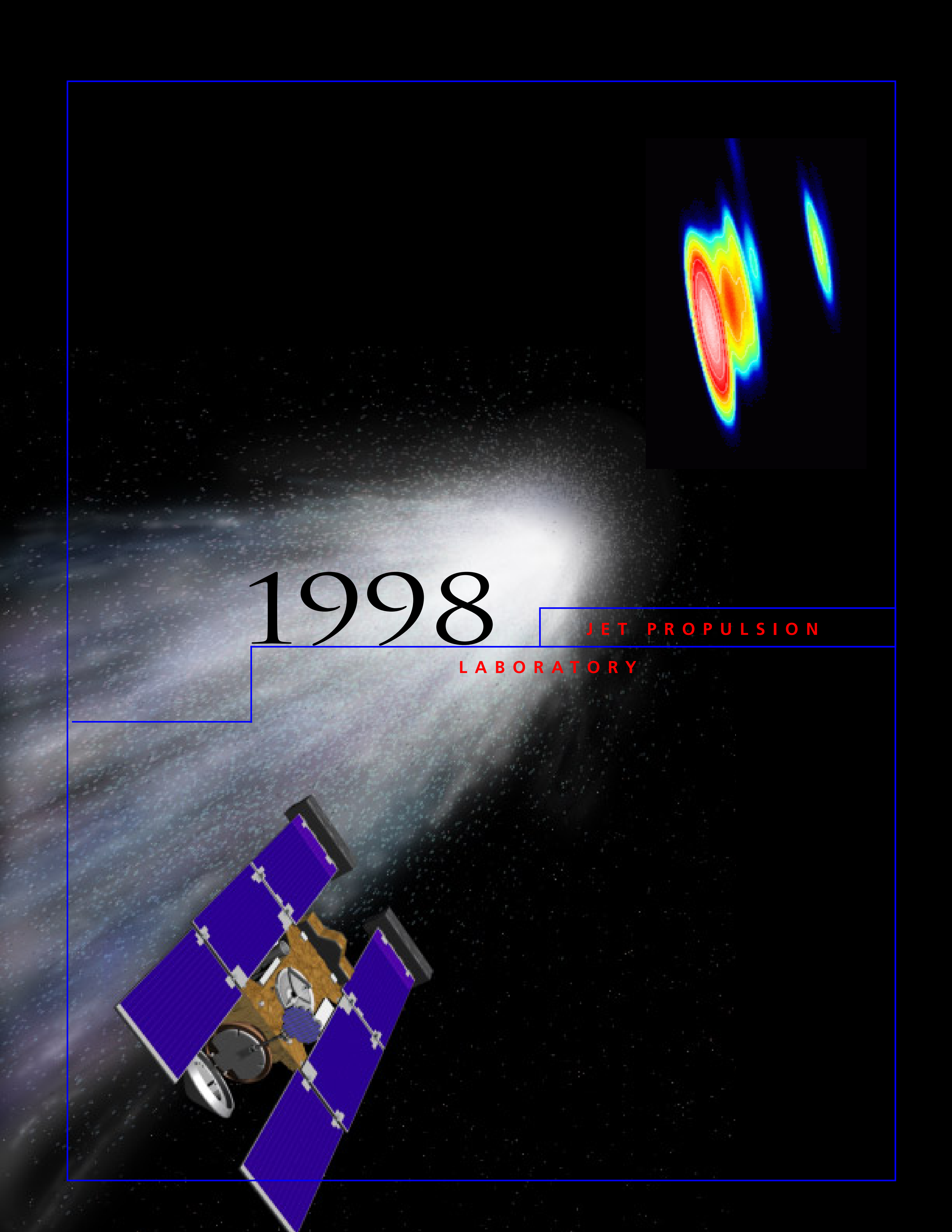
1998 JET PROPULSION LABORATORY



1998

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TWO KEY ANNIVERSARIES MADE 1998 especially memorable for the Jet Propulsion Laboratory. Forty years ago, on January 31, 1958, a rocket carried into orbit the first U.S. satellite — Explorer 1, designed and built by JPL in a remarkably short three months. Later that year, Congress created the National Aeronautics and Space Administration. JPL, a wing of the California Institute of Technology that had performed work for the U.S. Army in the 1940s and 1950s, was transferred to the new civilian space agency.

1998

That milestone created a partnership that, in the four decades since, has resulted in an unparalleled legacy of space exploration. JPL is the world's leading center for deep space exploration. JPL's missions for NASA have blazed the way in exploring every known planet in the solar system, except for distant Pluto. More recently, the Laboratory has directed its expertise toward spaceborne instruments that study Earth itself and the vast depths of the universe beyond our solar system. JPL technology has also been put to use solving down-to-earth challenges in fields from medical imaging to alternative forms of energy.

In the 1990s, NASA has been bringing to life a new philosophy of space missions. Unlike the large, complex spacecraft of preceding decades, the new breed of robotic explorers are smaller, with tightly focused science goals, developed on much smaller budgets and faster schedules. Instead of launching one major mission every few years, several of these small missions can be launched each year. In 1998, several such missions from JPL were poised to embark on a new wave of exciting space exploration.

Galileo's observations of Io indicated temperatures as high as 2,000 kelvins at one volcanic vent. Io's volcanism may have a lot in common with ancient volcanic processes on Earth and other planets.

ENGINEERS AND SCIENTISTS WERE BUSY throughout the year at work on space missions created for a variety of destinations and purposes. Some were bound for Mars, while others were new Earth orbiters studying our home planet, and others were designed to flight-test new technologies. A mission with the nostalgic name "Stardust" is preparing for launch early in 1999. Stardust will fly through the cloud of dust that surrounds the nucleus of a comet — and, for the first time ever, collect cometary material for return to Earth in the year 2006.

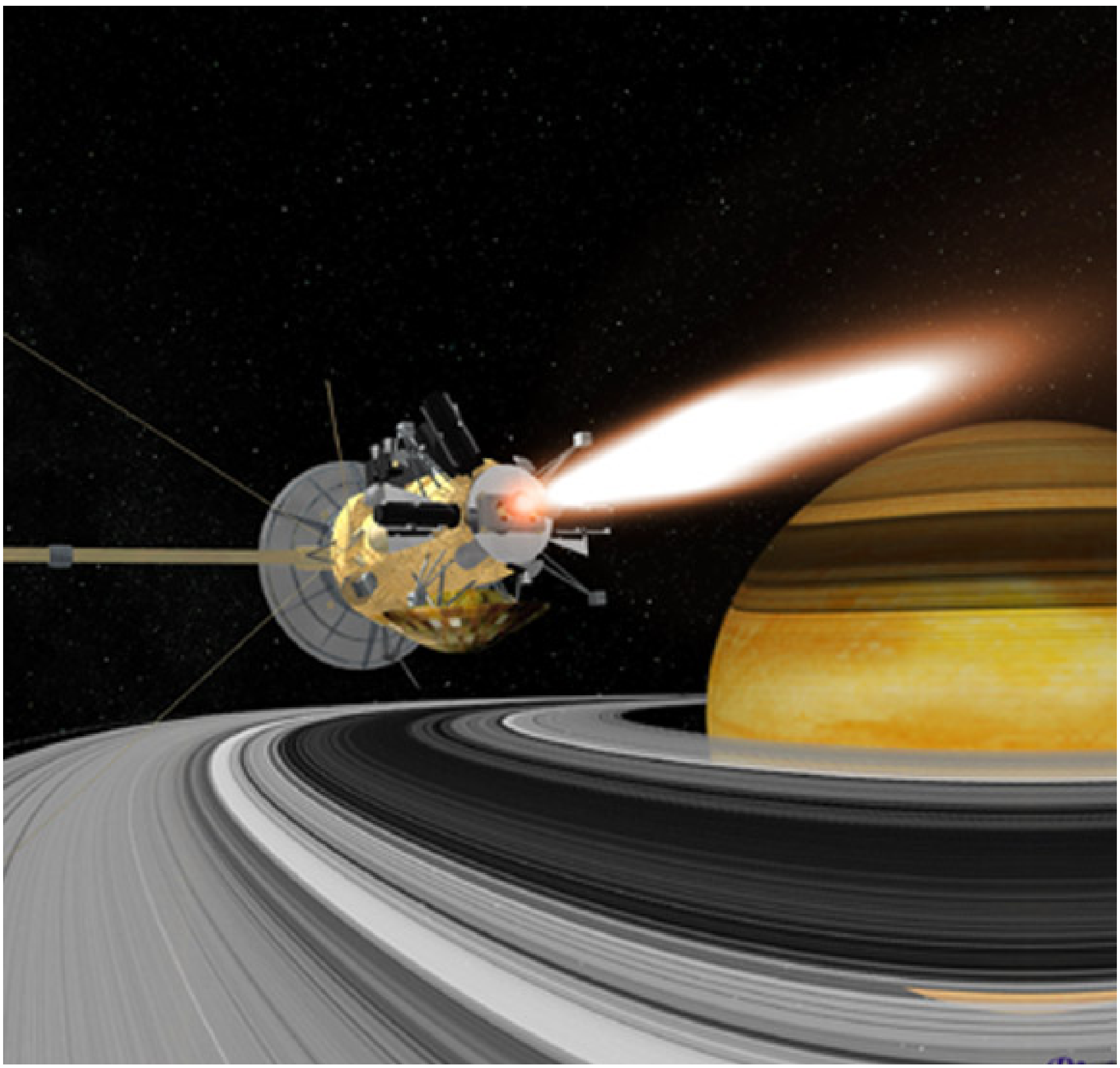
While new, small missions were being finalized, two classic planetary explorers were also busy.

GALILEO

The Galileo spacecraft spent its third year in orbit around Jupiter, enabling a variety of discoveries about the giant planet, its moons and its magnetic field. By studying how radio signals from Galileo were affected as the spacecraft flew by Jupiter's moon Callisto, scientists concluded that this natural satellite has an unusual interior and probably evolved differently than Jupiter's other major moons. Information on Callisto's magnetic field, meanwhile, suggests that it may hide a salty, liquid ocean beneath its icy, cratered crust.

Images of Jupiter's moon Io, meanwhile, revealed dozens of volcanic vents where lava sizzles hotter than any surface temperatures recorded on any planetary body in the solar system. Other pictures showed a close-up view of a fracture on Jupiter's icy moon Europa that stretches as long as the California segment of the San Andreas Fault. The Galileo craft joined the Hubble Space Telescope and an infrared telescope in Hawaii in observing two enormous storms that have been swirling in Jupiter's colorful atmosphere for centuries that recently joined to form a single larger storm. And the spacecraft's dust detector discovered a new, sparse ring composed of smoke-sized particles orbiting

A computer-rendered image of the Cassini spacecraft during its arrival at Saturn in 2004. After going into orbit, Cassini will make high-resolution observations of the planet and rings.



Jupiter in the opposite direction from the spinning planet and its moons. The new ring is distinct from a faint ring system discovered at Jupiter in 1979 by the Voyager spacecraft. In 1998, scientists used Galileo data to conclude that the better-known rings are formed by dust kicked up as interplanetary meteoroids smash into the giant planet's four small inner moons.

LAUNCHED IN 1997, THE CASSINI SPACECRAFT spent the year on the first leg of its interplanetary flight path to the ringed planet Saturn, where it will arrive in 2004 and drop an instrumented probe to the surface of Saturn's moon Titan. In April 1998, Cassini executed the first of several "gravity assist" flybys, passing close to Venus to borrow some of the planet's gravitational energy to speed it on to its destination.

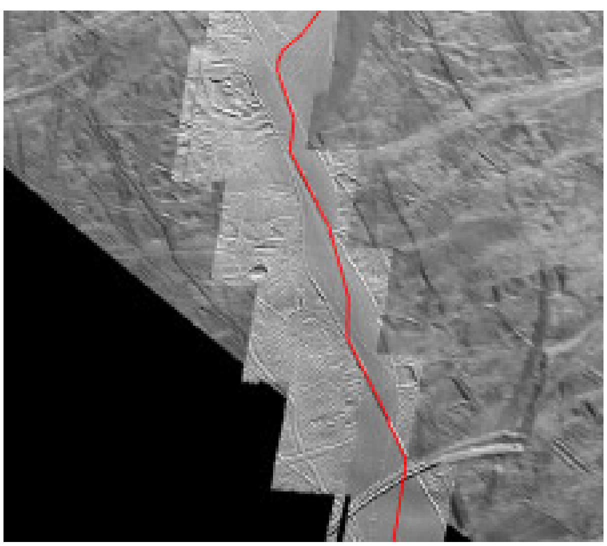
CASSINI

The U.S.–European Ulysses spacecraft completed its first looping orbit around the Sun. Launched in 1990, Ulysses flew first to Jupiter where the giant planet's gravity flung the craft out of the plane in which most of the planets orbit, allowing it to study the Sun's north and south poles. In August 1998, Ulysses detected a cataclysmic magnetic flare emanating from a star that cracked apart halfway across the galaxy. The burst from the star SGR1900+14, located in the constellation Aquila 20,000 light-years away, was created as the star's heavy metal crust fractured and released the most powerful wave of gamma ray radiation yet observed from this type of star.

The Near-Earth Asteroid Tracking system operates autonomously at this U.S. Air Force complex of telescopes on Haleakala, Maui, Hawaii. The system plays a vital role in monitoring near-Earth asteroids and comets.

ASTEROID TRACKING

CLOSER TO EARTH, JPL astronomers combed the sky for near-Earth objects such as asteroids and comets that come close to our planet. New computers were added to double the coverage of JPL's Near-Earth Asteroid Tracking system, which uses automated detectors on a telescope in Hawaii to scan for previously unknown comets and asteroids. Shortly thereafter, the system discovered two large asteroids about 1 to 3 kilometers (0.5 to 1.5 miles) in diameter that pass close to Earth. NASA meanwhile established a new program office at JPL to coordinate agency-wide efforts to study near-Earth comets and asteroids. In 1998 a JPL researcher was also named project scientist for the NASA portion of a joint U.S.–Japanese mission called MUSES-C that will be the first ever to send a lander and robotic rover to an asteroid, and return an asteroid sample to Earth.



This mosaic of Galileo images shows a strike-slip fault (red line) named Astypalaea Linea on Jupiter's moon Europa. Such faults on Europa are thought to be caused by the tidal pull of Jupiter.

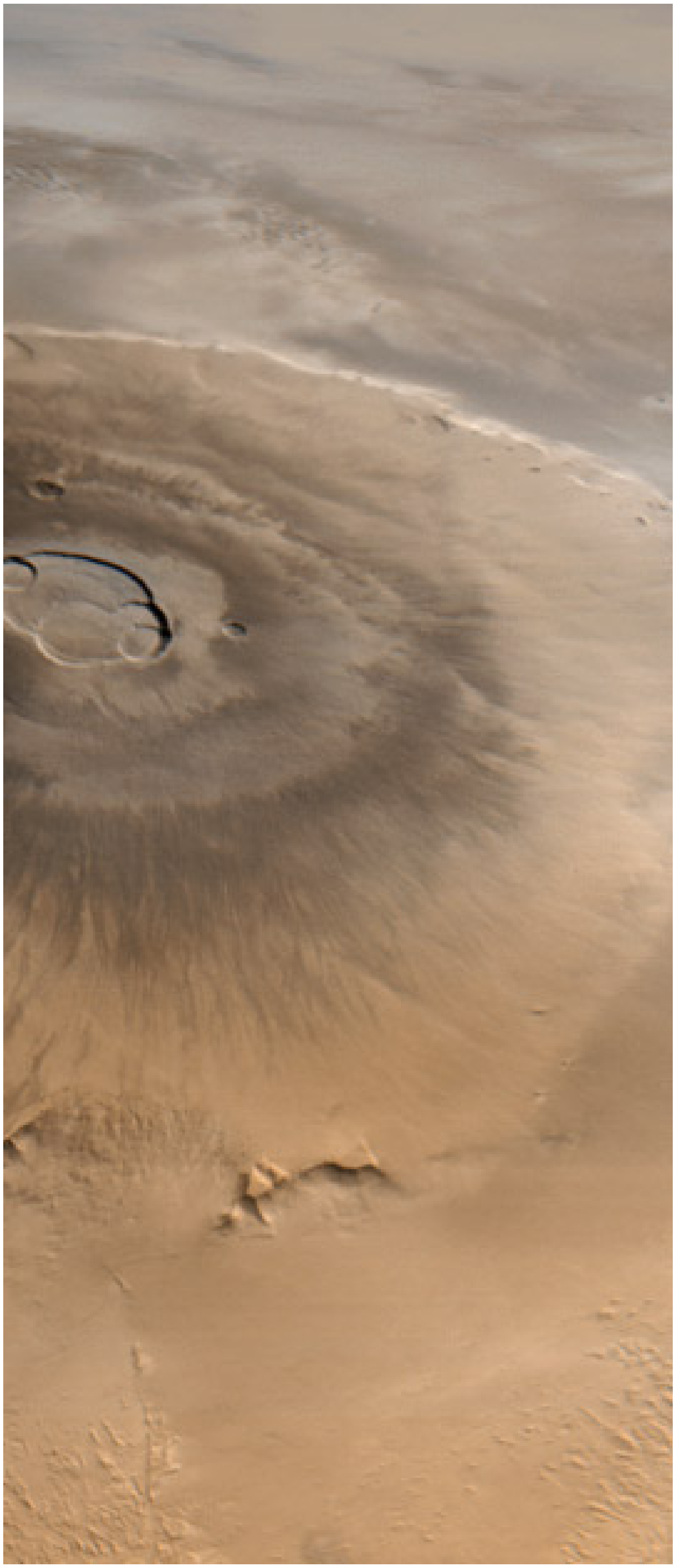
An image of part of the San Andreas Fault (red line) near the San Francisco Bay Area, at the same size and resolution as the Europa image. Plate tectonic forces cause such large strike-slip faults on our planet.

An artist's concept of Mars Global Surveyor over the surface of the red planet. The spacecraft is observing Mars from a low-altitude, nearly polar orbit during its prime mission of one Martian year (nearly two Earth years).

The red planet was very prominent in the minds of JPL engineers and scientists, as one spacecraft orbiting the planet relayed significant science findings, and two more missions were readied for launch.

MARS GLOBAL SURVEYOR PROVIDED SCIENTISTS with a new window on the planet from its vantage point in orbit, thanks to its suite of six instruments. For the first time ever, the spacecraft's camera captured the full evolution of a Martian dust storm, a swirling tempest that eventually grew to about the size of the South Atlantic Ocean. Other images revealed giant plates of solidified volcanic lava and evidence for active dunes near the planet's north pole, with sands that have hopped or rolled across the surface in recent months. The camera team also captured pictures of a feature known popularly as the "Face on Mars" that, in pictures from the Viking orbiters in the 1970s, resembled a helmeted human face. In the new, higher-resolution pictures, the resemblance vanishes, and most viewers conclude that the feature more obviously appears to be a natural formation.

Another instrument on Global Surveyor, the thermal emission spectrometer, discovered the first clear evidence of an ancient hydrothermal system in the form of remarkable accumulations of the mineral hematite, crystallized grains that typically originate from thermal activity and standing bodies of water. The instrument also took temperature measurements of Phobos, one of Mars's two small moons, which suggest that the natural satellite's surface must be composed largely of finely ground powder at least 1 meter (3 feet) thick. Measurements of the day and night sides of Phobos show such extreme temperature variations that the sunlit side of the moon rivals a pleasant winter



A Mars Global Surveyor view of Olympus Mons. The volcano is taller than three Mount Everests, wide as the entire Hawaiian Island chain and nearly flat (its flanks slope only 2 to 5 degrees).

day in Chicago, while only a few kilometers away, on the dark side of the moon, the climate is more harsh than a night in Antarctica.

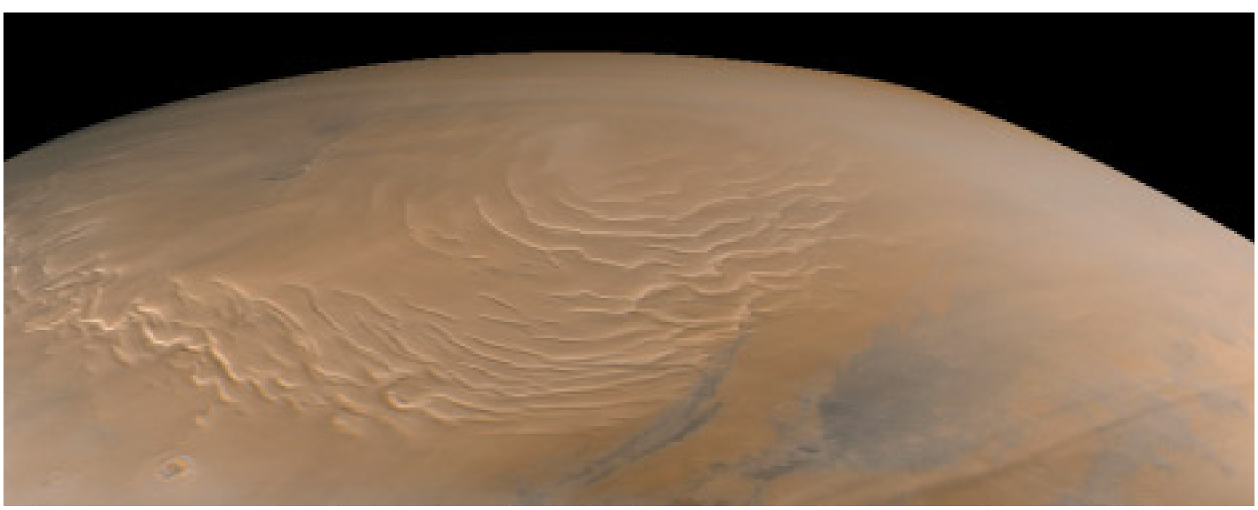
The spacecraft's laser altimeter, meanwhile, provided a three-dimensional picture of Mars's north pole that enables scientists to estimate the volume of the water-ice cap with unprecedented precision, and to study surface variations and the heights of clouds in the region for the first time. Global Surveyor's magnetometer demonstrated that Mars does not have a globally generated magnetic field like Earth's, but instead has small localized magnetic areas in patches around the planet.

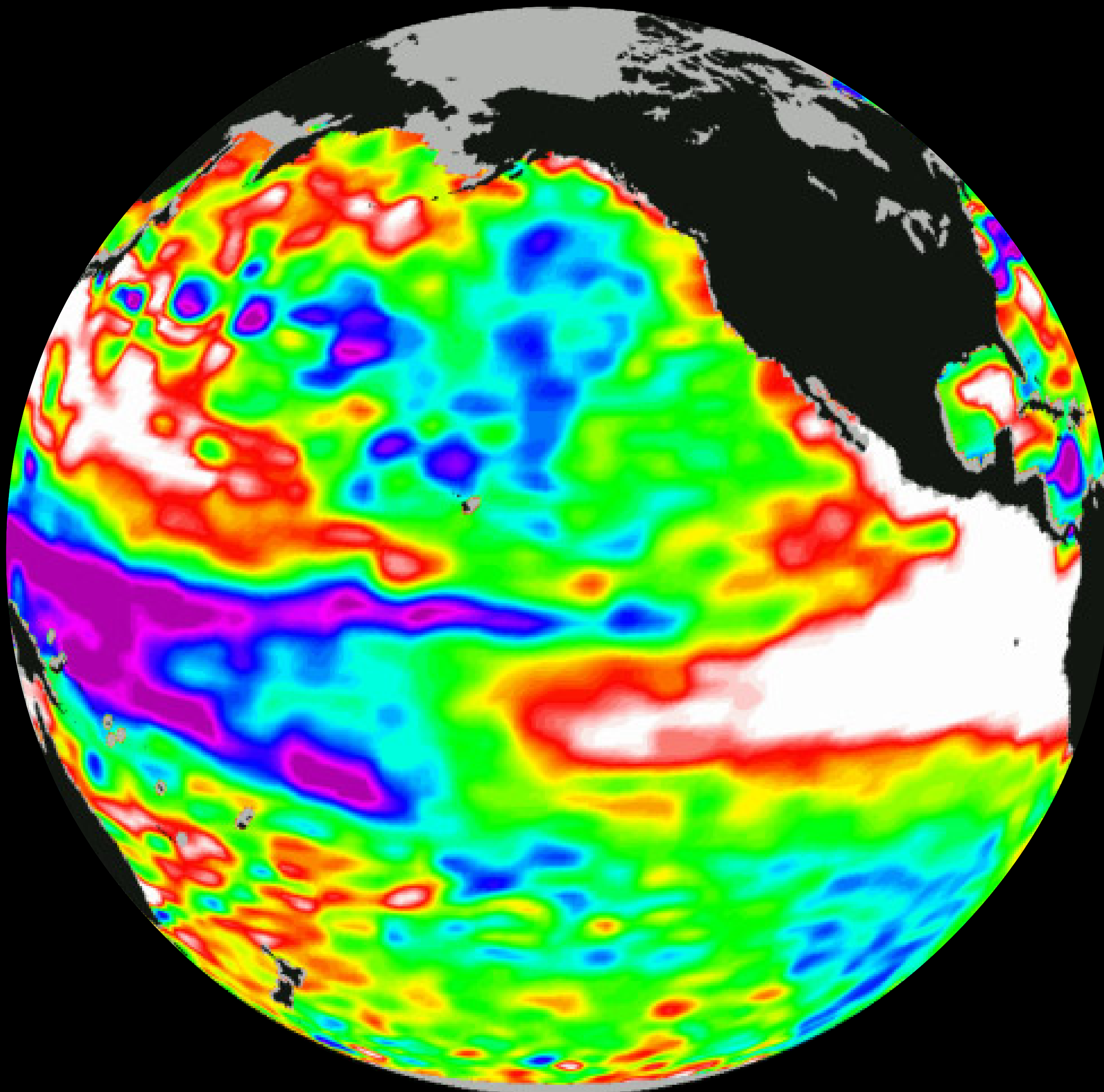
Launched in 1996, Global Surveyor arrived at Mars in September 1997 and spent all of 1998 gradually trimming its orbit from a looping ellipse to a circular shape. The spacecraft has been using a technique called

A color composite of images of the Martian north polar cap taken by Mars Global Surveyor. The layered terrain is believed to be composed of ice and dust deposited over millions of years.

"aerobraking," first demonstrated by JPL's Magellan spacecraft at Venus; during each looping orbit, the spacecraft skims through the planet's thin upper atmosphere where drag gradually slows it down. Plans call for the orbit to be finalized by spring 1999, when its two-year main mapping mission will begin.

IN ADDITION TO WORKING WITH GLOBAL SURVEYOR, JPL engineers and scientists continued to review results from the highly successful 1997 landing of Mars Pathfinder and its rover, called Sojourner. Final preparations were also made for an orbiter and lander developed jointly as the Mars '98 mission. Mars Climate Orbiter was launched in December 1998 and is scheduled to reach the red planet after a nine-month journey. Mars Polar Lander, launched just after New Year 1999, will carry a payload that includes a robotic arm. Polar Lander's target is the layered terrain near the planet's south pole, where it will excavate in search of water ice. Polar Lander also carries two microprobes called Deep Space 2, developed by NASA's New Millennium Program to test new technologies for small probes to explore planetary surfaces.





By January, the pool of warm water (white in the image) in the Pacific Ocean associated with El Niño had decreased by about 40 percent since its maximum in early November. The Topex/Poseidon satellite has been monitoring El Niño/La Niña conditions by measuring sea-surface heights.

AS THE YEAR BEGAN, AN OCEAN EVENT THAT DREW WORLD attention was in full swing — the 1997–98 recurrence of El Niño, an unusual water warming that takes place every few years in the Pacific Ocean. El Niños play havoc with weather on both ends of the ocean, bringing severe drought to the western Pacific and an increase in cyclonic storms in the eastern Pacific. The 1997–98 event was the strongest since a powerful El Niño in the early 1980s.

EL NIÑO

Perhaps the most detailed view of the phenomenon was afforded by Topex/Poseidon, a joint U.S.–French satellite controlled from JPL. Topex/Poseidon measures the shape of the ocean surface around the world once every ten days. Pools of warm water are visible as having a higher level than the surrounding seas. As the months progressed, Topex/Poseidon scientists could watch the march of the warm water pool across the Pacific from west to east. By June 1998, this incarnation of El Niño was weakening. Scientists then began to detect the flip side of the ocean effect — a so-called “La Niña” condition resulting in an uncharacteristically cold water pool in the Pacific.

By the end of the year, scientists concluded that the 1997–98 El Niño event may have been a major contributor to a temporary increase in average global sea level that was detected during the past year. Around the world, sea levels rose an average of about 2 centimeters (0.8 inch) before returning to normal. As the year ended, Topex/Poseidon made news with another kind of achievement — a first-ever experiment in which a satellite autonomously planned its own actions and generated a series of commands to steer itself.

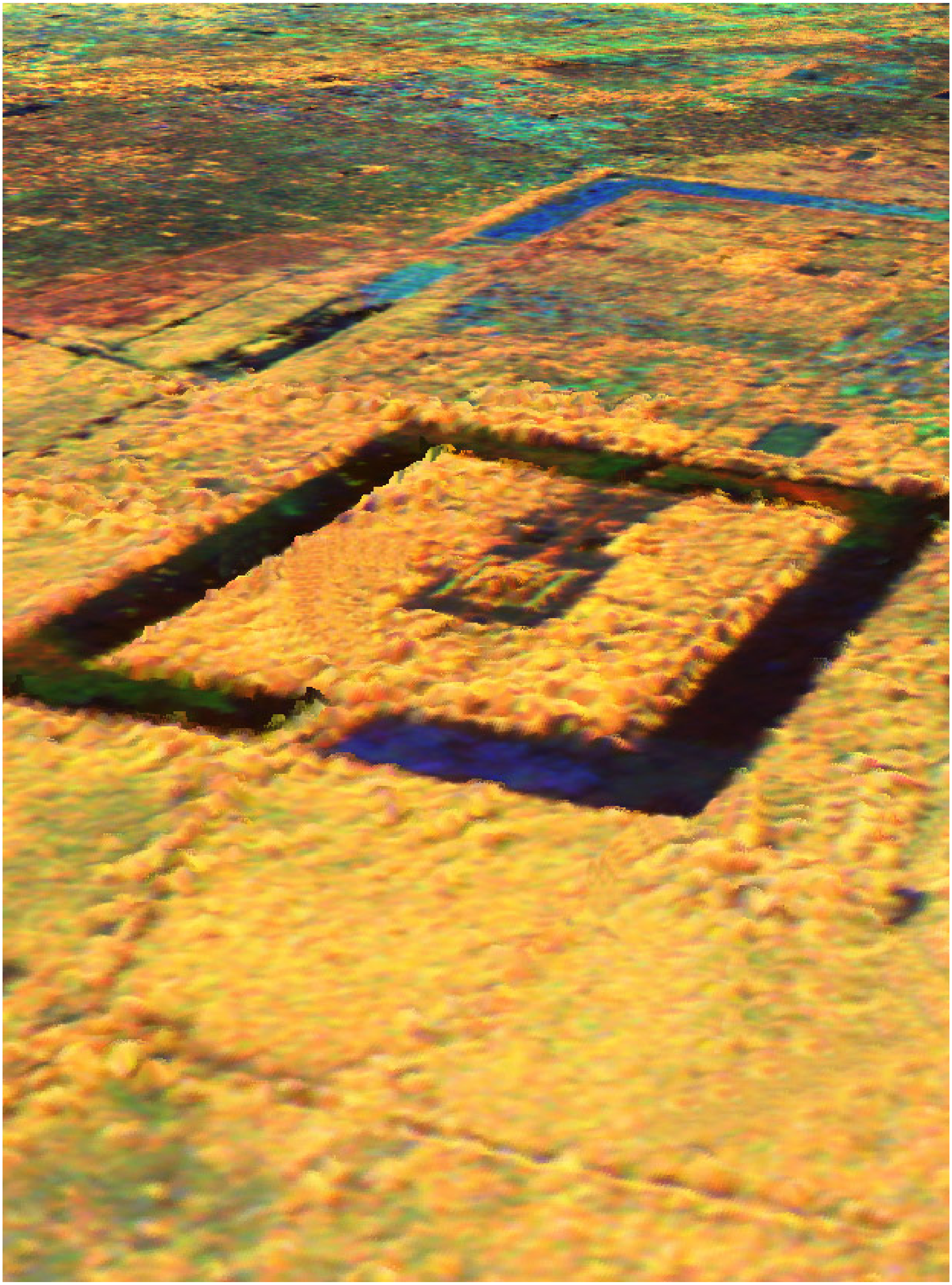
QuikScat will acquire all-weather, high-resolution images of near-surface winds over the global oceans for use in oceanographic, meteorological and climate studies.

The JPL-developed Airborne Synthetic Aperture Radar has provided new evidence of ancient temples in Cambodia. Radar images reveal many features not readily identifiable on the ground.

While Topex/Poseidon studied sea-surface heights, another series of JPL satellites was being developed to scrutinize winds near ocean surfaces. Called scatterometers, these instruments emit radar pulses and analyze how the pulses are reflected from ocean surfaces to detect tiny ripples caused by near-surface winds. Once assembled on the ground, the data offer scientists a visual map of winds over the world's oceans. In 1998, JPL was rapidly preparing a satellite called QuikScat to replace a previous JPL instrument called the NASA Scatterometer, which flew on a Japanese satellite lost during 1997. In June, the replacement instrument was shipped from JPL to the satellite builder in Colorado in preparation for launch in 1999.

SCIENTISTS WORKING WITH A JPL imaging radar instrument flown on airplanes announced the discovery of new evidence of a prehistoric civilization and remnants of ancient temples in Angkor, Cambodia. The finding was made possible by highly detailed maps created with data from the Airborne Synthetic Aperture Radar instrument. Later in the year, the instrument was flown for several weeks across the United States on a DC-8 jetliner exploring possible commercial uses for the imaging radar such as studies of agricultural yields, forest health, and volcanic and tectonic activity. The DC-8 that flew the airborne radar also carried a JPL experiment called the Airborne Cloud Radar, which is designed to improve our understanding of clouds and how they affect our environment.

In addition to these radar-mapping efforts, NASA announced the astronaut crew for a future shuttle mission to fly another JPL imaging radar instrument called the Shuttle Radar Topography

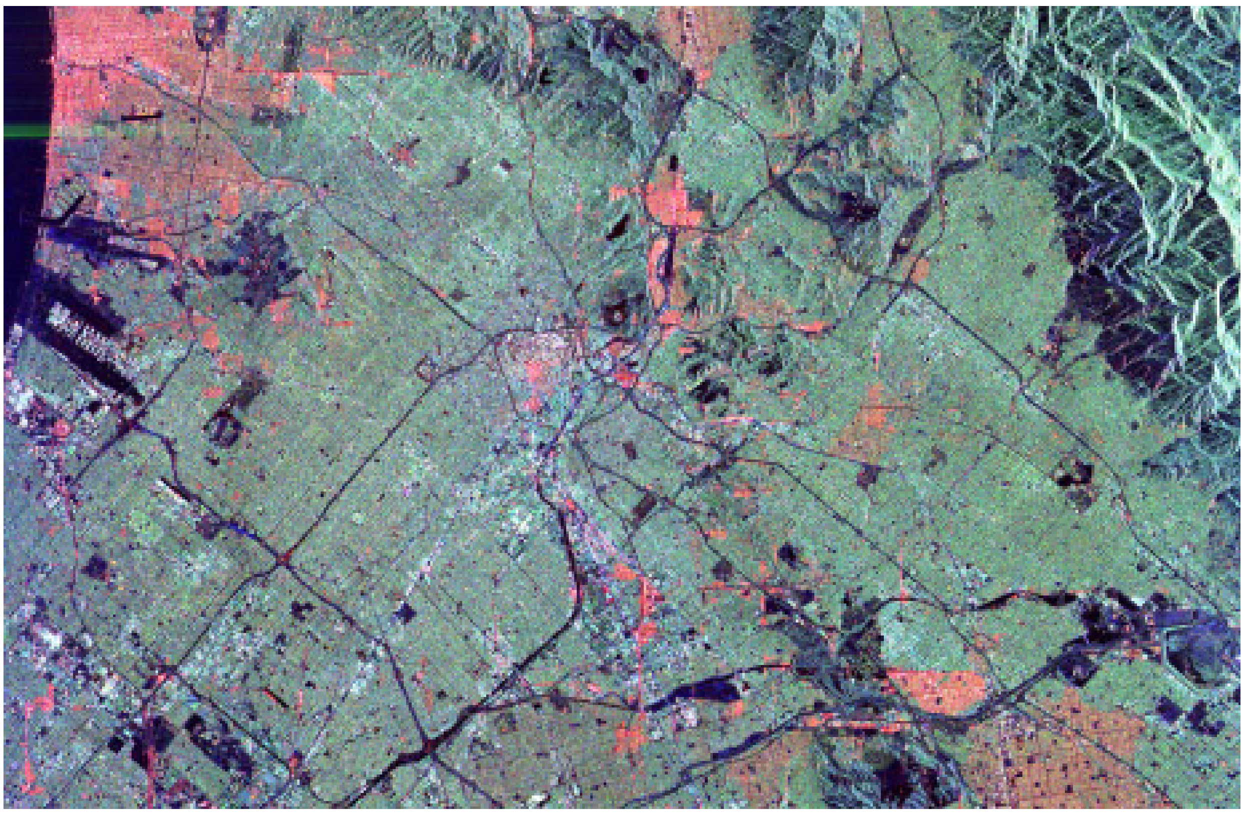


Mission. NASA also selected a JPL satellite project called CloudSat to develop further for possible launch under the agency's Earth System Science Pathfinders program.

EARTH

OTHER RESEARCHERS MADE SIGNIFICANT STRIDES during the year studying earthquakes and the movement of Earth's tectonic plates with radio receivers that can pinpoint their positions on the globe with high accuracy using signals from orbiting Global Positioning System (GPS) satellites. A team led by a JPL geophysicist announced that downtown and west Los Angeles are moving toward Southern California's San Gabriel Mountains, and the metropolitan area in between is being and will be squeezed slowly over the next several thousand years. New mountains, they speculated, may be forming to the south of the towering San Gabriels. The results were based on data from the Southern California Integrated GPS Network, an array of 60 current and 250 planned GPS receivers operated by JPL and other partners that continuously measures the constant, yet tiny, movements of earthquake faults throughout Southern California. During the year, a new online educational tool that allows students to track earthquake motions from their classrooms was made available at a JPL website.

In other Earth science news, an international team led by a JPL researcher announced the discovery of two new sites in Belize and Mexico that add further evidence to the theory that an asteroid or comet collided with Earth about 65 million years ago, killing the dinosaurs and many other species on the planet.



Data from the Southern California Integrated GPS Network indicate that downtown and west Los Angeles are creeping toward the San Gabriel Mountains (at right in this radar image), squeezing the metropolitan area in between.

The San Andreas Fault — the linear feature to the right of the mountains in this image — is seen at the surface, unlike blind-thrust faults such as the one associated with the 1994 Northridge earthquake.

The twin Keck telescopes in Hawaii have a superb view of the heavens from their location on Mauna Kea in Hawaii. For most of the year, the atmosphere above Mauna Kea is clear, calm and dry, enabling the telescopes to "see" far into the deepest regions of the universe.

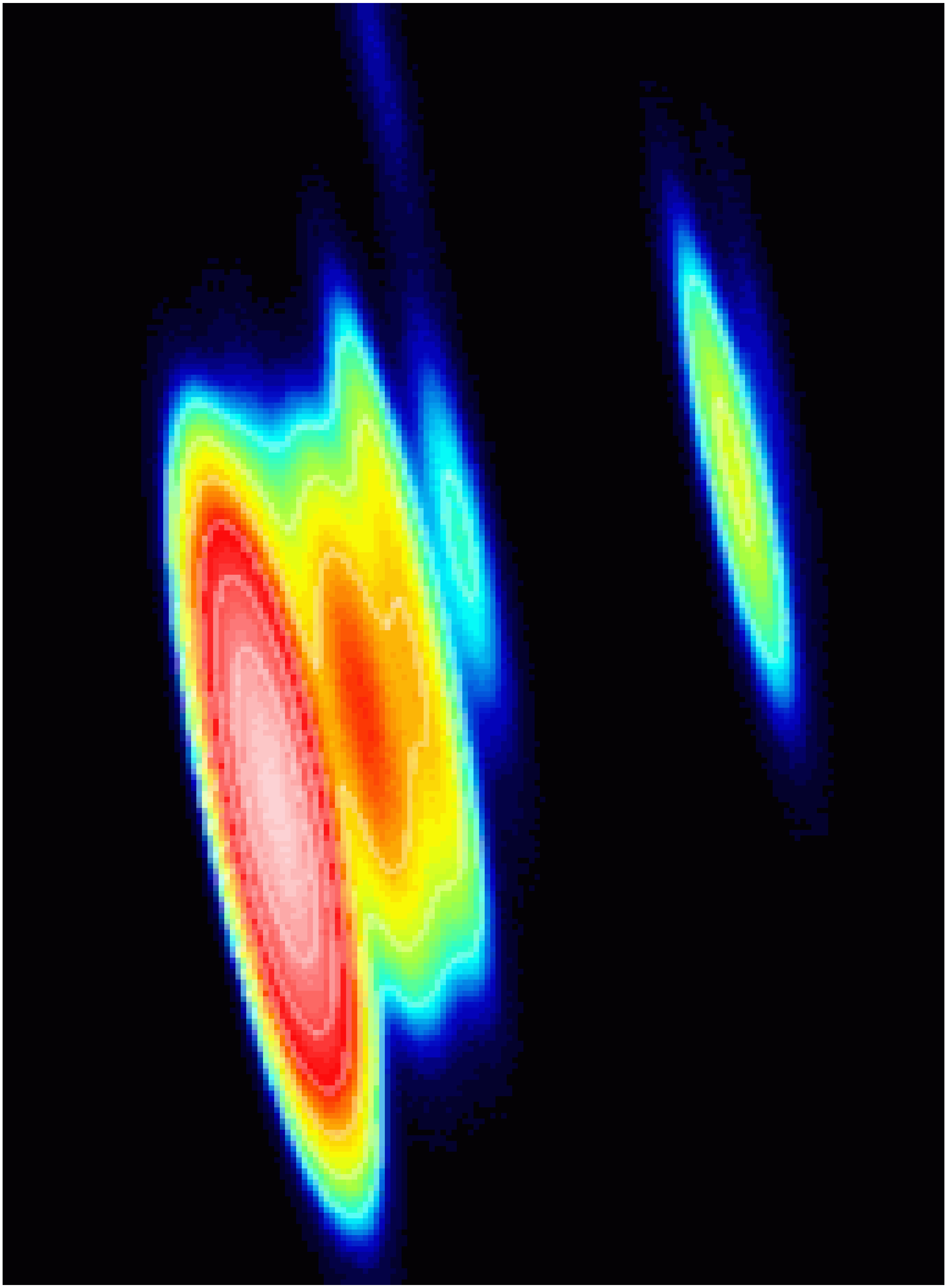
Joining the Laboratory's missions exploring Earth and its planetary neighbors were several teams at work on spacecraft and instruments to view the universe beyond the solar system.

NASA authorized the start of work on the Space Infrared Telescope Facility, an advanced orbiting observatory that will give astronomers unprecedented views of phenomena in the universe that are invisible to other types of telescopes. Scheduled for launch in 2001, the project represents the culmination of more than a decade of planning and design to develop an infrared space telescope with high sensitivity, low cost and long lifetime of at least two-and-a-half to as many as five years.

KECK II

ASTRONOMERS USED A JPL-DEVELOPED infrared camera with the new Keck II telescope in Hawaii to discover what appears to be the clearest evidence yet of a budding solar system around a nearby star. The team, led by a JPL astronomer, released an image of the probable site of planet formation around a star known as HR 4796, about 220 light-years from Earth in the constellation Centaurus. The discovery was made from the giant 10-meter (33-foot) Keck II telescope atop Mauna Kea, Hawaii, operated by the California Association for Research in Astronomy, a joint venture between the University of California, the California Institute of Technology and NASA.

The Laboratory selected two aerospace firms as potential industry team members for the Space Interferometry Mission, an innovative space system that will be launched in 2005 to measure precisely the location of stars and to search for planets orbiting nearby stars. JPL created a new initiative in the search for life beyond Earth with the formation of an astrobiology group at the Laboratory.



This image of an extragalactic gamma-ray source, Markarian 421, was captured by an array of ground telescopes and the Space VLBI Japanese satellite known as Halca. The arraying technique produces a giant virtual telescope with a diameter three times that of Earth.

QUASARS

IMAGES OF QUASARS BILLIONS OF LIGHT-YEARS AWAY are among the striking initial results of the Space Very Long Baseline Interferometry (Space VLBI) project, a new type of astronomy mission that uses a combination of satellite and Earth-based radio antennas to create a telescope larger than Earth. Very long baseline interferometry is a technique used by radio astronomers that electronically links widely separated radio telescopes together to form a single instrument with extraordinarily sharp "vision," or resolving power. The project, conducted by an international team, links a radio dish on a Japanese spacecraft with ground antennas in several nations.

The JPL-built main camera on the Hubble Space Telescope continued to work flawlessly as the orbiting observatory added to its legacy of astronomical discoveries. Among many findings during the year, two JPL astronomers searching Hubble's image archives announced the discovery of about a hundred previously unknown small asteroids — essentially rocks just over 1 to 3 kilometers wide (half a mile to two miles) — orbiting between Mars and Jupiter in a band of space debris known as the main belt.

Deep Space 1 will fly close to asteroid 1992 KD in July 1999. The spacecraft will zip past the mysterious, little-known space rock at a relative speed of nearly 56,000 kilometers (35,000 miles) per hour.

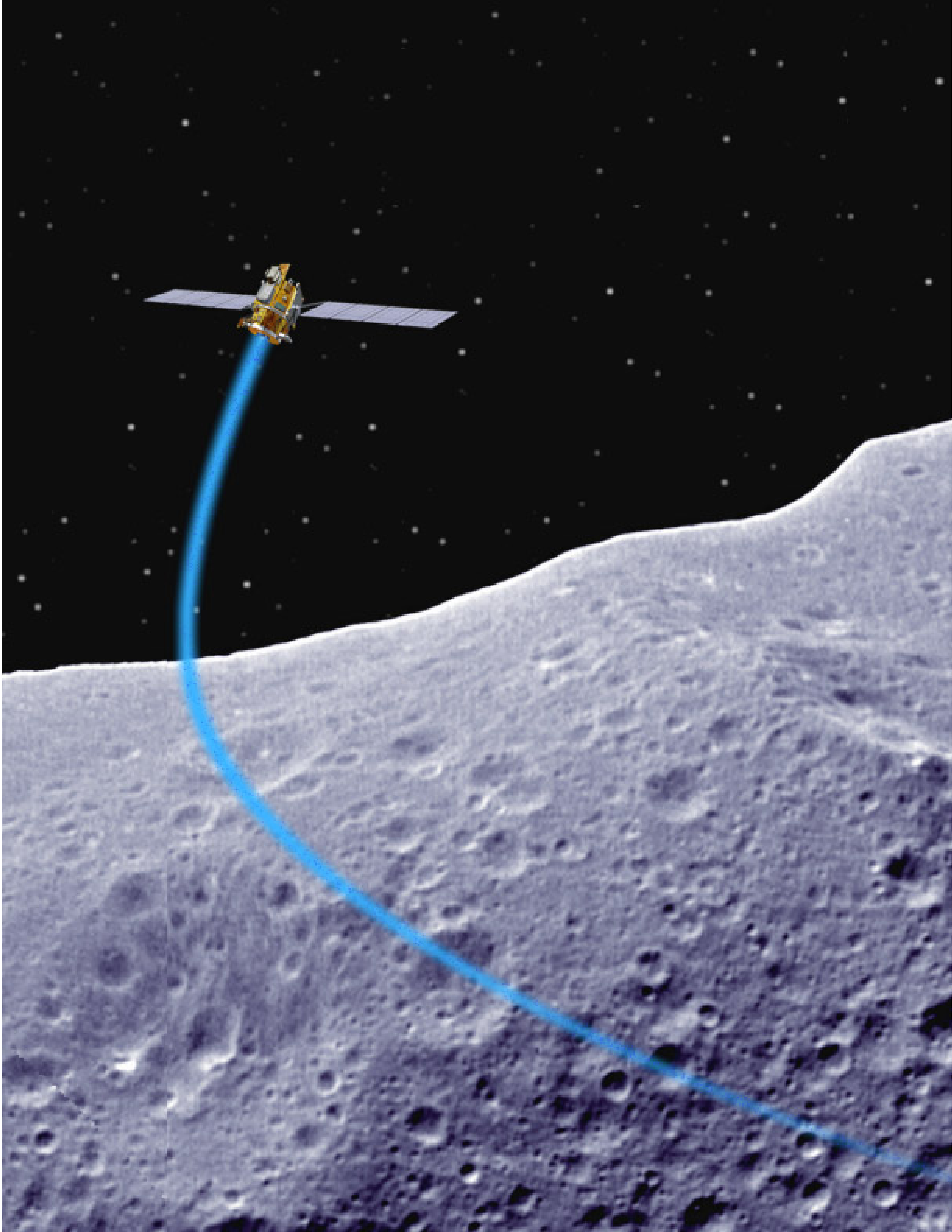
All of JPL's space missions depend on one key ingredient — the underlying technology that makes them possible. While engineers and scientists create spacecraft and instruments for scientific purposes, other teams are engaged in chasing technology itself, as well as novel uses of space technology in Earthly applications.

DEEP SPACE 1

TECHNOLOGY AND SPACE MISSIONS WERE MARRIED in a new and meaningful way with the first launch under the New Millennium Program, designed to create spacecraft that flight-test advanced technologies. Deep Space 1 was launched late in the year and shortly thereafter started up its ion engine, the first time such a futuristic propulsion system has been used beyond Earth orbit. In 1999 the spacecraft will continue to exercise the ion engine and its eleven other advanced technologies so that future science missions can use them with confidence.

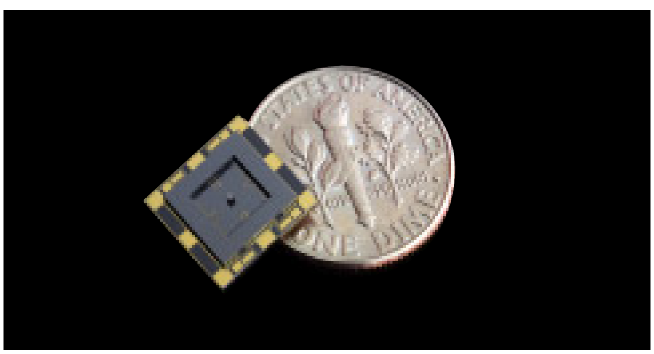
The second New Millennium project was launched just after New Year 1999, when two microprobes called Deep Space 2 were sent into space piggybacked on the Mars Polar Lander spacecraft. Just before arriving at the red planet, the two microprobes will be jettisoned and plunge to the surface of Mars in a test of new technologies for planetary surface probes. Also during 1998, JPL named project leadership for Deep Space 4, a mission under study that would test new technologies on a spacecraft bound for a comet.

In a separate effort developing advanced technologies, JPL engineers spent considerable time working on space-saving inflatable devices that could be used on missions of the future. Such hardware as dish antennas or the wheels of robot rovers could be stowed compactly for launch and then inflated on arrival. JPL also became one of several research organizations afforded a royalty-free license for



the Intel Corporation's Pentium microprocessor design to pave the way for the development of custom-made computer chips for future space missions.

JPL dedicated a new 465-square-meter (5,000-square-foot) facility called the Center for Integrated Space Microelectronics. This center will focus on the design, development, rapid prototyping and integration of integrated microsystems, advanced space avionics and computing technologies for



This microgyroscope is lighter, cheaper, higher performing and less complex than its conventional counterparts. It weighs less than 1 gram, under 0.03 ounce.

SYSTEM ON A CHIP

future deep space missions. These include such technologies as "systems on a chip," advanced nanodevices and nanostructures, reconfigurable and evolvable hardware, modular software and revolutionary computing technologies for spacecraft control.

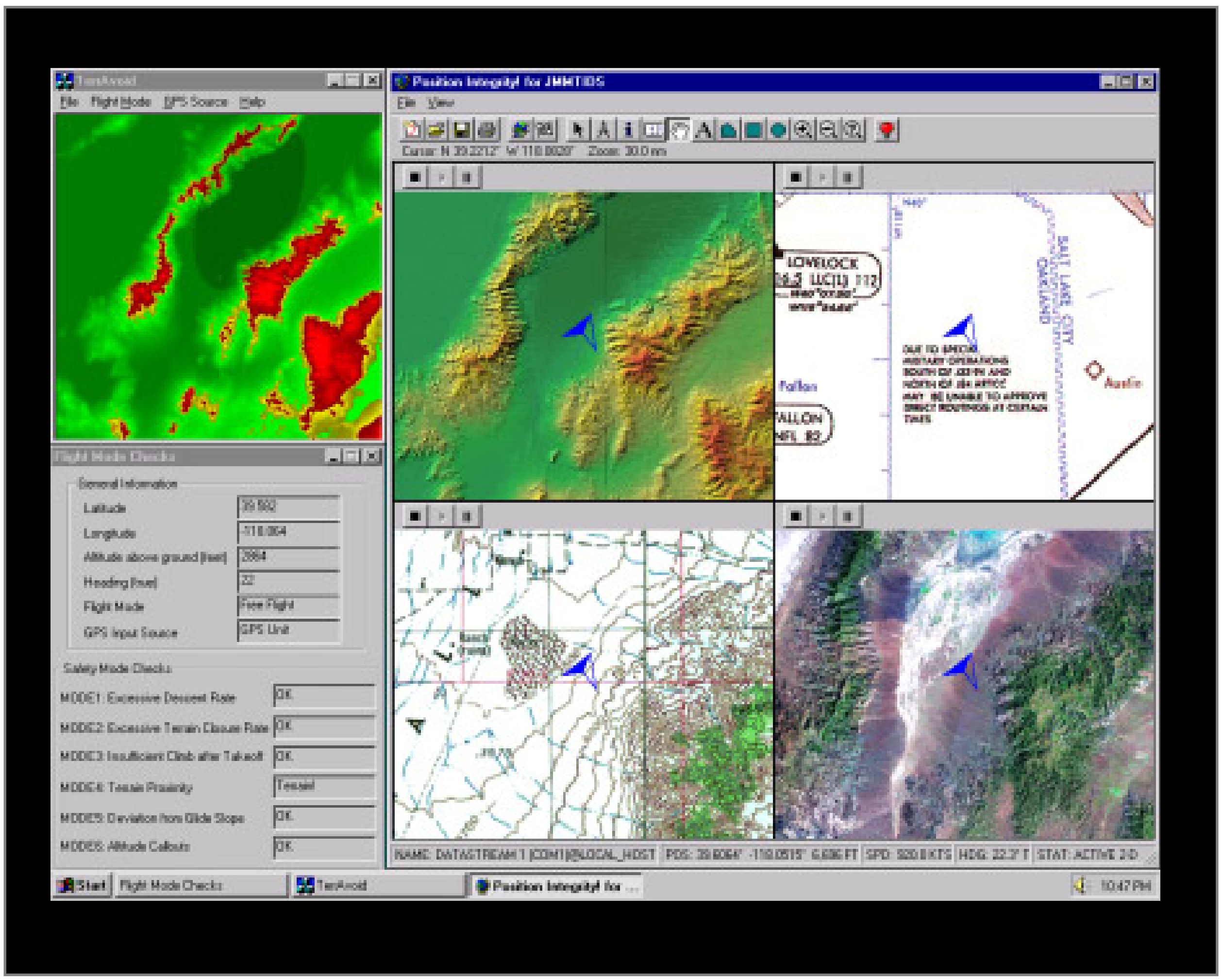
Turning space technologies toward terrestrial uses, the Laboratory pioneered efforts on a number of fronts. JPL and the Ford Motor Company signed a licensing agreement for use of an advanced °neural network technology to diagnose engine misfiring under the hoods of Ford automobiles, among many potential applications. With the advent of this new chip, vehicles should show a reduction in emission levels.

JPL'S TECHNOLOGY AFFILIATES PROGRAM, which brings together the Laboratory's engineers and entrepreneurs from the business world, resulted in two new software packages enabling private pilots to use laptops to avoid hazardous terrain and find their place on maps. Pilots of small planes, for whom such tools have been largely unavailable until now due to cost and the sheer size of bulky hardware, may soon be able to carry an onboard personal computer that is the equivalent of collision-avoidance systems now used by the military and commercial airlines.

The Technology Affiliates program also gave birth to an agreement between JPL and Alyeska Pipeline Service Company, the Anchorage-based operator of the Trans Alaska Pipeline System, to study improved oil spill detection technologies for trans-Alaska pipeline applications. The agreement calls for the investigation of technologies that can provide remote-sensing detection of oil releases below the present leak detection threshold. New technologies may also help the company find leaks more quickly.

Yet another Technology Affiliates project was a new traffic technology that can warn motorists quickly of rapidly approaching emergency vehicles and trains. The Emergency Vehicle Early Warning Safety System equips emergency vehicles with transponders that communicate via microwave with receivers on large visual displays at intersections. As the vehicles approach the intersections, signal lights turn yellow, then red, for cross-traffic, and approaching drivers also view flashing vehicle symbols on the visual displays.

To bring technology to other potential users, NASA selected California State Polytechnic University, Pomona, to work with the agency in transferring technologies developed for the space program to private industry and the educational sector. To be known as the NASA Commercialization Center, the incubator will provide U.S. start-up or existing high-technology firms and U.S. educational



Through the Technology Affiliates Program, JPL-developed mapping software was licensed to a private company for development. The result was a terrain-avoidance system for pilots that graphically maps out and highlights threatening conditions. Six mutually supportive graphic windows provide pilots with enhanced situation awareness through triangulated views of the same overflown region.

institutions with business development support services, including advice on such topics as marketing, sales, finance, accounting, and legal and manufacturing issues. As needed, these companies will be teamed with personnel from JPL or NASA's Dryden Flight Research Center.

While the end of the Cold War has meant that JPL has undertaken fewer tasks for the U.S. Department of Defense, in one notable new project the Laboratory won an 18-month contract from the Defense Advanced Research Projects Agency to lead a consortium to create a miniature tactical mobile robot for urban operations. Drawing on robotics technologies developed for the space program, the "backpackable" microrover will break new ground in small robot size (under 40 centimeters or 16 inches in length), light weight, maneuverability and real-time perception for navigation and reconnaissance.

Not all technology work at JPL was conducted with a serious mien. For the fourth year in a row, the Laboratory invited toy, game and multimedia designers to a seminar to learn more about JPL's missions and partnership programs. JPL also created a partnership with the producers of television's "Babylon 5" to provide technical assistance on science and astronomy for "Crusade," a new science fiction series set in the year 2250 that will debut on Turner Network Television early in 1999.

The Deep Space Communications Complex near Canberra, Australia.

The ground-based antennas of JPL's Deep Space Network in California, Spain and Australia provided more than 92,000 hours of transmitting and receiving for 52 space missions over the year, including spacecraft orbiting Mars and Jupiter. The total hours were up 16 percent over the previous year.

DEEP SPACE NETWORK

THE NETWORK SUCCESSFULLY HELPED TO FIND AND RESTORE contact with an orbiting NASA solar observatory after the spacecraft had been lost for more than a month. The network also used its antennas for direct studies of the solar system and the universe with radio waves. About 60 times during the year, it tracked asteroids, planets and other solar system objects by radar. Some of the radar work helped identify regions near the poles of the Moon for water searches by a spacecraft orbiting the Moon. Radio astronomy using Deep Space Network antennas measured magnetic fields in the cores of star-forming clouds, and found carbon-chain chemicals — possible clues to the origins of life — in interstellar space.

Upgrades to the network continued with installation of a new 34-meter-diameter (110-foot) antenna in Australia employing an advanced technology — beam waveguide — which makes an antenna easier to operate and maintain. It is replacing a 34-meter antenna built in 1962. In other technological progress, a new data-compression technique was developed that is expected to aid communications efficiency for future Mars rovers.

The JPL Deep Space Operations Center is the hub for communications with spacecraft exploring the solar system.

GOLDSTONE

JPL FOUND A NEW USE FOR ONE OF THE ANTENNAS no longer needed for space communications at the Deep Space Network's Goldstone site in Southern California. The 34-meter (110-foot) dish is now a radio telescope operated remotely by students and teachers from around the country, through the Apple Valley Science and Technology Center. Classrooms anywhere can operate the nine-story-tall antenna via Internet connections to Apple Valley.

DYNAMIC CHANGE HAS BEEN THE HALLMARK not only of JPL's spacecraft and instrument projects. Throughout the 1990s, the Laboratory's institutional environment has been actively evolving to make JPL a more effective organization. Many significant developments in this area took place in 1998.

BUSINESS SOLUTIONS

Over the past several years JPL has been working vigorously to adopt process-based management. In a traditional business organization, employees are grouped together by their functional specialty — for example, accounting or quality assurance. Under the philosophy of process-based management, the organization studies itself and develops a map of "processes" that drive its business activities — developing new products, communicating knowledge and so on. Employees in turn participate in teams that cut across functions and oversee a given process from inception to final delivery.

The New Business Solutions project has been reengineering JPL's business systems and administrative processes, focusing on finance, acquisition and human resources. The project installed and tailored an integrated system, relying as much as possible on off-the-shelf business software. In addition, the Enterprise Information System has been developing the framework that allows the Laboratory's computers to communicate and operate together. A JPL process called Define and Maintain the Institutional Environment has transferred all paper-based administrative rules to an online system, making it possible for the Laboratory to cease printing its 14 administrative manuals.

The Develop New Products project has set out to cut the development time of products such as spacecraft and instruments by half, and to reduce average costs by one-third. This effort has been developing processes for use by emerging flight projects.

One key goal for JPL is to win certification ISO 9001 certification in 1999. Developed by the International Organization of Standards, the ISO 9001 standard requires organizations to create and maintain documentation that describes how they function. In 1998, JPL put considerable effort in preparation for visits by ISO auditors.

At NASA's direction, JPL and other centers have been gradually downsizing their workforce over a number of years. Unlike similar moves in the private sector, this effort does not result from a downturn in business; on the contrary, JPL is busier than ever. The intent, rather, is to focus JPL's in-house activities on its core mission of managing space missions and developing technologies in the national interest. Functions that can be performed as well by private companies are being spun off to industrial partners. JPL's highest workforce level was in 1992, when the Laboratory had 6,063 employees and 1,816 on-site contractors. In 1998, this was down to approximately 4,899 employees and 650 on-site contractors. The goal is to reach a total workforce of about 4,800 before the end of the decade.

In September, Caltech entered into a new five-year contract with NASA to continue managing JPL as a federally funded research and development center through the year 2003. The estimated annual value of the cost-plus-award-fee contract is $1.25 billion, for an estimated total value of $6.25 billion over the life of the contract. In fiscal year 1998, JPL's business base was about $1.215 billion.

National Aeronautics and
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Pasadena, California

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