
1999
Jet Propulsion Laboratory

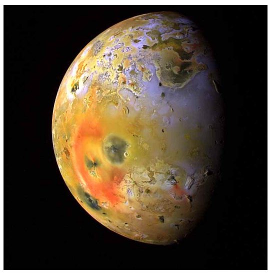
The Jet Propulsion Laboratory, located in the foothills near Pasadena, California, is the nation's lead center for the robotic exploration of space.

INTENSE ACTIVITY IN SPACE missions was the hallmark of the Jet Propulsion Laboratory as a new generation of smaller, less-expensive spacecraft were sent out from Earth. From late 1998 to mid-1999, JPL launched a craft testing a futuristic ion engine, an orbiter and lander bound for Mars, a mission to fly by a comet and return a sample of its dust to Earth, a small infrared telescope, and an Earth-circling satellite that uses radar to gauge winds over the oceans. This unprecedented schedule resulted in spectacular achievements, tempered by highly visible mission losses. Weighed together, the successes and failures dramatically underscored the difficulty and risk involved in the unique business of space science and exploration.

Among the achievements, the ion-engine-powered Deep Space 1, comet-bound Stardust and Earth-orbiting SeaWinds were joined by such on-going missions as Mars Global Surveyor, Galileo and Cassini in delivering on their promise — and, in some cases, providing surprising new views of space and Earth. At the same time, mission teams were disappointed by the losses of an orbiter and lander at Mars, as well as a small infrared telescope. JPL worked closely with NASA to learn from these experiences and build successful future missions.

The Laboratory also achieved a key goal by winning the International Organization of Standards' "ISO 9001" certification — a standard shared by the world's best engineering organizations.

As the year rolled to a close, clocks rolled over from 1999 to 2000. Operations teams at JPL and NASA watched with satisfaction as a major campaign of Year 2000 readiness paid off with no problems among the thousands of computer systems that support the Laboratory's missions. With that auspicious beginning, JPL was positioned to step into the 21st century and embark on even yet unimagined future explorations.



Jupiter's moon Io dazzles with brilliant colors, seething lava flows and magnificent volcanic plumes. The Galileo spacecraft continues to defy Jupiter's massive radiation belts in pursuit of close-up images.

JPL USED BOTH NEW AND long-running missions to continue exploring our solar system in 1999. One JPL-managed spacecraft launched in February will fetch dust from a comet's tail. Another mission, approved this year, will punch a hole in a comet's nucleus to study the interior. The Laboratory also manages other spacecraft dispatched earlier to some of our solar system's largest and smallest members. In July, one passed closer to an asteroid than any envoy from Earth had ever managed before. Another continued to circle the biggest planet, Jupiter. And a third swung back past Earth two years after its launch to get an extra gravitational boost on its way to Saturn.

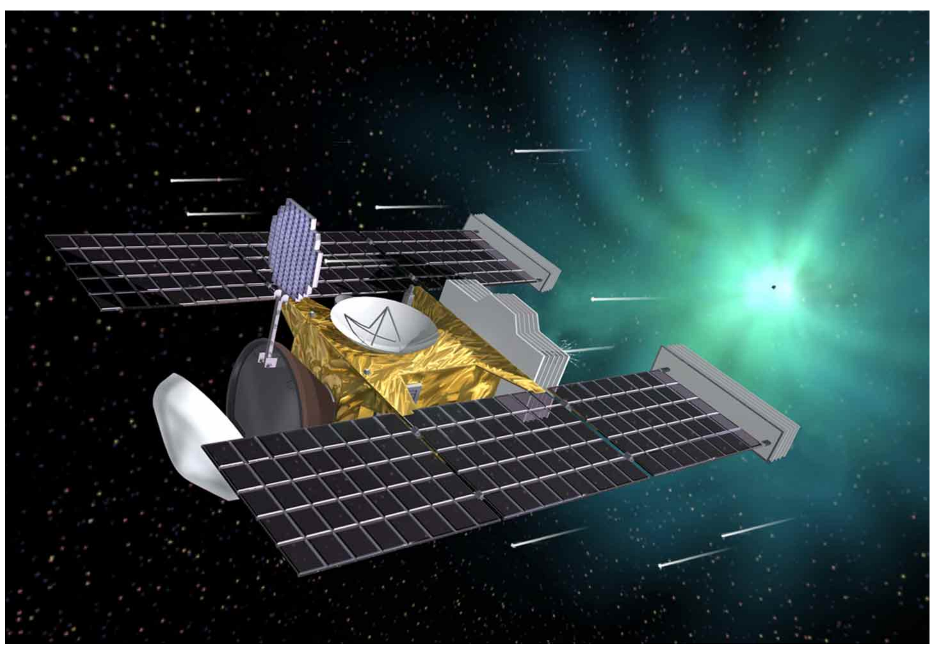
The Galileo spacecraft, orbiting Jupiter since 1995, kept producing surprises throughout 1999 during close-up studies of the planet's moons.

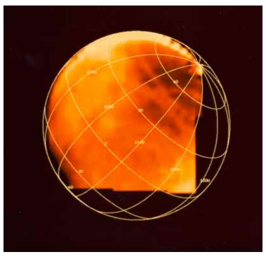
Galileo visited Jupiter's moon Io in October and November. One set of images captured a fountain of bright lava spurting more than 1.5 kilometers (1 mile) high from a fissure on Io's surface. Others showed huge lava lakes with continuous upwellings of fresh lava. Coordinated studies with Galileo instruments and with infrared telescopes in Hawaii and Wyoming revealed striking changes in heat output from Io's largest volcano, Loki. The two passes revealed that Io is even more active than previously suspected, with more than 100 erupting volcanoes. The intensity of vulcanism and heat of the lava provide a present-day parallel for understanding conditions believed to have existed on early Earth.

Jupiter's radiation belts posed a risk of instrument damage from intense radiation near Io, so mission planners scheduled the Io approaches at the end of a two-year extension of Galileo's original two-year mission. Earlier, the craft passed near other moons. Readings in near-infrared wavelengths revealed two very reactive chemicals — sulfuric acid and hydrogen peroxide — on the icy surface of Europa. Other findings show that Callisto has a thin atmosphere, apparently resupplied steadily with carbon dioxide from the moon's surface or interior. Galileo survived the hazards near Io, although radiation-related problems garbled some pictures until JPL engineers came up with a solution. NASA approved an additional extended mission for Galileo through early 2001.

The Stardust spacecraft is on a mission to gather samples of cometary and interstellar dust particles and return them to Earth.

The Cassini spacecraft, launched in 1997 on a mission to reach Saturn in 2004, passed near both Venus and Earth in the summer of 1999 to use their gravity for acceleration. Scientific instruments on the spacecraft searched for lightning on Venus — without finding any — and examined magnetic fields and plasma waves around Earth. By the end of the year, Cassini had entered the asteroid belt between Mars and Jupiter.

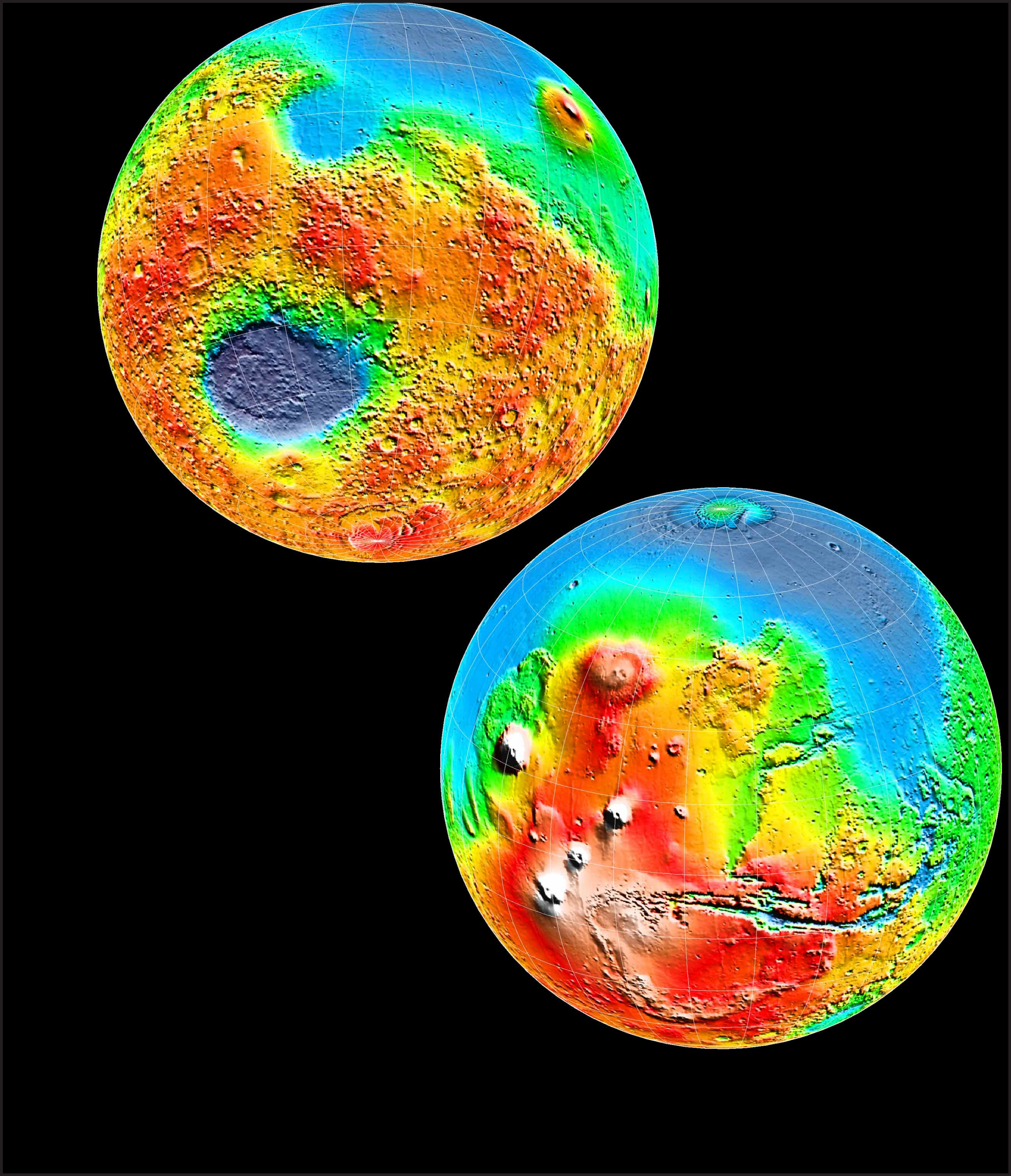


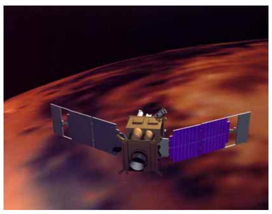


Frozen sulfuric acid on Jupiter's moon Europa is depicted in this image produced from Galileo instrument data. Europa is bombarded by sulfur ions from its sister moon Io.

Stardust was launched on a Delta rocket on February 6 from Cape Canaveral. It is the first U.S. mission dedicated solely to a comet and the first launched to bring back samples from outside the orbit of the Moon. It will collect dust samples as it passes Comet Wild 2 in early 2004, as well as samples of interstellar dust particles as it wheels around the Sun. The spacecraft's dust collectors will use a superior grade of a substance called aerogel developed at JPL to collect the micron-sized particles.

In early July, a new mission, Deep Impact, was approved to explore a comet by breaking a small chunk of it apart. JPL will partner with the University of Maryland and Ball Aerospace to travel to Comet P/Tempel 1, send an impact probe into its surface, and image the particles which fly out from the impact. The mission is slated for launch in January 2004, and will interact with the comet in July 2005.





The two hemispheres of Mars were brought into sharp relief by the altimeter on board Mars Global Surveyor. The crater-scarred southern hemisphere contrasts with the smoother northern hemisphere.

THE YEAR 1999 WAS PIVOTAL FOR JPL's Mars program, as audiences around the world shared the disappointment of scientists and engineers when two missions to the red planet were lost. Mars Climate Orbiter entered the planet's atmosphere too low when it arrived in September and did not achieve orbit. In December, Mars Polar Lander and the Deep Space 2 microprobes were lost on their final descent to the icy terrain near the planet's south pole.

Another spacecraft, meanwhile, revealed new perspectives on Mars as it continued a highly productive orbital mission. Early in the year, Mars Global Surveyor finalized its orbit and embarked on its main two-year science mission assembling a detailed map of 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 used a technique called "aerobraking" first demonstrated by JPL's Magellan spacecraft at Venus; during each looping orbit, the spacecraft skimmed through the planet's thin upper atmosphere where drag gradually slowed it down. By spring 1999, the reshaping was complete.

As the main mission began, Global Surveyor also noted another key milestone when it deployed its steerable dish antenna to pave the way for a steady stream of pictures and other data from Mars. Mission managers likened this to switching from a garden hose to a fire hose in the amount of information the spacecraft can transmit.

One instrument on Global Surveyor provided surprising evidence of past movement of the Martian crust, further evidence that ancient Mars was a more dynamic, Earthlike planet than it is today. Scientists using the spacecraft's magnetometer discovered banded patterns of magnetic fields on the Martian surface that are strikingly similar to patterns seen in the

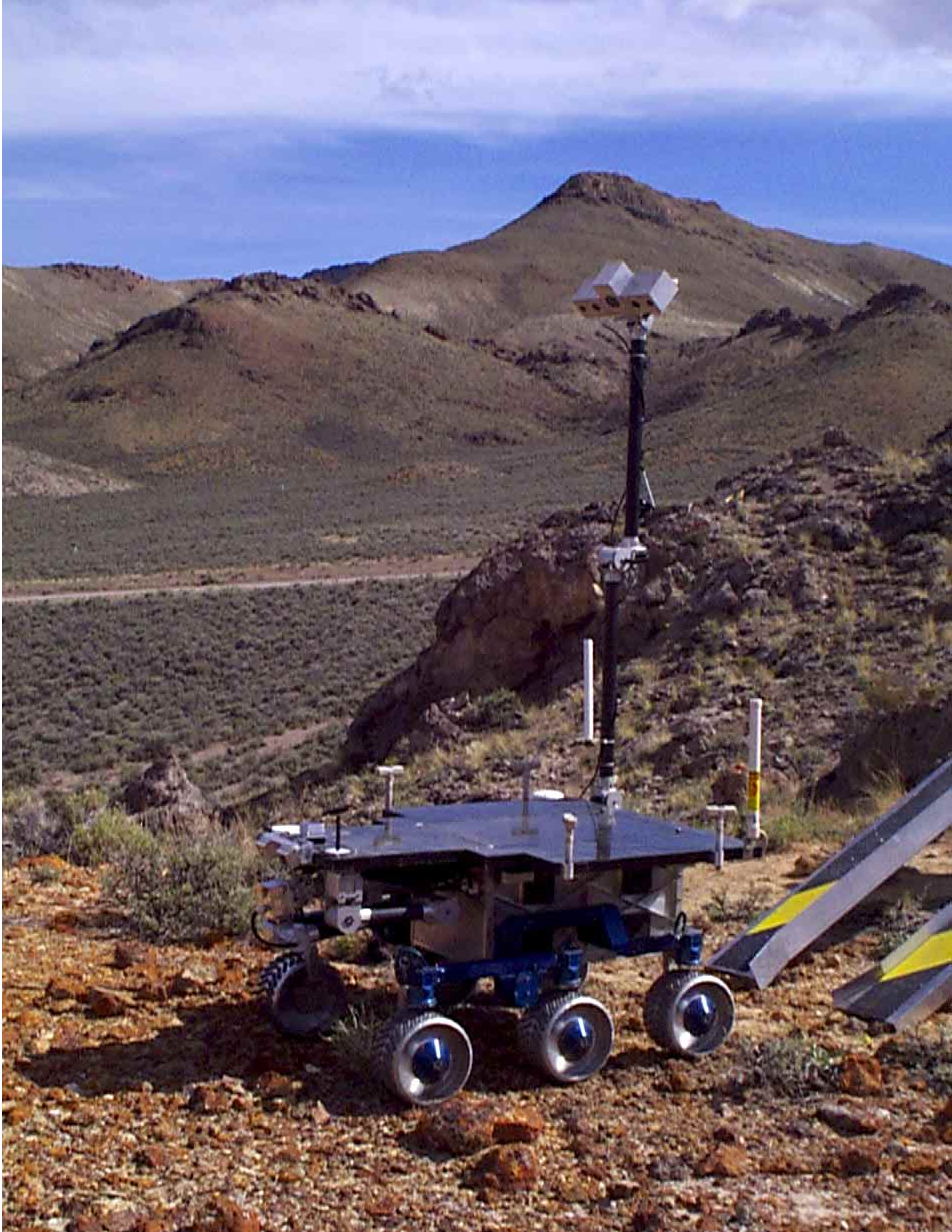
Mysterious Martian landscapes await the next generation of JPL-designed robot rovers.

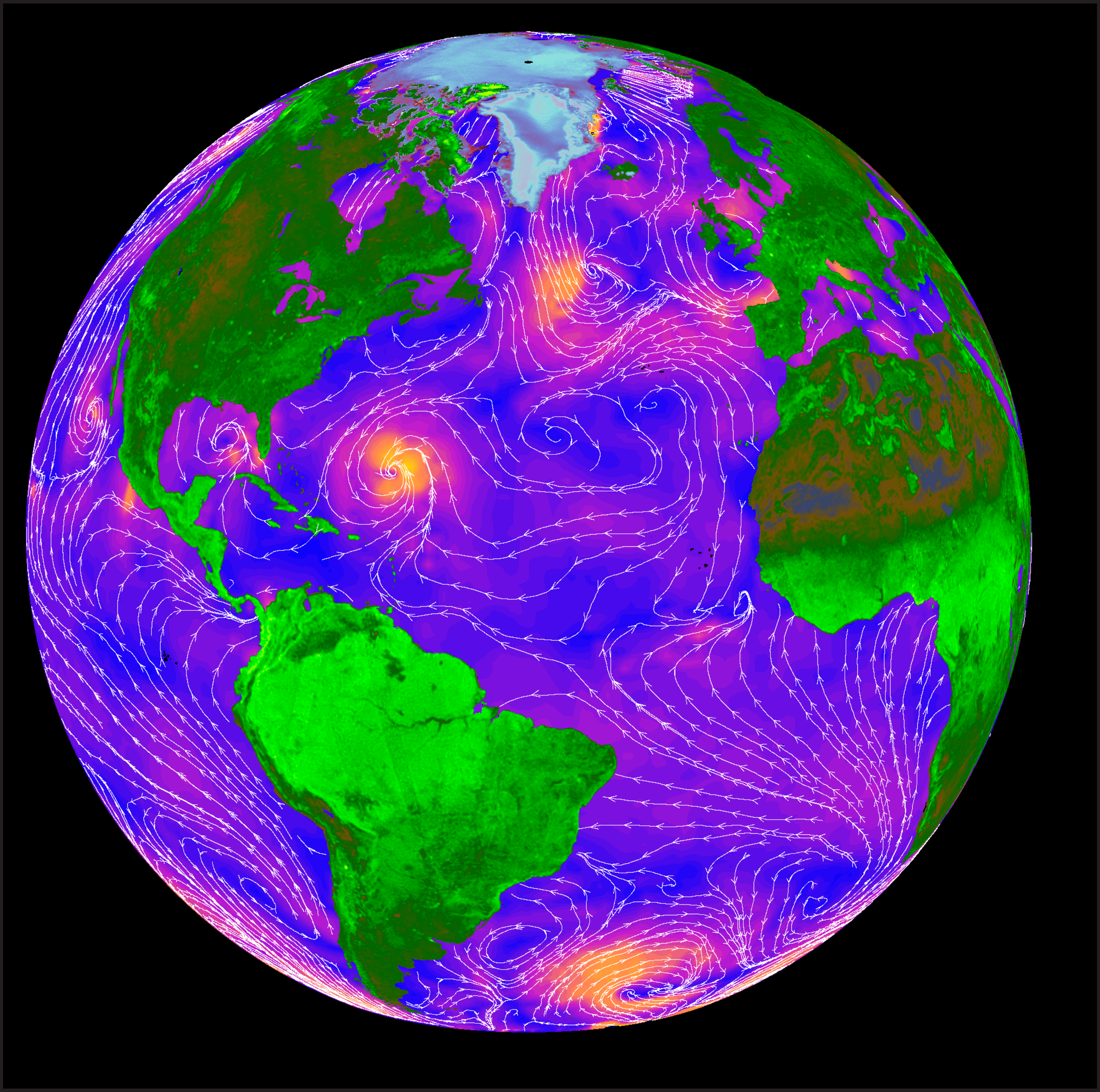
crust of Earth's sea floors. If the bands in fact are the signature of crustal plates that spread apart, it could mean that the Martian surface long ago moved and spread like Earth's does today, causing earthquakes and the formation of mountain ranges.

The team responsible for Global Surveyor's altimeter released a global map of the Martian surface offering a highly detailed portrait of the peaks and valleys that make up the planet's elevation. An impact basin deep enough to swallow Mount Everest and surprising slopes in the huge canyon Valles Marineris are among the highlights that the map depicts.

Throughout the year, Global Surveyor's camera continued to capture images that suggest the red planet is a different place today than it was two years previously when the spacecraft arrived — Mars is a world constantly reshaped by forces of nature, including shifting sand dunes, monster dust devils, wind storms, frosts and polar ice caps that grow and retreat with the seasons. Scientists used those images particularly in a search for any telltale signs of water on Mars, either past or present — a key to determining if life could have ever formed there. In 1999, the imaging team announced that it could find no existing visual evidence of shorelines that would have surrounded oceans that may have once existed on Mars.

Back on Earth, engineers field-tested a robot rover called Fido with practice runs around an ancient lake bed in California's Mojave Desert. The rover, six times the size of the ambling vehicle that moved from rock to rock during the Mars Pathfinder mission in 1997, boasts advanced technology that includes the ability to navigate over distances on its own and avoid natural obstacles without receiving directions from a controller. Plans call for such a rover mission to be launched possibly in 2003.





A false-color image based on SeaWinds measurements enables us to see wind direction and speed (orange is fastest; blue is slowest).

EARLY IN THE YEAR, scientists focused on studying the aftermath of Hurricane Georges on coastal areas in Louisiana by using NASA images to help them understand where sand moved and how vegetation was impacted by saltwater on two coastal barrier islands and the Atchafalaya River Delta. They were particularly interested in images of the Chandeleur Island chain because of the severe damage caused by Hurricane Georges in fall of 1998.

The images were gathered by the JPL's Airborne Visible/Infrared Imaging Spectrometer on board a National Oceanic and Atmospheric Administration aircraft on October 28, 1998. The instrument measures 224 spectral channels, giving scientists a highly detailed look at surface activities that are invisible to the naked eye. Scientists noted that the instrument's data was so rich in imagery and the resolution so good that they had for the first time the ability to completely characterize the land cover on Louisiana's barrier islands. The data are also offered to other scientists conducting coastal habitat research on a wide variety of issues, including marine fish habitat conservation and coastal wetlands restoration.

Meanwhile, the Topex/Poseidon ocean topography satellite was given a new lease on life as engineers successfully switched the principal onboard instrument to operate on its backup unit. The satellite, launched in 1992, was originally designed to last three to five years. With the switch to a fresh altimeter, Topex/Poseidon may last for months or years to come. The new capability enables cross-calibration of Topex/Poseidon with its successor, Jason-1, which is planned for launch in 2000.

The ocean-viewing instrument SeaWinds captured the fury of Typhoon Olga as it grew in intensity in the China Sea, packing high winds of more than 50 knots (92 kilometers or 57 miles per hour) and delivering torrential

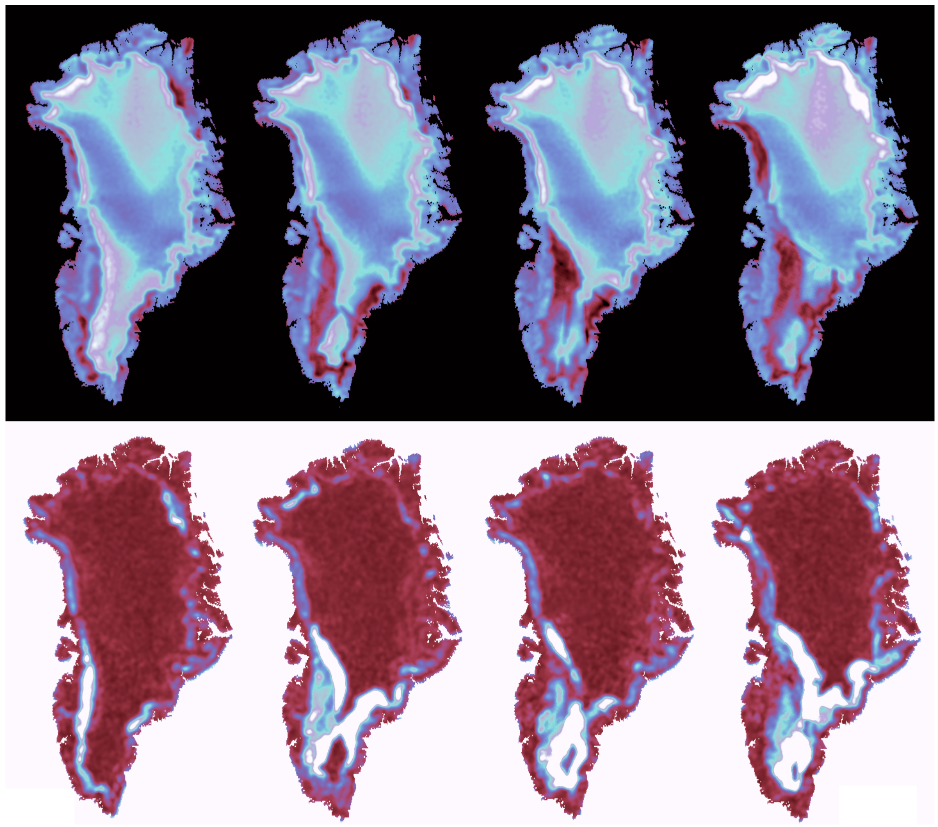
The SeaWinds microwave radar on QuikScat was launched in June 1999 from Vandenberg Air Force Base in California.

rains to South Korea, North Korea and other coastal areas of south Asia. SeaWinds flies aboard the QuikScat spacecraft. The instrument allows scientists to determine the location, structure and strength of tropical depressions, typhoons and severe marine storms very quickly as they develop. It provides a near-global portrait of wind speeds around the world every day.

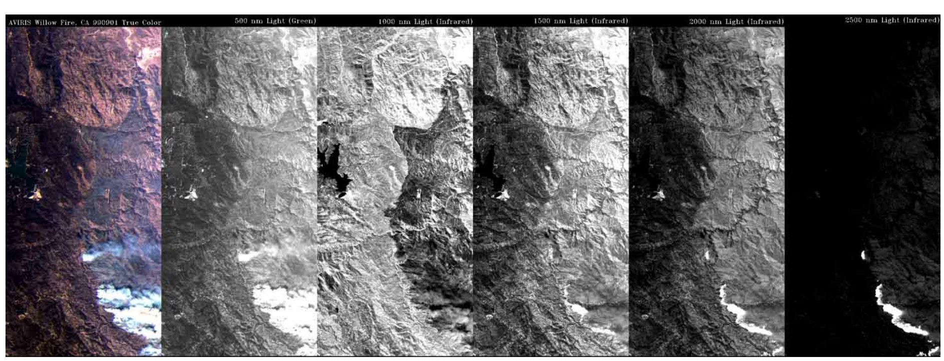
In addition, SeaWinds monitored an iceberg the size of Rhode Island. Scientists were able to watch an iceberg's breakup for the first time with daily radar observations to better understand the effects of ocean winds and climate on melting polar ice. Icebergs can pose a threat to commercial, cruise and fishing ships if they break up and pieces are blown into shipping lanes.

As a prelude to the 21st century, NASA's Earth sciences flagship satellite Terra was launched into a polar orbit around Earth on December 18. On board were two instruments contributed by JPL. One, the Multi-angle Imaging SpectroRadiometer, is unlike any instrument ever flown before in space. Viewing Earth simultaneously at nine widely spaced angles, the instrument collects global images with high detail in four colors at every angle. This allows scientists to distinguish different particles in the atmosphere, as well as cloud forms and land surface covers. The second JPL experiment on Terra is the Advanced Spaceborne Thermal Emission and Reflection Radiometer, an instrument developed jointly with Japan. It will be used to obtain detailed maps of land surface temperature, reflectance and elevation.

Time-series imagery of SeaWinds data allows daily and seasonal monitoring of the Greenland ice sheets.



JPL's Airborne Visible/ Infrared Imaging Spec- trometer "sees" at different wavelengths, revealing hot spots in images of a forest fire.



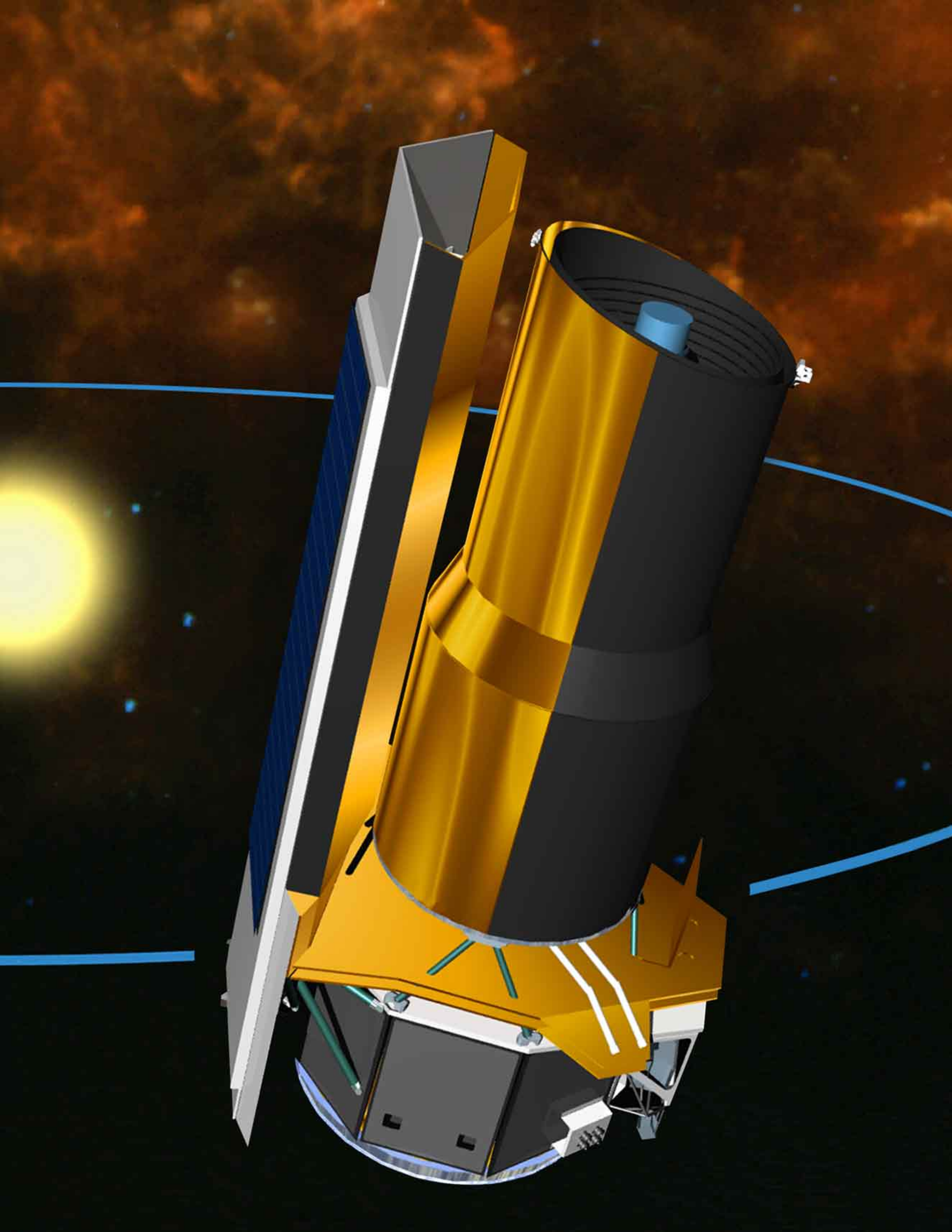
THE LABORATORY CONTINUED TO LOOK BEYOND our solar system, developing spacecraft and instruments to peer far into the universe.

Glowing gas surrounds young stars in a colorful stellar nursery. This near-infrared image of the Orion nebula was captured by the Two-Micron All-Sky Survey.

The Wide-field Infrared Explorer, a mission designed to study starburst galaxies, was launched from California's Vandenberg Air Force Base. The orbiting telescope was unable to complete its mission, however, because its cover came off earlier than planned, causing the loss of onboard coolant.

Many of that mission's scientific goals will be picked up by future space missions, including the Space Infrared Telescope Facility, an orbiting observatory scheduled for launch in 2001 whose targets of study will include the early universe, planetary discs around nearby stars, ultraluminous galaxies and brown dwarfs. In 1999, development continued on the spacecraft and its three science instruments neared completion. The chamber that will house those instruments was completed, as were the spacecraft's liquid-helium cryostat and the flight versions of the 85-centimeter-diameter (33-inch-diameter) beryllium primary mirror and the secondary mirror.

A pair of ground-based telescopes yielded a colossal assortment of dazzling images — enough to fill the hard disks on hundreds of home computers — under a program called the Two-Micron All-Sky Survey. Sponsored by NASA and the National Science Foundation, the survey used twin 1.3-meter (51-inch) telescopes in Arizona and Chile to capture images that were later combined and processed by the JPL/Caltech Infrared Processing and Analysis Center. The enormous database, which represented only the portion of the sky surveyed up to that point, was made available on line for the public and astronomers.



The Space Infrared Telescope Facility will detect infrared radiation (heat) emitted by celestial objects in our solar system and the far reaches of the universe.

JPL selected a contractor to build two spacecraft for a unique formation-flying mission scheduled to launch in 2005. The Space Technology 3 mission will use separate spacecraft to create a virtual large telescope looking out to the Milky Way galaxy and beyond, much larger than any instrument that could be carried by one satellite alone.

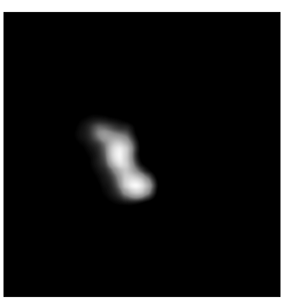
NEW TECHNOLOGIES ARE DEVELOPED, tested and then flown as part of every JPL mission. But no longer are technologies developed just for space. JPL is going one step further and comes full circle to land these technologies back on Earth in the hands of U.S. companies for public use.

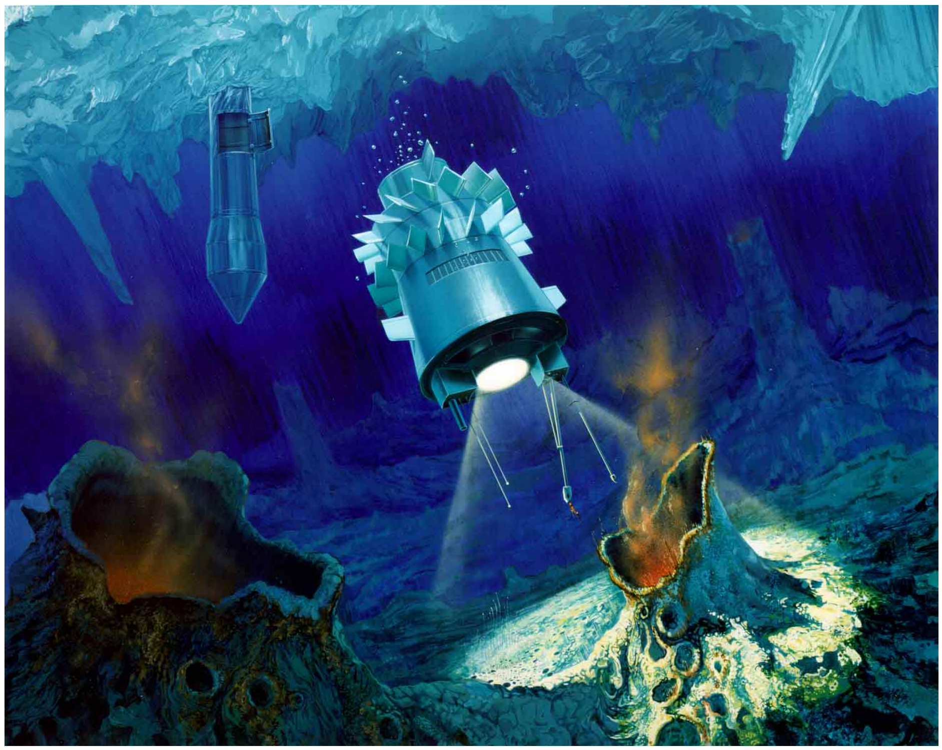
Space instruments are constantly evolving and are smaller and more powerful than those made 30 years ago. Many technologies are being developed at JPL's Center for Space Microelectronics Technology.

One example of a technology designed for space research but which also has tremendous commercial applications is artificial muscles. Artificial muscles allow space robots animal-like flexibility and manipulation ability. They will be tested on a small NASA rover destined to explore an asteroid. This type of technology could lead to the future development of insect-like robots that emulate biological creatures. Years from now, these devices could also conceivably replace damaged human muscles.

The JPL-managed New Millennium Program was busy conceiving and flying missions designed to test new space technologies. The program's first mission, Deep Space 1, was launched in late 1998 and completed its prime mission in 1999 with great success, flight-testing a dozen advanced technologies. Among these was a futuristic ion engine tested for the first time beyond Earth orbit. Exerting thrust only as strong as the weight of a sheet of paper resting on the palm of a hand, the engine over the long haul can propel a spacecraft more efficiently than can a conventional chemical rocket.

Despite target-tracking difficulties, Deep Space 1's miniature camera-spectrometer captured images of tiny, irregular asteroid Braille.





JPL is developing robots to operate in extreme environments. This artist's concept envisions a submersible investigating an alien ocean.

Deep Space 1 flew by asteroid 9969 Braille at a distance of 26 kilometers (16 miles), piloted only by artificial intelligence software — a first in spaceflight history. Deep Space 1's mission was extended for scientific studies of comets and asteroids. The spacecraft was redirected for two possible comet encounters: with Comet Wilson-Harrington in January 2001, and with Comet Borrelly in September 2001.

In August, a mission consisting of three very small satellites, called the Nanosat Constellation Trailblazer, was selected as the next New Millennium Program mission. The mission will validate methods of operating several spacecraft as a system and test eight technologies in the harsh space environment. Late in the year, another New Millennium mission was selected. The mission — known as Earth Observing 3 — will test advanced technologies for measuring temperature, water vapor, wind and chemical composition with high resolution, in space and over time.

Turning their efforts from space to private industry, JPL created a commercial advisory council. The council includes aerospace and financial management business and technology leaders to advise JPL on how to maximize research and technology developments to benefit U.S. business and industry. JPL continuously seeks to find new ways to cooperate with industry in joint research and development, promoting entrepreneurship and new business growth. U.S. industry is ultimately the key beneficiary of the council's advice.

JPL'S DEEP SPACE NETWORK PROVIDES communications between Earth and spacecraft through large antennas in California, Spain and Australia. The network logged more than 93,000 hours of tracking support for 46 missions over the year, including launch support for Deep Space 1, Stardust, Mars Climate Orbiter, Mars Polar Lander, the QuickScat ocean-weather satellite and others. Some of the data flowing through the network came from the Galileo spacecraft's studies of the moons of Jupiter, from Cassini's swingbys of Venus and Earth, and from the approach of NASA's Near Earth Asteroid Rendezvous to the asteroid Eros.

Using antennas as radio telescopes, the network advanced research about the fine structures of radio emissions from galaxies and the magnetic fields

Mission control technicians stay in touch with the Deep Space Network complex near Canberra, Australia.

The Deep Space Network's largest antennas at Goldstone, California, and near Madrid, Spain (with sheep).

in regions where stars are born. Studies of emissions from Jupiter provided new information about radiation belts around the planet.

The Deep Space Network helped demonstrate a technology allowing a spacecraft computer that is monitoring onboard systems to let personnel on the ground know whenever an urgent need arises for their intervention, even when the network's large antennas are not tracking the spacecraft. The message comes on a beacon signal that cannot carry a large flow of data. After the beacon has indicated that antenna tracking is needed, more information can be sent about the situation requiring attention. The technology was demonstrated with the Deep Space 1 spacecraft.

Network engineers helped lay plans in 1999 for a communications and navigation infrastructure at Mars to support future missions there. The planned system, called the Mars Network, would begin with a relay satellite. The network would provide great enough increases in data flow and navigation to allow new concepts for Mars exploration missions.

The Deep Space Network completed a rigorous Year 2000 certification process to ensure that all systems would accommodate the calendar change from 1999 to 2000.

Resembling a small city in the San Gabriel Mountain foothills, JPL continually strives for improvements in carrying out NASA's mission of space exploration.

PERHAPS THE CENTERPIECE OF JPL'S institutional accomplishments in 1999 was the winning of ISO 9001 certification, achieved in the spring some six months ahead of schedule. Developed by the International Organization of Standards, ISO 9001 is a hallmark of the world's best engineering organizations. The standard requires organizations to create and maintain documentation that describes how they function. At the Laboratory, this means that all processes, procedures and any other "rules" reside in an online system that any employee can easily search. JPL put considerable effort into preparation for a visit by outside auditors that culminated in their recommendation of the Laboratory for ISO certification.

Dovetailing with the ISO 9001 push was continual work to transform the Laboratory into a process-based organization — one in which work is thought of, performed and managed as an end-to-end process.

The Develop New Products project demonstrated new processes, tools and infrastructure support that enable spacecraft and instrument projects to reduce development time and cost with improved quality. The team worked with a new Earth-orbiting mission, CloudSat, as a pilot project exercising tools developed under the project.

The Laboratory also undertook a special initiative to align the efforts of each of its employees with NASA's strategic objectives. JPL published a document, the JPL Implementation Plan, describing its role in achieving the goals in the space agency's strategic plan. Each area of the Laboratory in turn formulated written goals to help achieve pieces of the overall plan. Managers and supervisors were encouraged to translate this into personal goals for each employee during the process of annual performance reviews.

JPL and other centers continued to downsize their staffs to achieve NASA's goal of a more focused workforce. 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 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 1999, this was down to approximately 4,712 employees and 632 on-site contractors. The goal is to reach a total workforce of about 4,800 before the end of the decade. In fiscal year 1999, JPL had a business base of about $1.3 billion.

National Aeronautics and
Space Administration

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