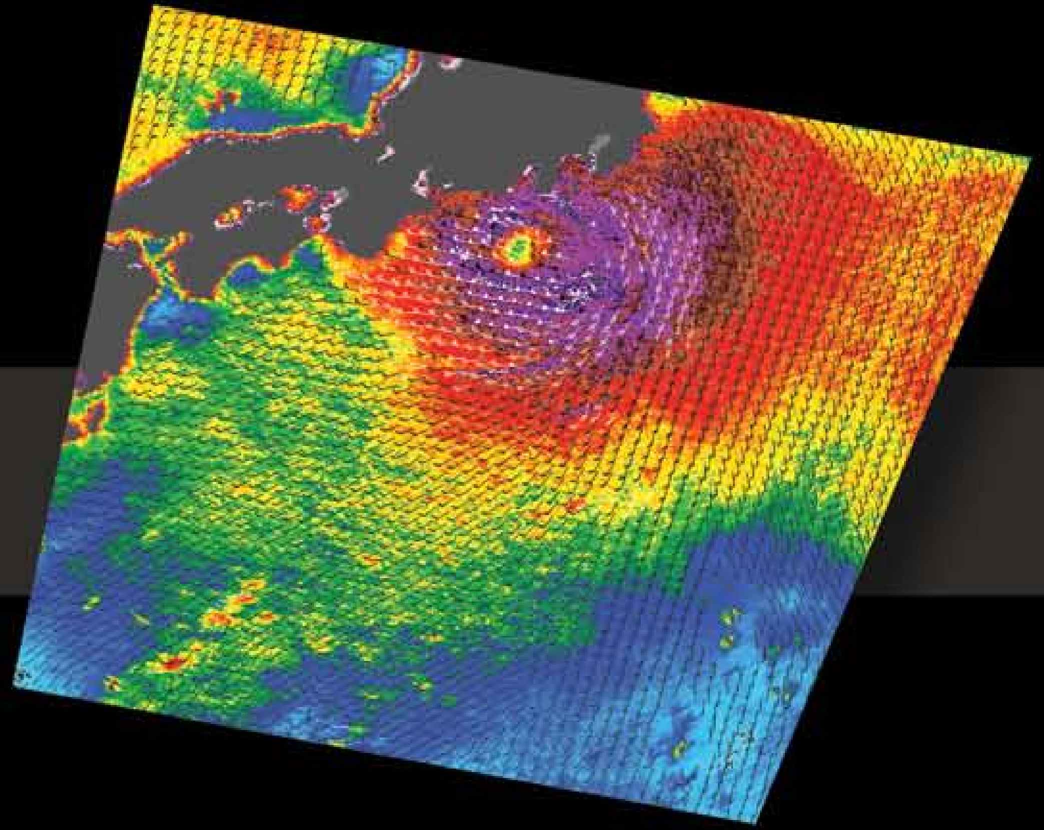
After years of data from JPL missions and many other sources, 2007 may be remembered as a year when public consciousness of Earth's changing environment dramatically increased.

One major agent of that change was a series of four reports issued by the United Nations' Intergovernmental Panel on Climate Change. Created in part with data from JPL Earth missions, the reports acknowledged the scientific consensus that Earth is warming — with human activity as the "very likely" cause.

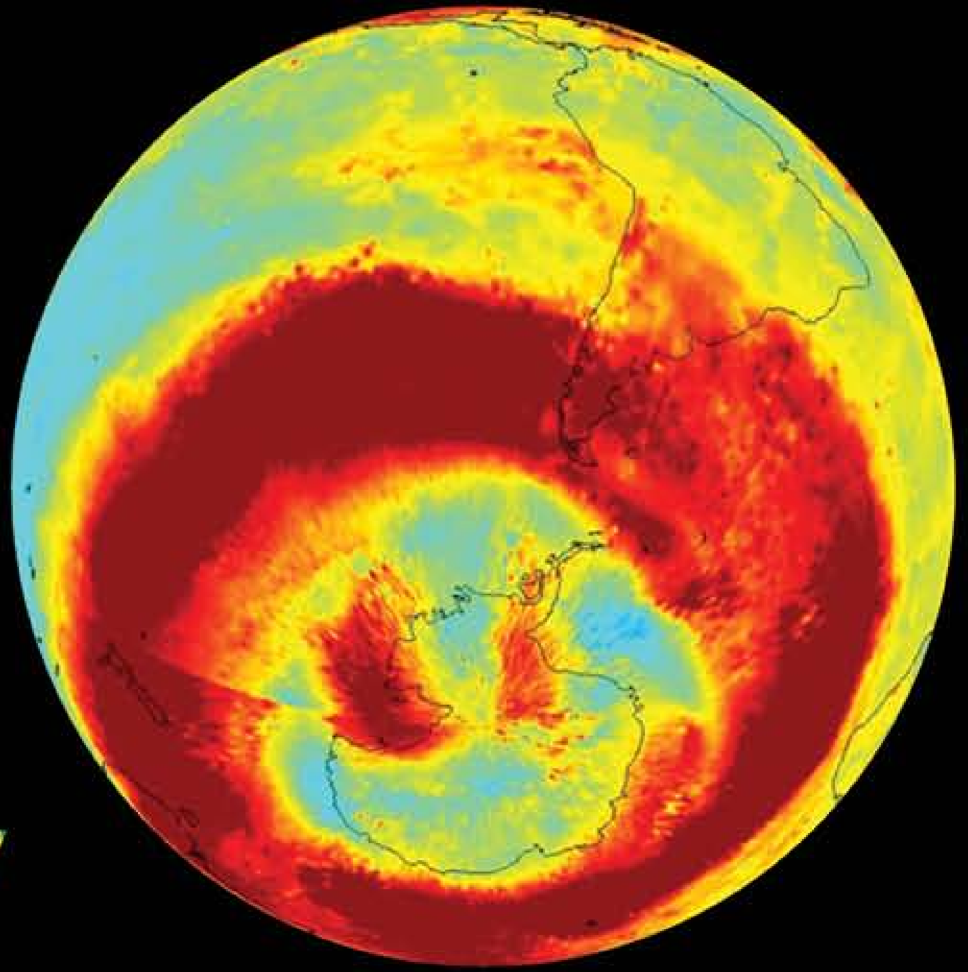
Throughout the year, several JPL researchers continued to publish reports chronicling record loss of ice at Earth's poles. Using data from the Quick Scatterometer and other satellites, one team announced in April that two years ago the Arctic replaced very little of the thick sea ice it normally loses and replenishes each year. Replenishment of this thick, perennial sea ice each year is essential to the maintenance and stability of the Arctic summer ice cover. The satellite also found the first widespread melting in Antarctica seen by satellite — a loss of an ice mass the size of California.

In October, another team of JPL scientists found a 23-percent loss in the extent of the Arctic's thick, year-round sea ice cover during the past two winters, based on data from the Quick Scatterometer and from buoys. The drastic reduction of perennial winter sea ice was the primary cause of summer 2007's fastest-ever sea ice retreat on record and subsequent smallest-ever extent of total Arctic coverage. Another satellite, CloudSat, looked

Typhoon Fitow is viewed by the Quick Scatterometer satellite just before making landfall in Japan in early September 2007 (below).



Growth of the annual ozone hole in the Antarctic is captured by the Atmospheric Infrared Sounder.



Monitoring Earth

at the role of clouds in warming in the Arctic. It found less cloudy skies over the western Arctic, where most of the ice loss occurred, which heated the surface enough to warm ocean waters by 2.4 degrees Celsius (4 degrees Fahrenheit) — enough to melt 0.3 meter (one foot) of sea ice.

Mounting evidence compelled JPL and Caltech to combine their intellectual resources to improve ways to monitor and understand global change, and to mitigate adverse effects by identifying alternative renewable reduced- or zero-carbon energy sources. In 2007, a Global Change and Energy Working Group was formed, focusing initially on global change physics, modeling and observations, as well as energy alternatives.

Among other results from JPL missions, several satellites chronicled events on Earth such as Southern California wildfires. The destructive fires were viewed by the Advanced Spaceborne Thermal Emission and Reflection Radiometer instrument on NASA's Terra satellite, as well as the Atmospheric Infrared Sounder on NASA's Aqua satellite. In November, as tropical storms churned off Florida's coast, scientists announced they had developed a promising new technique for estimating the intensity of tropical cyclones from space using the CloudSat satellite.

JPL's Tropospheric Emission Spectrometer instrument on NASA's Aura satellite provided a novel way of tracing how water vapor moves through Earth's atmosphere. Most people probably remember charts of the water cycle from their grade-school days, with clouds raining on the land, water running down rivers to the seas and then evaporating back into the clouds.

But new studies using the satellite instrument showed most water vapor enters the atmosphere in the tropics not from the oceans, but from water that evaporates during tropical thunderstorms, as well as water "exhaled" by forests.

One team of JPL climatologists conducted a study of temperatures from around California, concluding that the Golden State is heating up. Average temperatures in California rose almost one degree Celsius (nearly two degrees Fahrenheit) during the second half of the 20th century, with urban areas blazing the way to warmer conditions. The team pointed to the steady march of concrete in the form of urbanization, rather than global warming, as the likely cause. Climatologists also studied the La Niña condition — or unusually cold water in the eastern Pacific.

Among upcoming missions, two satellites, the Orbiting Carbon Observatory and the Ocean Surface Topography Mission, moved forward toward launches in 2008. Test flights were conducted of an imaging radar instrument designed to fly on crewless aircraft to study earthquakes, volcanoes, landslides, glaciers and other dynamically changing phenomena. They will all contribute pieces to better understanding of the environment of our home planet, and how it is changing.

Josh Willis

The ocean, says Josh Willis, is a noisy place. Not that it's hard on the ears. Willis is in the business of taking the temperature of the world's seas. He says, "There are so many trends, large and small" — that's the noise — "that it takes lots of data to see the big picture of what's going on."

Getting that big picture is important, because heat moving around in the ocean is a key part of global warming trends that may cause profound changes in the planet. An oceanographer who came to JPL in 2004 as a postdoctoral scholar and stayed on as a staff scientist, Willis has been using all the tools he can find — from satellites to buoys to sensors chucked off the stern of container ships — to see the ocean temperature picture more clearly.

One thing that scientists have come to learn is that melting ice in Greenland or Antarctica isn't the only cause of rising sea level. About half of the gradual sea level rising now taking place can be traced to the thermal expansion of sea water itself.

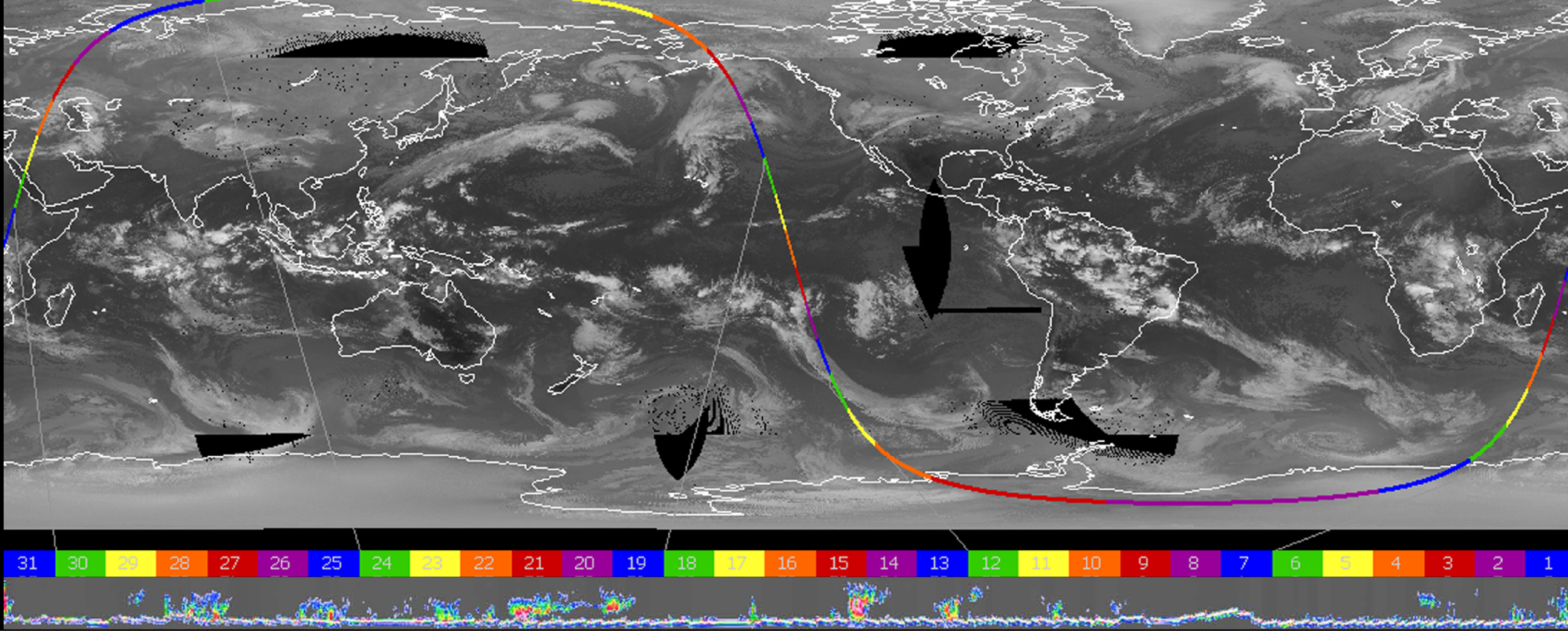
Willis is also interested in studying what scientists call the "conveyor belts" of the seas — the large-scale motion of deep water across the world's oceans, rising as it heats and sinking as it cools. Are the pathways that carry water masses from one continent to another on the scale of centuries changing as a result of global warming? He and his colleagues would like to know.

Willis, who comes from a family of three generations of cabinet-makers, credits "a couple of really good physics and math teachers in high school" with his abiding interest in science. After earning a bachelor's in physics and math at the University of Houston and a master's in physics at UC San Diego, Willis went for an oceanography doctorate at the Scripps Institution of Oceanography in La Jolla.

"At that point in my life, I realized I wanted to do something closer to home," he says. "One thing rewarding about this work is that I feel it can make a difference."

Quicklook Images

A single orbit's worth of data from the CloudSat satellite is presented in this view. The satellite's orbital track is shown on the global map at top. The false-color shapes at the very bottom are the actual data gathered by CloudSat — offering a three-dimensional view of the clouds over which it flies.



The Whirlpool Galaxy, one of the brightest spiral galaxies in the sky, is rendered in a dramatic way by combining observations from a quartet of spacecraft — JPL's Spitzer Space Telescope and Galaxy Evolution Explorer, as well as NASA's Hubble Space Telescope and Chandra X-ray Observatory.

Among JPL's missions that peer into the universe past our own solar system, two established space observatories continued to yield newsmaking results — while others were in the pipeline to join them.

The tantalizing field of exoplanets — planets that orbit stars other than our own sun — played a big role in findings by the Spitzer Space Telescope, which marked its fourth anniversary. In February, scientists announced that the infrared observatory had, for the first time ever, captured enough light from two giant planets to measure their spectra, or chemical signatures. One of the planets orbits a star 150 light-years away in the constellation Pegasus, while the other is 63 light-years away in the constellation Vulpecula. In May 2007, astronomers using Spitzer data released a map of the surface temperature of the second of the two planets, called HD 189733b — the first-ever map of an exoplanet. And in July, another team announced that observations with Spitzer showed the same exoplanet is a scorching-hot gas planet steaming up with water vapor. This fit astronomers' predictions for the so-called "hot Jupiter" worlds — gas giant planets larger than Jupiter but not so big that they ignite to become stars of their own.

Like Luke Skywalker's home world of Tatooine in *Star Wars*, Spitzer observations suggest that planetary systems around double stars are probably common. Since more than half of all stars are twins, or binaries, the finding suggests the universe is packed with planets that have two suns.

The Helix Nebula, a cosmic starlet often photographed by amateur astronomers for its vivid colors and eerie resemblance to a giant eye, is caught in a closeup by the Spitzer Space Telescope.

Spiral galaxy M106 appears two-toned in a composite image that combines infrared data from Spitzer with observations by other space- and ground-based observatories (left inset).

The search for exoplanets — worlds orbiting other stars — is a high priority for JPL astronomers (right inset).

Using Spitzer and NASA's Chandra X-ray Observatory, astronomers say they discovered hundreds of black holes hiding deep inside dusty galaxies billions of light-years away. The massive, growing black holes represent a large fraction of a long-sought missing population. Their discovery implies there were hundreds of millions of additional black holes growing in the infant universe, more than doubling the total amount known at that distance. "We had seen the tip of the iceberg before in our search for these objects," said an astronomer on the team. "Now, we can see the iceberg itself."

While Spitzer beheld the universe in the infrared, another spacecraft, Galaxy Evolution Explorer, plied the ultraviolet spectrum. In August, the science team announced that the observatory caught sight of something never before seen in space: a comet-like tail stretching an incredible 13 light-years long, streaming behind a star shooting through space at supersonic speeds. The star, called Mira, has been known to astronomers for 400 years, but until now the existence of the bizarre tail was unknown. Astronomers likened it to a jet's contrail or a speedboat's turbulent wake — only on a vast, interstellar scale.

In December, NASA announced it had selected three teams of scientists to begin studying discs of dust around nearby stars using the Keck Interferometer on Mauna Kea, Hawaii. The sophisticated new system developed and managed by JPL combines the observing power of the two large Keck telescopes into the equivalent of a single super-telescope. One of the three teams is led by a JPL astronomer.

JPL has a key role in the Herschel Space Observatory, a European space-based telescope that will study the universe in the far-infrared and submillimeter spectrum. (Submillimeter means wavelengths between the far-infrared and radio bands.) Planned for launch in 2008, Herschel includes two instruments developed by JPL. Support for the U.S. astronomical community will be provided by a Herschel Science Center sponsored by NASA and established at Caltech. The same rocket that will launch Herschel will also carry Planck, another European observatory designed to study cosmic background radiation left over from the Big Bang. JPL designed advanced cryocoolers for the Planck spacecraft.

Among other upcoming missions, JPL is managing development of Kepler, a space-borne telescope that will survey distant stars to determine the prevalence of Earth-like planets. Kepler will detect planets indirectly, based on transits — watching a star's light dim slightly as a planet passes in front of it. Following launch in 2009, JPL will turn the mission over to NASA's Ames Research Center for science operations.

JPL is also project manager for the Wide-field Infrared Survey Explorer, or Wise, spacecraft. The observatory will make an all-sky survey, producing an infrared catalog of objects ranging from asteroids to brown dwarf stars to distant galaxies. Launch is planned for late 2009.

Amy Mainzer

Some kids spend much of high school or college trying to decide what color their parachute is — whether to try for a career as, say, a dentist or stockbroker or poet. Not Amy Mainzer. "I decided I wanted to become an astronomer," she says, "when I was about 6."

It didn't run in her family. "In fact," says Mainzer, who grew up in Akron, Ohio, "both my parents are artists. When I was a little kid, I liked to read books on Greek mythology. I spent a lot of time reading encyclopedias. I'd look up Andromeda, and next to the Greek legend there was also a picture of this galaxy. So I thought, wow, that's really interesting."

A decade and a half later, with a freshly minted bachelor's from Stanford in physics with honors, Mainzer found herself "completely broke" — so she decided to take a year off school and work. At Lockheed Martin in Palo Alto she ended up on the project that would become the Spitzer Space Telescope. Mainzer's contribution was to create a little device called a fine-guidance sensor that helps to point the infrared space telescope.

After going back to school for a master's (from Caltech) and Ph.D. (from UCLA), both in astronomy, Mainzer was invited in 2003 to come to work at JPL. Today she is deputy project scientist for the Wide-field Infrared Survey Explorer — a spacecraft due to launch in 2009 that will conduct wide surveys to help find interesting targets for higher-powered, but more narrowly focused, space telescopes.

Being a scientist in a flight project environment "is great," says Mainzer, who enjoys painting watercolors and gardening with California native plants. "I get to be part of thinking up a science problem, building an instrument that meets that need and then using it. I love the end-to-end process."

In September, JPL and Caltech were very pleased when NASA announced plans to restart a flight project it had cancelled the previous year. The Nuclear Spectroscopic Telescope Array, or NuStar, is designed to use arrays of special mirrors to focus high-energy X-rays from stars and galaxies. Led by a Caltech principal investigator, the project is managed by JPL. With the restart, launch is targeted for 2011.

JPL continued to lead the community in exploring a variety of mission concepts for the exploration of extrasolar planets, including both large-scale, flagship missions and moderate-scale projects. One of these, the Space Interferometry Mission PlanetQuest, completed a 10-year program developing ground-breaking technologies and is ready to proceed to development. The project team made significant progress in reducing the mission's cost while maintaining nearly all its science capability to be affordable by NASA in the coming decade.

The M81 galaxy, sporting near-perfect arms that spiral to its center, looks sharp in a composite of images from the Spitzer Space Telescope, Galaxy Evolution Explorer and the Hubble Space Telescope.

Astronomy missions in development include the Nuclear Spectroscopic Telescope Array (left inset) and the Space Interferometry Mission PlanetQuest (right inset). JPL also has a key role on Europe's Herschel mission (center inset).

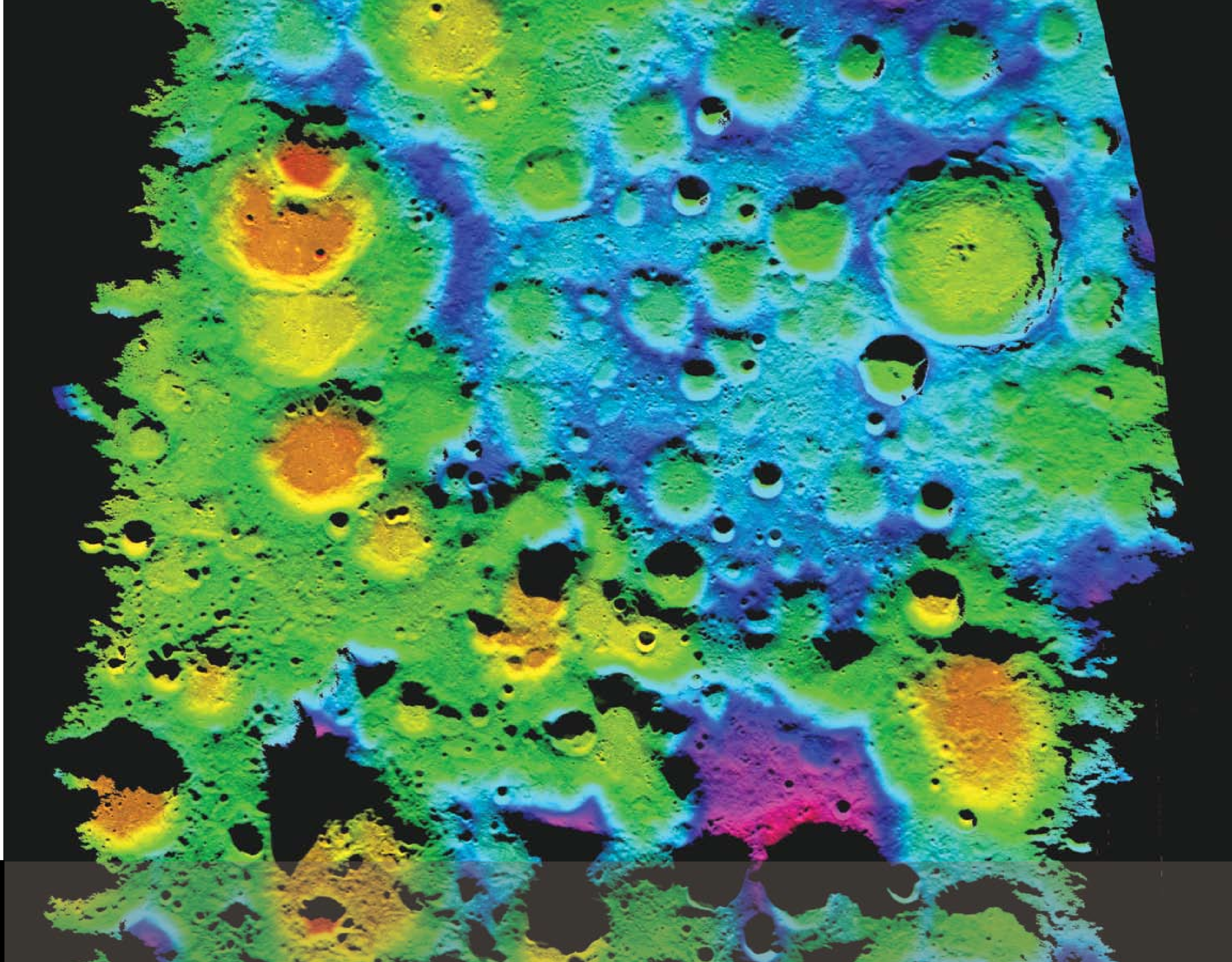
Using Deep Space Network antennas at Goldstone, California, as a scientific radar instrument, researchers made topographic maps of terrain near the moon's south pole that will provide valuable help in planning future human exploration missions.

With 40 missions and numerous critical flight events to support, JPL's global Deep Space Network experienced one of its busiest years ever — not only serving as the communication gateway for spacecraft in flight now, but also actively conducting research to create systems of the future. Increasing attention is being paid to network modernization through infusion of new technologies.

Among key events on JPL missions, the Deep Space Network relayed communications between spacecraft and ground during and after the launches of the Phoenix Mars lander and the Dawn mission to the asteroid belt. The network supported many key activities on Cassini at Saturn and the wakeup of the dormant Deep Impact spacecraft. The network also serviced the regular communication needs of 10 other JPL spacecraft. Thanks to the relative firehose of data sent by Mars Reconnaissance Orbiter, 2007 by far marked the greatest volume of information the Deep Space Network has ever handled.

But nearly two-thirds of the missions supported by the network were from other NASA centers or international space agencies. These included assisting with the launch of Japan's Selene spacecraft as well as the Venus and Mercury flybys of NASA's Messenger mission.

Besides their role as a communications gateway, the network's antennas at Goldstone in the California desert are also used for radar science — and it was here that one of the year's most exciting developments resulted. For decades, scientists have used Goldstone's 70-meter (230-foot) antenna to bounce radar signals off distant objects such as asteroids or the closer planets to create images of their surfaces. In 2007, the Goldstone antenna was trained on the region near the south pole of Earth's moon. NASA planners are keenly interested in that region — home to numerous craters that offer



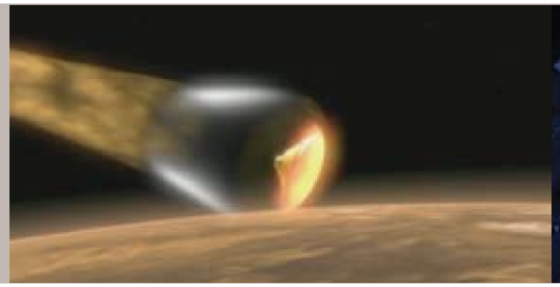
perpetual shade — as a likely location for a future human moon base. The darkness of the craters' floors makes studying them difficult with optical instruments.

Using antennas at Goldstone as a scientific radar instrument, researchers were able to obtain topographic maps of the moon's shadowed southern craters at higher resolution and greater accuracy than any previous measurements. Images captured of the moon have a resolution of up to 20 meters (about 65 feet). Engineers are planning upgrades to improve the radar image resolution to 4 meters (13 feet). In a separate effort, scientists used Goldstone antennas to bounce a radar signal off Mercury, which resulted in the news that the closest planet to the sun has a liquid core.

Other Deep Space Network technologists spent the year finding ways to enhance and extend its communications capabilities. One of the more intriguing areas of research was in optical communications — using lasers rather than radio signals to send data between spacecraft and the ground. In 2007, JPL engineers showed they could send live high-definition television over a system that emulates transmission from Mars with a laser emitting less power than a nightlight bulb. The system uses new detectors made of indium gallium arsenide and niobium titanium nitride that can count individual photons. As a result, it is able to achieve error-free reception even during daytime.

Engineers also enhanced radio systems by adding capabilities at higher frequencies such as

The network's communication complexes are located around the globe in California's Mojave Desert, Australia and Spain.



Numerous missions supported by the Deep Space Network include the newly launched Phoenix Mars lander (left inset) and the Dawn spacecraft (right inset).

Not long after the Deep Impact spacecraft made history in 2005 by firing a projectile into the nucleus of a comet, ground controllers put it in sleep mode. Two years later, with a new mission to explore another comet, it was time to awaken Deep Impact.

In the meantime, the system of computers on the ground that were used to guide and control the spacecraft had been whittled away; workstations had found homes on other missions. To get ready for Deep Impact's second life, it was necessary to build a new ground system — in a hurry.

Enter Kathy Rockwell's team. "We had a lot to do on a very fast schedule," says Rockwell, a systems engineer who was asked to lead a team of a half dozen individuals responsible for building, testing and delivering the new system in just three months.

For Rockwell, the challenge was another assignment in a six-year JPL career that has focused on ground systems. An Orange County native, she majored in biology at Pomona College and expected to go to medical school, but was put off by the "blood and guts." Through friends she got a job as a computer programmer at TRW for NASA's Gamma-Ray Observatory, in time going back to school for a computer science degree. A few companies later, she had the opportunity to come to JPL. ("I fell in love with the Lab within a week," says Rockwell, who also found a spouse at JPL; she and her husband are avid hikers and rock-climbers.)

Her first major job at the Lab was to deliver software for Deep Impact that would communicate with the spacecraft using a new international protocol modeled on Internet communications. And then this year came the challenge for the ground system makeover.

When the time came to wake up Deep Impact, everything was a go — and the spacecraft was off on its new adventure.

Kathy Rockwell

the microwave Ka-band. JPL provided Ka-band equipment to a group of antennas operated by the Australian government so that they can be arrayed together with Deep Space Network facilities to increase the system's listening power.

In 2007, engineers continued refurbishments to extend the life of the Deep Space Network's older antennas and facilities, many of which date to the 1960s. Structures and electronics were upgraded on the oldest antennas, including the large 70-meter (230-foot) antenna at each of the three complexes in California, Australia and Spain; the upgrades are expected to add a decade to each of the antennas' lives. For the first time in its 40-year history, the Deep Space Network's site in Spain was linked to the commercial power grid of the Madrid metropolitan area. At year's end, work continued to connect this new power source to systems inside the Madrid complex. The site, which lies an hour's drive outside the Spanish capital, has been powered solely by diesel generators. In 2008, drawing power for the site from the commercial grid will help improve air quality in the region.

In addition to the antennas and complexes, engineers focused on improvements to the ground system and the network's overall software architecture. Using a commercial, off-the-shelf product, JPL deployed an industry-standard messaging service on its flight operations network. Users such as personnel working on spacecraft missions can subscribe to receive information updates on the status of events such as transmission of command uploads to spacecraft.

Beyond the Deep Space Network, engineers enhanced JPL's multimission ground system by replacing its 1960s-era navigation software. The new system, called Monte, improves performance and uses modern software technologies that will make it much easier to maintain. The Phoenix Mars lander is the first flight project to use the new navigation system. In another initiative, JPL rolled out a new multimission sequencing system specifically for rover missions.

A balloon flight to measure ozone destruction in the Arctic Circle is typical of research by JPL scientists beyond the Laboratory's flight projects.

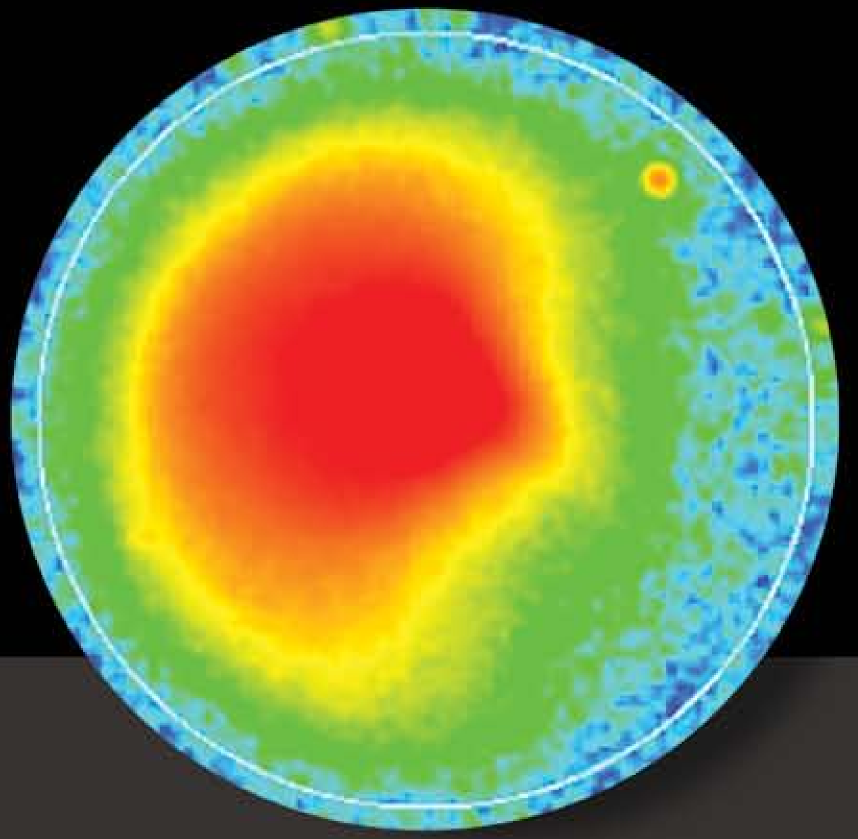
The Laboratory's community of scientists helps define the questions that spacecraft missions are designed to answer — while its cadre of technologists provides the ways and means of getting flight projects accomplished. In 2007, both were active on many fronts.

Many young scientists gain their first experience of JPL as NASA Postdoctoral Fellows. The program allows those who have just received their Ph.D.'s to come to the Laboratory for two to three years to conduct research, gaining further experience in their fields of interest. In 2007, well over one hundred postdoctoral fellows worked at JPL across numerous disciplines within Earth science, planetary science, astrophysics and technology. In August, the Laboratory held its first annual Postdoc Research Day, where the research community was invited to prepare posters and share their accomplishments with the rest of JPL.

Another valuable program for scientists early in their careers is the Laboratory's active program of suborbital research. Using aircraft and sounding rockets that conduct studies across numerous disciplines, suborbital projects not only offer scientific results but also provide excellent training for future principal investigators on competed space missions.

Although the vast majority of JPL science and technology research is funded through competed proposals to national agencies — chiefly NASA — there are several highly competitive, internal funding programs available to JPL scientists and technologists to further their research interests. The Director's Research and Development Fund builds and strengthens stra-

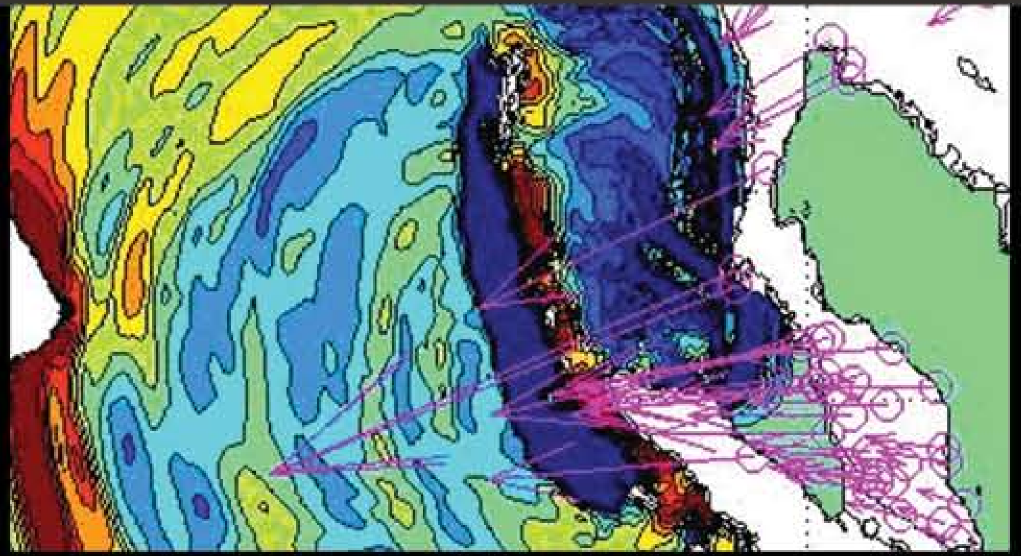
Photo credit: Swedish Space Corp. via Brian Drouin



JPL astronomers used telescopes at multiple observatories to study the coma of Comet Echeclus (left).

The robotic arm for the Phoenix Mars lander (bottom left) is an example of technologies created at the Laboratory.

The Ways and Means



Simulating the 2004 Indian Ocean tsunami, JPL researchers showed how Global Positioning System data could be used to create a warning system.

tegic relationships with domestic universities and partners by pursuing science and technology studies of strategic value to the Laboratory. In 2007, 117 proposals were submitted, and 17 awards were made. Another program, the Strategic University Research Partnership, focuses more specifically on partnerships with 10 universities with which JPL has forged formal ties. The Research and Technology Development program provides yet another avenue for scientists and technologists to gain funding for their cutting-edge research.

JPL scientists may work with the Laboratory's own flight projects, but just as often may use observations from missions managed by other centers or agencies. In 2007, for example, one team of scientists published maps of water content across Mars, working with data from the European Space Agency's Mars Express orbiter. Or they may combine flight project data with observations from the ground. Another team used the Spitzer Space Telescope along with Palomar and other observatories to conduct a study of the large grains in the coma of Comet Echeclus.

Another study focused on tsunamis — the unusually large sea waves created by undersea earthquakes or volcanic eruptions. Researchers found that Global Positioning System (GPS) stations near coastlines were able to detect tsunamis before they reach coastal regions — demonstrating the value of expanding NASA's GPS network to create a global tsunami warning system. Other scientists demonstrated in the laboratory the ability to image an extra-solar planet the size of Earth — far smaller than the giant gas planets detected so far around other stars.

Technologists were responsible for many innovations that improved space missions or offered promising approaches for future ones. One such technology came to the aid of the Phoenix mission, which was studying orbital pictures of the Red Planet from Mars Reconnaissance Orbiter to choose a suitable landing site. More than 36 gigabytes of images were collected at three potential landing sites, but less than one-hundredth of one percent could be analyzed by time-consuming manual methods. JPL technologists created a rock detection and mapping system that can assess the boulders in more than a gigabyte of orbiter imagery in just a few minutes. By the end of the year, the software had detected and mapped more than 10 million hazard rocks. Without the technology, it would have been impossible to meet the landing site certification review deadline.

In other work, technologists made the first test flights of an imaging radar flown on a crewless aircraft to study earthquake faults and vegetation cover. Working with a contractor, JPL helped develop a stellar compass for spacecraft to use to find and control their orientation in space. Combining microgyroscopes, a star camera and innovative software, the device weighs much less and draws much less power than traditional systems.

JPL made substantial contributions to NASA's Constellation program, which is charged with creating a new generation of spacecraft for human spaceflight and exploration of Earth's moon. The Laboratory played a leadership role and provided key personnel to teams designing the Altair lunar lander. JPL also led efforts to establish common architectures throughout the Constellation program so that software and avionic components are interoperable. The Laboratory won an assignment to develop a communications adapter that will link the new Crew Exploration Vehicle with the International Space Station.

JPL's celebrated, six-wheeled Athlete vehicle found itself in the limelight when engineers used it to demonstrate how astronauts could roam across the moon in a mobile habitat. They also displayed new control technologies that

Alfonso Saiz-Lopez

As a young doctoral student, Alfonso Saiz-Lopez spent months at remote stations on Ireland's rugged, windswept western coast and in Antarctica wielding a 2-meter-long (6-1/2-foot) telescope of his own design in search of subtle molecules in the atmosphere.

Efforts like that have led to unusual honors for Saiz-Lopez. Named the European Geosciences Union's Outstanding Young Scientist, he also received a similar honor, the James R. Holton Junior Scientist Award, from the American Geophysical Union.

It is considerable acclaim for a researcher only two years after receiving his degree. Now a NASA Postdoctoral Fellow at JPL, Saiz-Lopez specializes in stalking molecules of iodine in the atmosphere — and understanding what appears to be their significant role in ozone loss.

During his childhood in the plateau of La Mancha in south-central Spain, Saiz-Lopez recalls, "I was always interested in understanding some of the curiosities in our environment. I was puzzled about the changing colors in the sky — the sunset, blues turning into orange." After earning bachelor's degrees in physical chemistry and environmental science at the University of Castilla-La Mancha, he went to England for his master's and Ph.D. in atmospheric physical chemistry at the University of East Anglia. ("No one else in my family had ever gone to university," he says, "much less been involved in science.") Since coming to JPL, he has been hunting elusive atmospheric molecules with instruments on orbiting satellites.

He is also enjoying Southern California. "I very much like California, especially the open-mindedness of people," says Saiz-Lopez, who relaxes by hiking, seeing movies and reading.

If the spacecraft of tomorrow are smarter, it may be thanks at least in part to Steve Chien.

The technologist has spent his 17-year JPL career studying artificial intelligence — or "what in the NASA world is called autonomy," says Chien. A few years ago, he created software that enabled a NASA Earth satellite to recognize natural events such as volcanic eruptions and floods on its own to pinpoint them for further study. In 2007, the software was adapted and uploaded to the Mars Exploration Rovers; it helps the rovers pick out localized windstorms called dust devils from the pictures they take.

The software "can be used in just about any NASA mission," says Chien, who says it could improve future projects ranging from future Mars rovers to space telescopes to outer-planets orbiters. As a first step, the software might help a spacecraft detect interesting events and send a picture for human review on Earth. As a larger step, the spacecraft could act on its own to take more pictures of an event it detects. "The end goal is to have a spacecraft actively looking for interesting things and changing its plans to explore — for example, to have a rover notice an interesting rock, autonomously drive up and place instruments on it," says Chien. "But any time a rover moves, it's risky, so we approach a scenario like that cautiously."

Artificial intelligence may have been a natural calling for Chien, whose late father was an electrical engineering professor at the University of Illinois at Urbana-Champaign who also studied machine smarts. Graduating from high school at 16, Chien went to the same campus for his bachelor's, master's and doctoral degrees (all in computer science; for his undergrad degree he included minors in economics and math). Outside of his JPL work, Chien is involved in a startup company backed by the Virgin Group, using artificial intelligence concepts to create an online marketplace for private jets — "something like Expedia or Lending Tree for private aviation."

"My father was very career focused and a driven individual," says Chien, who calls it a "typical immigrant thing"; both his parents came to the United States from China after World War II. His mother is a self-taught real estate developer and investor who earned an MBA before it became fashionable. Among his three siblings, two are corporate executives in the business world, and the other is a supercomputing researcher who is now vice president of technology at Intel. "We're all classic overachievers," says Chien. "I joke that I'm the slacker in the family."

Steve Chien

allow astronauts to use every leg on the vehicle as a manipulator or tool, apart from its role in mobility. In September, NASA's lunar architecture team recommended mobile habitats using JPL's Athlete vehicle as a model. In 2007, the Laboratory also made significant progress on a radiometer that will fly on the Lunar Reconnaissance Orbiter, as well as two instruments that will monitor air quality in habitats such as the space station.

About 15 percent of JPL's budget consists of work for non-NASA sponsors. In pursuing such work, the Laboratory emphasizes trend-setting technologies and flight demonstrations that have direct benefit to both its non-NASA and NASA sponsors. Current areas of emphasis include lightweight optics and radars, quantum technologies, full-spectrum optical systems, advanced image processing systems, integrated data fusion capabilities and climate monitoring and environmental sensors and data analysis.

In the commercialization arena, JPL works to transfer space technologies to outside partners for terrestrial use. Imaging software used on Mars Reconnaissance Orbiter was licensed to a medical technology firm to create a novel, non-invasive way of detecting atherosclerosis. The system uses standard ultrasound technology with sophisticated software to give patients a readout of their vascular age.

JPL also invites commercial partners to help develop technologies of key interest to space missions. In 2007, the Laboratory pursued a number of innovative partnerships in the area of Global Positioning System (GPS) and navigation. The efforts will help improve navigation for Earth science missions that depend on GPS for their science, such as the currently orbiting Gravity Recovery and Climate Experiment, or Grace, as well as the soon-to-be-launched Ocean Surface Topography Mission.

Key mission events such as launch of the Phoenix Mars lander capture the imaginations of the public across the United States and around the world.

Whether the subject is the launch of a Mars lander or unpuzzling images from the flyby of a moon of Saturn, sharing the excitement of JPL's missions with the public comes down to the art of storytelling.

One of the Laboratory's most compelling stories is the saga of how its involvement in space science came about — the creation and launch of Explorer 1 a half-century ago. In 2007, JPL made many preparations to make the anniversary come alive for public audiences, many of whom are far too young to remember the Cold War event of the 1950s. The Laboratory produced a 55-minute film documentary, *Explorer 1: Beginnings of the Space Age,* as well as a 20,000-word book on the background of the historic mission. Toward year's end, JPL and Caltech staff helped decorate a float for the Tournament of Roses parade celebrating Explorer 1 and linking it to the missions of today. Other preparations included commemorative banners to be displayed on the streets of Pasadena and around JPL, as well as a special Web site and plans for events in January 2008 that would bring retirees who worked on the mission back to the Laboratory.

In telling other stories, JPL frequently worked with partners in the entertainment industry to weave developments from space missions into the public imagination. The Laboratory hosted the set designer for the upcoming *Star Trek XI* film, and organized plans for events with Walt Disney Pictures in conjunction with the release of *Wall-e*, a new Pixar animated feature about a wayward robot. The *Star Trek: The Next Generation* 30th Anniversary DVD was released, featuring content on how future JPL planet-finding missions might be able to find planets similar

to Spock's home planet, Vulcan. A collaboration with Lucasfilm resulted in the use of *Star Wars* images and clips to illustrate a feature story about the Spitzer Space Telescope's observations of planets orbiting double stars. The Laboratory also continued to find audiences for videos and podcasts on venues such as iTunes and YouTube.

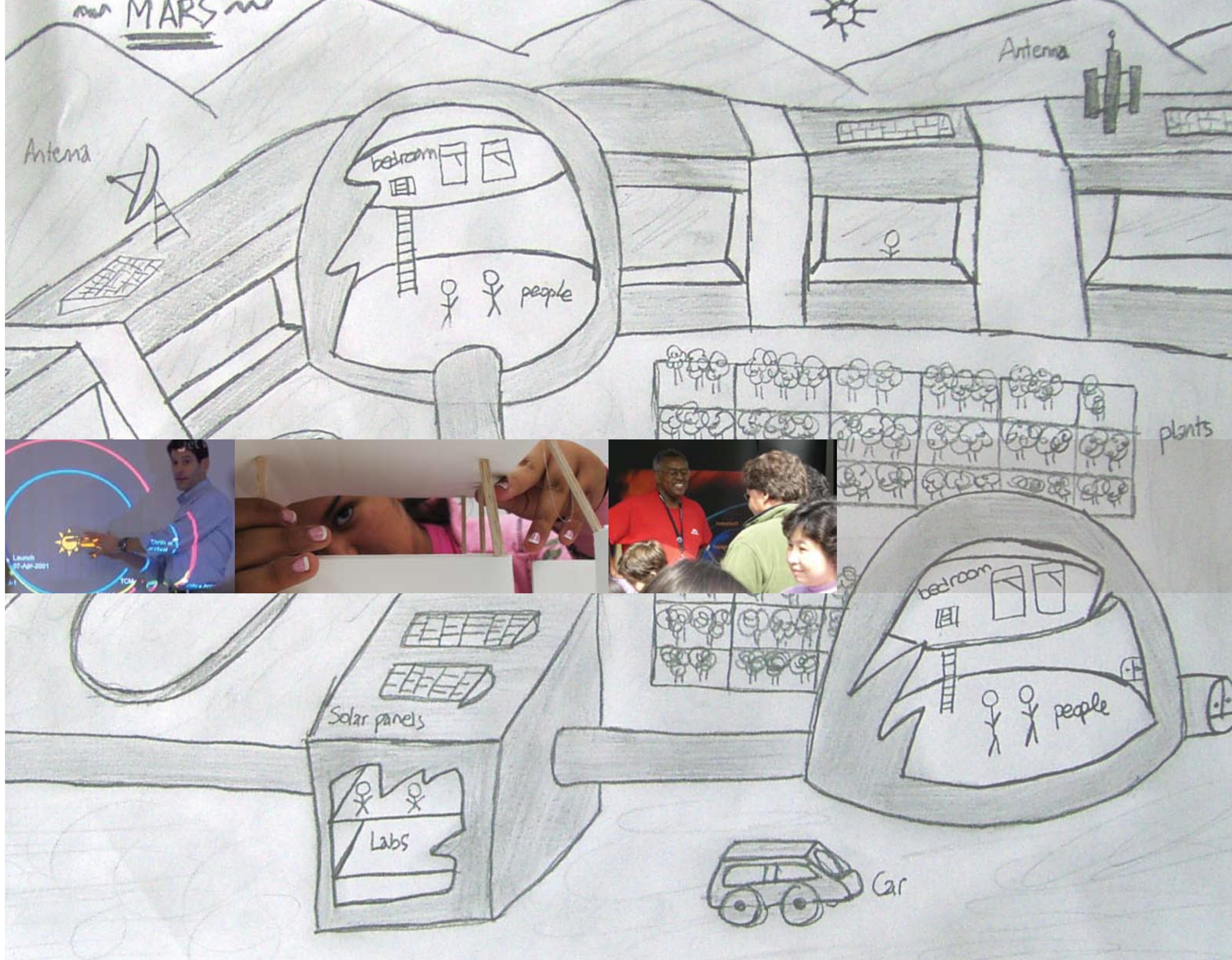
Many public encounters with JPL, however, were not via mass-delivered media but in one-on-one experiences. The Laboratory hosted more than 23,000 visitors who arrived on nearly 600 tours. Seventeen public events with exhibits were attended by nearly 57,000, including a monthly local lecture series that drew an audience of more than 5,000. JPL hosted regional competition for 24 Los Angeles–area teams entering the Science Bowl, a Department of Energy–coordinated tournament for high school students. JPL staffed the Ocean Sciences Bowl held in Los Angeles, and also provided staff and extensive support for First Robotics, a national engineering contest in which student teams build and operate robots.

Hundreds of students wrote essays to enter the Cassini mission's Scientist for a Day contest. The award-winning "Reading, Writing and Rings" Cassini literacy program continued to find wide use in schools.

On the Web, JPL debuted a new site called Virtual Field Trip designed to prepare schoolchildren for their first visits to the Laboratory. JPL received a handful of honors in the W3 Awards given by the International Academy of the Visual Arts, including a best-of-show for a video on the search for life outside Earth, a gold award and several silvers. For the second year, JPL's public home page received a nomination for a Webby

JPL's Imagine Mars program ▷ challenges young people to develop critical thinking by conceiving how they would organize settlements on the Red Planet (background image and center inset).

Leaders of flight projects frequently use events such as talks and the Laboratory's annual open house to share their results with the public (left and right insets).



Picture a Mars dotted with human communities — not merely spartan lander sites, but outposts of civilization with homes and gardens and meeting squares.

Sound like the product of a very active imagination? That's precisely the point. Visions like these are the frequent output of Imagine Mars, a public engagement program JPL manages for NASA in partnership with the National Endowment for the Arts. Targeted primarily to under-served youth across the country, Imagine Mars builds space-science literacy through the arts.

According to David Delgado, Imagine Mars' creative lead, the program isn't just about interesting students in science and technology. It can also, he says, "empower them to become informed decision makers and critical thinkers in an increasingly technology-driven world."

In the program — which can last from a single day to many months — participants are challenged to think about how to build a Mars community. What would they bring? What would they leave behind? How would they live and work? Participants are introduced to concepts such as gravity and atmospheric conditions to understand how their initial ideas would have to change to meet the challenges of the extreme Martian environment, and the expression of their new knowledge and ideas for the future comes in the form of drawings, songs, plays and presentations.

Delgado has a unique combination of skills to bring Imagine Mars to life. A native of Santa Barbara, he majored in anthropology at UCLA. After teaching English in South America for two years, Delgado came back to Southern California and graduated from Pasadena's Art Center College of Design. After working as art director at several advertising agencies in Los Angeles, he arrived at JPL in 2005.

Since then, he has led Imagine Mars activities with a number of high-level partners, including the U.S. Department of Housing and Urban Development's "Neighborhood Networks." Notably, he is working to help hurricane-affected youth in Louisiana cope with the devastation and rebuilding of their own community, a natural link to building one from the ground up on another planet.

"I see myself as both an artist and a teacher," says Delgado, who comes from a medical family (his father, from Mexico, is a pediatrician, his mother a nurse). "As an artist, I want to communicate what goes on here at JPL to people in a meaningful and memorable way. As a teacher, I want to carry that message one step further, so that it becomes a building block in their personal growth."

David Delgado

award. The most-downloaded multimedia product JPL produced during the year was a Cassini interactive guide to Saturn's moons Titan and Enceladus, while the Spitzer Space Telescope podcast series *Hidden Universe HD* hit the No. 1 spot on iTunes for podcasts of any kind. In the international Mercury Communications Awards, JPL's annual report won gold and grand awards for writing, and the *Universe* newspaper was honored with a bronze award.

JPL's Night Sky Network, an amateur astronomy club network of 220 clubs in all 50 states, added two more outreach toolkits and boosted its national impact to reaching a total of 600,000 since 2004. Night Sky Network and Center for Astronomy Education programs were awarded a total of $3 million in grants from the National Science Foundation.

A collaboration between JPL and a software developer resulted in the release of an educational product incorporating NASA/JPL images and videos. Designed for children in second grade, the "Jump Start World" package is a three-dimensional learner center that allows students to select from 50 NASA/JPL video sequences to watch. The collection is increased monthly as subscribers download new video segments from a Web site.

Taking advantage of the large number of community colleges (30) in five local counties, JPL offered programs enabling their top students to work directly with Laboratory scientists and engineers. While at JPL, they gain experience and develop credentials that will benefit them as they move on to complete their educations. JPL's major involvement with community colleges, which began in 1997, has afforded some 400 students such opportunities — 55 in 2007 alone.

After many years in planning, NASA launched a space shuttle mission with a crew including an educator astronaut as a mission specialist. JPL supported the mission's education activities and led NASA efforts to reach informal education organizations and communities. JPL's Solar System Ambassadors and Educators offered 160 activities related to the educator shuttle mission across the country, directly involving more than 50,000 people and thousands of others indirectly.

Revitalizing the Laboratory's infrastructure and physical facilities is a high priority for JPL.

The processes that make up JPL's institutional environment cover a diverse range of functions, from business operations to information technology to human resources. Much energy was focused in 2007 on making enhancements to those many areas.

One change with a great impact on most JPL employees was the adoption early in the year of an alternative workweek schedule. Also called "9/80," the schedule allows employees to complete 80 hours of work in nine workdays every two weeks, giving them every other Friday off. About 70 percent of the Laboratory's staff went on the 9/80 schedule, which had been the top desired benefit in an employee survey. Considerable work was required to implement a new online timekeeping system, but the rollout went smoothly and feedback on the new schedule was very positive.

In the same employee survey where staff backed an alternative workweek, they also expressed a desire for more progression opportunities in JPL's career levels. This prompted the Laboratory to undertake in 2007 a comprehensive redesign of its job classification framework. The goal is to add career levels for exempt, nonexempt and management employees. Teams spent the year creating the new job family classification structure and developing job family matrices. Implementation of the new structure is scheduled for fall 2009. The Laboratory also introduced new training for employees in diversity and inclusion — ideas on nurturing a welcoming environment for employees and affiliates from all ethnic and cultural backgrounds.

In the information technology realm, JPL entered into a major new contract with an outside vendor for desktop services — the many functions that go into providing and

Had it not been for Mary Rivera's student internship at JPL, would her degree in international business from Cal State Los Angeles have taken her into some enterprise beyond America's borders?

Rivera may never know. While finishing her bachelor's degree in business and computer information systems a decade ago, she took an academic part-time job at the Lab working in facilities. After graduating, she took a permanent job in JPL computer security. Some years and a master's degree (from Claremont Graduate University in computer information systems) later, protecting information technology assets turned into her career.

But her international interests returned on one front. In recent years, Rivera has been involved in coordinating how JPL's foreign national workforce gains access to the Lab's computer resources. Implementing online systems to automate access "was fairly difficult," Rivera recalls; export reviewers had to clear JPL computers and Web sites system by system. "Now everyone can see a lot more than they could in the beginning. People are a lot happier."

When she was younger, looking ahead to her career, "I thought I'd be traveling," says the Los Angeles native, the daughter of parents from Ecuador and the first generation of her family to go to college. "But I enjoy the work, and interacting on the job with people from many different countries." And after-hours? "I have a two-year-old daughter," she says, "so on weekends, my trips are pretty much to the playground."

Mary Rivera

maintaining desktop computers across the Laboratory. In the process, JPL sought to improve computer support with such enhancements as integrated messaging (e-mail, calendaring, instant messaging, list services and newsgroups that interact smoothly), improved telephone support and simplified bundles of standard software. The new contract was to take effect at the beginning of calendar year 2008.

In other information technology initiatives, JPL added computing capacity to meet supercomputing needs for new flight projects such as the Phoenix Mars lander. The count of central processing units was more than doubled to 2,624, and a petabyte (a quadrillion — or million billion — bytes) of disk storage was added. Numerous other tasks were under way in other areas such as online transfer of engineering data, disaster recovery, modernization of flight networks, introduction of new procurement, subcontractor personnel and student tracking systems, instant messaging and desktop on-demand television replay of recorded events.

Information technologists also sought to test and offer new capabilities to improve work life such as online Wikis for information-sharing. Online systems were also introduced for materials inventory and vehicle fleet management.

Export compliance was an area that required a great deal of focused effort and cooperation across many institutional, business and computer security teams. The Laboratory is obligated to make sure that it does not inadvertently disclose to foreign audiences technologies that are defined under federal law as being of key strategic value to the United States. Because of the numerous ways that JPL staff communicates with external colleagues and the public — not to mention the many foreign citizens on JPL's workforce — this is a challenge to manage successfully. In 2007, JPL adopted a set of rules defining different categories of information release to make the requirements as easy as possible to follow. JPL debuted a revised export compliance Web site for employees, as well as a new online system to automate and streamline the process for clearing scientific and technical information for public release.

The Laboratory proved its commitment to being environmentally responsible on a number of fronts. JPL won the top overall award in the State of California's "Flex Your Power" program, a partnership of state government, utilities and business to save energy. JPL also won the national award of the Association of Energy Engineers for having the highest-achieving energy program in the western United States. On another conservation front, JPL received the Metro Corporate Award for the breadth and effectiveness of its employee rideshare program, which has become a model for the transportation industry.

One place where a "green" philosophy is much in evidence is in the Flight Projects Center, a major new building that will offer labs, offices and meeting rooms for about 600 staff. Ground was broken in May, and contractors spent the balance of the year carrying out substantial work to regrade and prepare the hillside site.

In business operations, JPL became the first NASA center to have a fully validated capability for earned value management — a project management process that helps managers assess and check status of work by analyzing integrated cost and schedule performance data. The Laboratory received a validation letter in March from the government's Defense Contract Management Agency. JPL flight projects using the earned value management system include Aquarius, Dawn, Kepler, the Moon Mineralogy Mapper, Mars Science Laboratory, Orbiting Carbon Observatory, Phoenix, Space Technology 8 and the Wide-field Infrared Survey Explorer.

In business outreach, the Laboratory coordinated its 19th annual conference for small business in March. NASA's deputy administrator, Shana Dale, was keynote speaker for the event attended by more than 1,000 people.

In 2007, JPL received an unqualified audit opinion from PricewaterhouseCoopers LLP for fiscal year 2006. That was among many validations that attested to the health of JPL's institutional operations, in which the Laboratory aspires to a level of excellence matching its technical accomplishments.

Rami Wehbe

When Rami Wehbe arrived in Los Angeles from Lebanon at age eighteen, it was a tough transition. Tearing himself away from a very close family to attend college in the United States, he had to adapt to a new culture and become proficient in English.

A few years later, things are different. With a degree in mechanical engineering (from Cal Poly Pomona) and an MBA (from USC) under his belt, Wehbe found himself in demand with several offers from groups at JPL when he finished school in May 2007.

"I switched from the business side to the technical," says Wehbe, who also logged time working as an oil company engineer in Africa after receiving his bachelor's degree before returning to school for the MBA. "I started at JPL as an administrator in the optics section, but I wanted to attack things from the technical side — to pay my dues as an engineer." A few months after his arrival, he switched to an engineering position doing design and structural analysis on the Space Interferometry Mission.

Wehbe was offered a job under what is known as JPL's early career hire program, which offers incentives to managers to recruit "fresh-outs" newly graduated from college. The aim is to ensure that there is a plentiful pipeline of talent at the early end of the career spectrum to offset JPL's aging population of engineers and scientists.

After a few years in residence in Southern California, he says he plans to stay: "I really like the culture and the people," says Wehbe, whose passion outside work is soccer, a game in which his team won a local championship. "JPL has some of the smartest people."

Major External Awards

Leon Alkalai and Gregg Vane
Elected to International Academy of Astronautics

Paul Backes and Larry Matthies
Technical Field Award in Robotics and Automation, Institute of Electrical and Electronics Engineers

Yoseph Bar-Cohen
President's Award, International Society for Optical Engineering

Josette Bellan
Elected Fellow, American Institute of Aeronautics and Astronautics

Donald Bickler
Elected Fellow, American Society of Mechanical Engineers

Charles Elachi
International von Kármán Wings Award, Aerospace Historical Society

Elected to Board of Councillors, National Academy of Engineering

Gravity Recovery and Climate Experiment Mission Team
William T. Pecora Award, U.S. Department of the Interior

Daniel Helmick, Yang Cheng, Daniel Clouse, Max Bajracharya, Larry Matthies and Stergios Roumeliotis
Best Paper Award, Robotics Society of Japan

Gerard Holzmann
Honorary Doctorate, University of Twente, The Netherlands

Jet Propulsion Laboratory
Flex Your Power Award, California Flex Alert Network

JPL Media Relations and Institutional Communications Teams
Best in Show, Gold Award for Web Videos, W3 Awards, International Academy of Visual Arts

JPL Rideshare Program
Diamond Award, Los Angeles County Metropolitan Transportation Authority

JPL TerraLook Team
Finalist, St. Andrews Prize, University of St. Andrews, Scotland

Rosaly Lopes and Pamela Conrad
Wings Award, Girl Scouts of the San Fernando Valley

Mars Reconnaissance Orbiter
Selectee, "America's 100 Best," Reader's Digest

Mars Reconnaissance Orbiter Development and Operations Teams
Stellar Award, Space Center Rotary Club of Houston

Thomas May
Legacy Award, U.S. Small Business Administration

Firouz Naderi
Von Kármán Award, Engineers Council of the San Fernando Valley

Franklin O'Donnell
Grand Award, All Writing Categories, Mercury Communications Awards

Gold Award, Annual Report Writing, Mercury Communications Awards

James Rose
Commendation, Space Topic Study Group, American Philatelic Society

Alfonso Saiz-Lopez
James R. Holton Junior Scientist Award, Atmospheric Science Section, American Geophysical Union

Stardust Team
Stellar Award, Space Center Rotary Club of Houston

Nelson P. Jackson Award, National Space Club

Space Laureate Award, Aviation Week & Space Technology

Edward Stone
Philip J. Klass Award for Lifetime Achievement, Aviation Week & Space Technology

Ashitey Trebi-Ollennu
Sir Monty Finniston Achievement Medal, Institution of Engineering and Technology

Barbara Wilson
Decoration for Exceptional Civilian Service, Secretary of the Air Force

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Grail, Juno, Mars Global Surveyor, Mars Science Laboratory, Mars Reconnaissance Orbiter, Odyssey, Phoenix, Rosina, Spitzer Space Telescope, Stardust

Ball Aerospace & Technologies Corporation
CloudSat, Deep Impact, Kepler, Mars Science Laboratory, Spitzer Space Telescope, Wide-field Infrared Survey Explorer

ITT Corporation
Deep Space Network Operations, Mars Science Laboratory

Orbital Sciences Corporation
Dawn, Orbiting Carbon Observatory, Space Technology 8

Northrop Grumman Space & Mission Systems Corporation
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Lockheed Martin Integrated Systems
Desktop and Institutional Computing

Computer Sciences Corporation
Information Technology Infrastructure Support

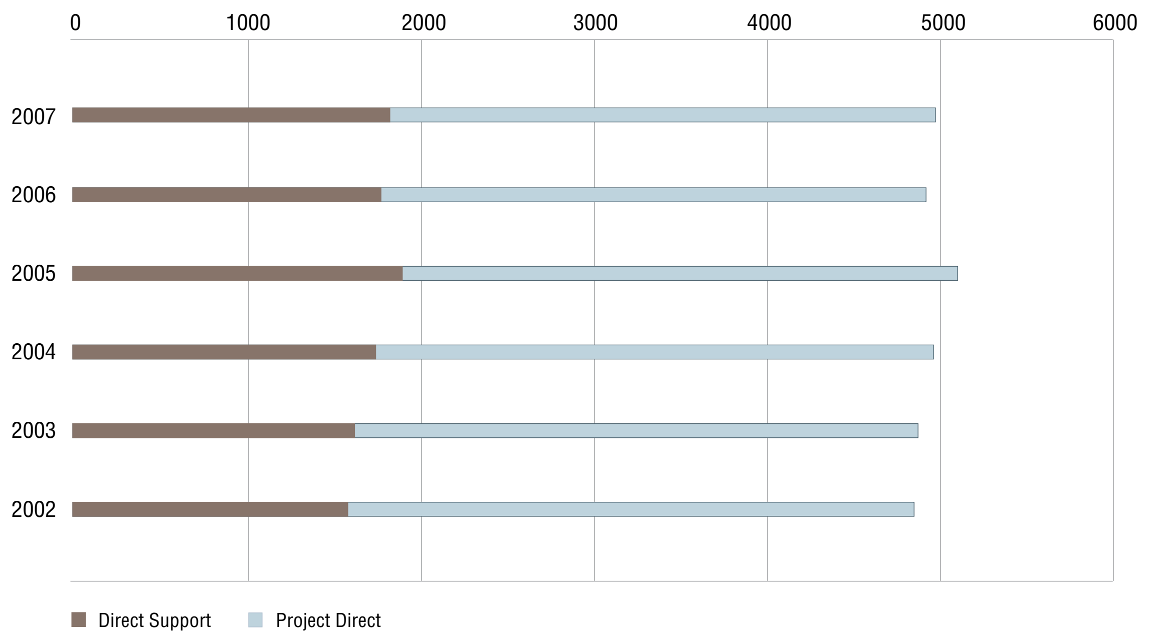
Northrop Grumman Information Technology
Technology and System Development Support

Utah State University Research Foundation
Wide-field Infrared Survey Explorer

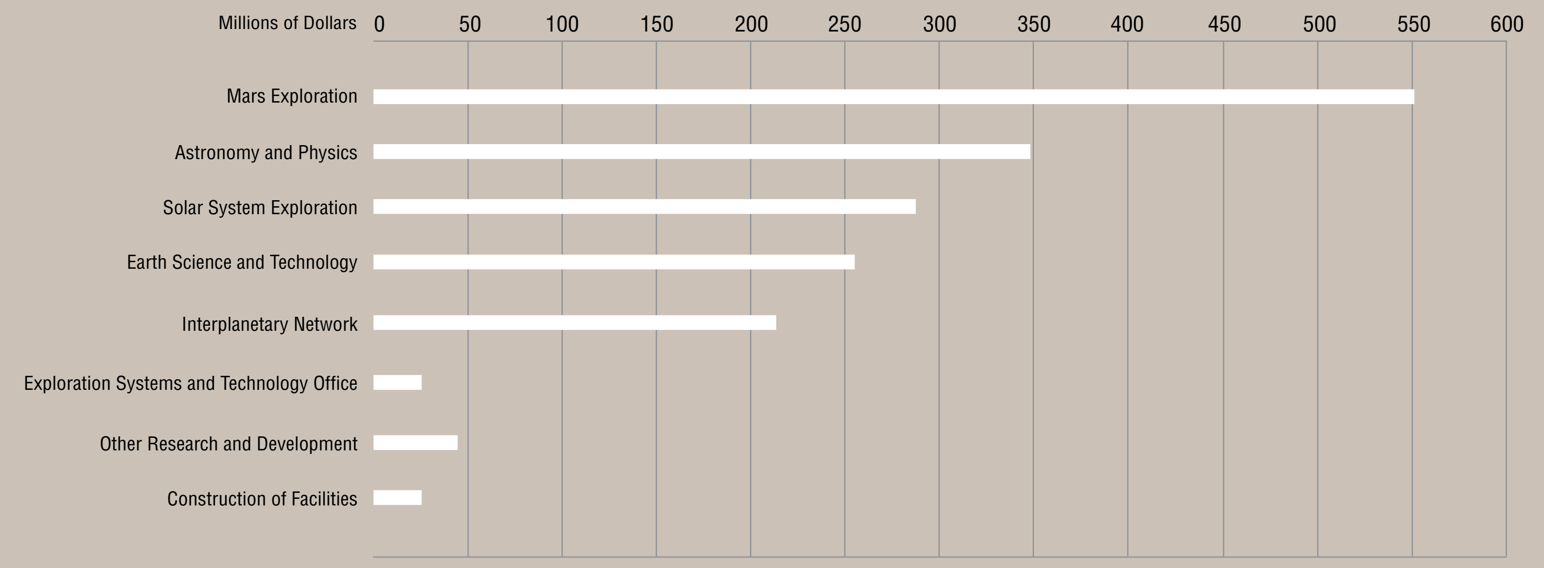
Swinerton Builders
Construction of Flight Projects Center Building

Personnel & Costs

Personnel

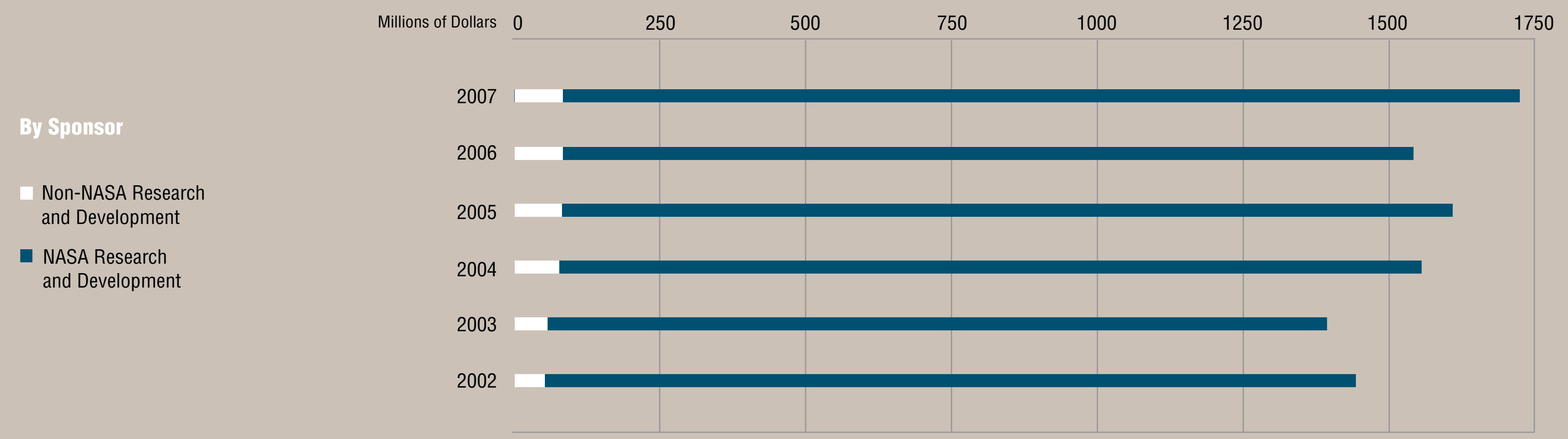


Total Costs By Program



The processes that make up JPL's institutional environment cover a diverse range of functions.

By Sponsor



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A new view of the famous Eagle Nebula was recorded by the Spitzer Space Telescope.