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Jet Propulsion Laboratory

ANNUAL REPORT



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ON THE COVER
The Spitzer Space
Telescope's infrared
array camera
captured this
glowing stellar
nursery 2,450 light-
years distant. This
cloud in the emission
nebula IC1396 is
opaque seen in
visible light.

Annual Report

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Director's MESSAGE

If you stepped outdoors on the final evening of 2003 and looked up into the night sky, among the many celestial events taking place were these: A hundred million miles away from Earth, a dust storm swirled across the terracotta peaks and gullies of Mars, as two six-wheeled robots bore down on the planet — soon to join two orbital sentries already stationed there. A few hops across the inner solar system, another spacecraft was closing in on a ball of ice and rock spewing forth a hailstorm of dust grains, heated as it swung in toward the Sun. Closer in, two newly lofted space telescopes scanned the skies, their mirrors gathering photons that had crossed the empty vastness of space for billions of years, recording ancient events in unimaginably distant galaxies. And streaking overhead every few minutes directly above our home planet, a handful of satellites was recording the unfolding events of a tropical cyclone off the east coast of Africa and a blizzard that carpeted the northwestern United States.

The exploration we undertake is important for its own sake



All told on December 31, 2003, the night sky was sprinkled with 17 NASA/JPL spacecraft —

from the nearest Earth-watchers to a pair of robotic explorers on the outermost edges of the solar system where light itself takes hours to reach us. Listening to their automated murmurings are the ten-story-tall metallic ears of the Deep Space Network, communication sentinels arrayed across three continents around the globe.

As 2003 drew to a close, the Jet Propulsion Laboratory was on the cusp of an extraordinarily busy period, a time when JPL will execute more flybys, landings, sample returns and other milestones than at any other time in its history.

NASA's vision statement challenges all of us in the agency "To improve life here, to extend life to there, to find life beyond." JPL missions make unique contributions to each of these three endeavors. The Laboratory fields many instruments and satellites for NASA's Earth science enterprise, which betters our quality of life by providing unequalled monitoring of our home planet. Life here is also enhanced by the many space technologies that find their way into earthly uses from biomedical imaging to precision navigation, and by inspiring young minds — the next generation of explorers. As for extending life to there — sending humans off-world on exploration ventures — their way has always been blazed by robotic scouts of the kind originated at JPL.

It is the final piece of NASA's vision — the search for life beyond our planet — that perhaps most captures the public's imagination, and to which JPL is making a distinctive contribution. Although the rovers poised to land on Mars are not designed to look directly for biological activity, they can help confirm whether that planet ever had liquid water in sufficient quantity to support life of some kind. Later this decade, we will be dispatching an even more capable rover with sensors sensitive to chemical and biological signatures, and we are poised to bring samples back shortly thereafter.

Besides Mars, one of the other places in the solar system that scientists consider most promising to shed light on biological evolution in the solar system is the vast ocean believed to lie beneath a frozen crust on Jupiter's moon Europa. We are studying the possibility of conducting extended studies with an innovative spacecraft that would use nuclear technology to allow it to hop from one Jovian

moon to another. Another spacecraft is poised to spend four years exploring Saturn's moon Titan, which could help us understand the early Earth. And we are also laying plans to cast our gaze in search of life far beyond the confines of our own solar system, about a decade from now deploying space telescopes to search for Earth-like planets around neighboring stars that might harbor life.

When I think of these exciting projects, I cannot help but be gratified that NASA and the nation have entrusted us to explore, on their behalf, the solar system and beyond. And I cannot help but be thankful in knowing that I am surrounded at JPL by such remarkably talented and penetrating minds. Every team likes to think of itself as the best, but at JPL our people really are — this is the most amazing congregation of scientific, engineering and business talent anywhere. Each team we have at JPL is truly a dream team. In large measure I think this is owing to JPL's unique identity as a federal laboratory staffed and managed by the California Institute of Technology. This campus connection provides an infusion of thinking from the academic world that would not be possible without this relationship. And if our link with Caltech roots us in scientific and engineering excellence, our connection to NASA propels us to soar as far as our imagination and ingenuity can take us.

The exploration we undertake is important for its own sake. And it serves other purposes, none more important than inspiring the next generation of explorers. If the United States wishes to retain its status as a world leader, it must maintain the technological edge of its workforce. What we do here is the stuff of dreams that will inspire a new generation to continue the American legacy of exploration.



Charles Elachi

What we do here is the stuff of dreams that will inspire a new generation to continue the American legacy of exploration.

Astronomy & PHYSICS

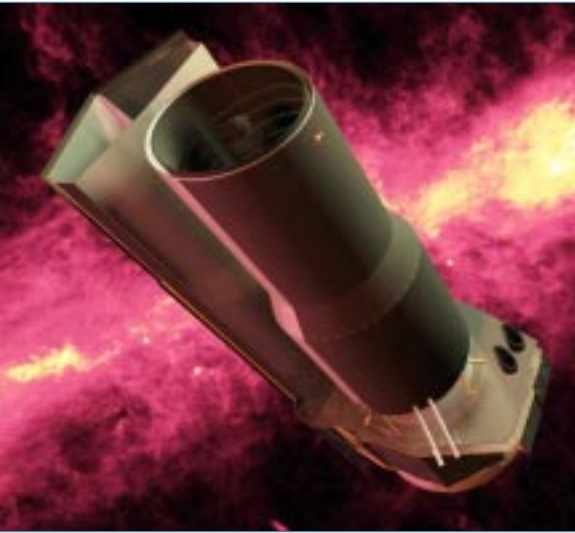
*Spitzer Space Telescope
short-wavelength
infrared view of spiral
galaxy Messier 81.
Spitzer was launched on
August 24, 2003. JPL's
Wide-Field and Planetary
Camera 2 captured a
brilliant supernova
remnant in the Large
Magellanic Cloud.*

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nce the province of science fiction, the idea of sending telescopes into space to escape the distorting effects of Earth's atmosphere became science fact with the launch of Hubble and other NASA orbiting observatories. In 2003 they were joined by two new eyes on the universe, the Spitzer Space Telescope — known until shortly after launch as the Space Infrared Telescope Facility — and the Galaxy Evolution Explorer.





The plane of the Milky Way as it might look in an infrared view forms a brilliant backdrop for the Spitzer Space Telescope in this artist's depiction.

As its working name suggested, the Spitzer Space Telescope views the cosmos in the infrared, wavelengths of heat energy lying just outside the visible spectrum. Launched in August, the telescope — named for Dr. Lyman Spitzer, Jr., the astronomer who in the 1940s first proposed placing telescopes in space — took up its station on a first-of-its kind Earth-trailing solar orbit. In December, the Spitzer team released their first observations, of a glowing stellar nursery; a swirling, dusty galaxy; a disc of planet-forming debris; and organic material in the distant universe.

The Spitzer telescope is continuing to capture images of distant galaxies and the dusty planetary construction zones around stars, as well as other space objects. Much of the universe shines brightly in the infrared, including distant galaxies, brown dwarfs, which are failed stars, and cosmic dust — what scientists refer to as the “far, the cold and the dusty.” Spitzer’s sensitive infrared sight allows it to illuminate this otherwise dark side of the cosmos. Lockheed Martin Space Systems Company in Sunnyvale, California, designed and built the Spitzer spacecraft, while the telescope assembly was executed by Ball Aerospace and Technologies Corporation in Boulder, Colorado. To reduce its own infrared radiation, the Spitzer telescope is cooled to a few degrees above absolute zero by liquid helium; the supply of liquid helium is adequate for a lifetime of five years or more.

Our other new space telescope, the Galaxy Evolution Explorer, works the other end of the energy spectrum, gathering ultraviolet light just beyond the upper end of the visible range. Launched in

April via an aircraft-ferried Pegasus XL rocket from Florida, this spacecraft is mapping the history of star formation over the last 10 billion years. It is accomplishing this colossal task using state-of-the-art ultraviolet detectors designed to single out galaxies dominated by young, hot stars. The mission is led by a principal investigator at JPL’s parent institution, the California Institute of Technology.



Spitzer's cryogenic telescope assembly is prepared for vibration testing.



This Galaxy Evolution Explorer image of the galaxy in Andromeda (M31) shows blue regions of young stars tracing out the spiral arms.



Astronomers are beginning to understand how galaxies like our own evolve and transform

About three months after launch, the Galaxy Evolution Explorer radioed its first batch of images consisting of hundreds of galaxies, both near and far. From the data, astronomers are beginning to understand how galaxies like our own evolve and transform. Orbital Sciences Corporation in Germantown, Maryland, designed, built and launched the spacecraft.

Amid these new ventures, we must not forget JPL's role in the most famous space telescope of all — the venerable Wide-Field and Planetary Camera 2, the main camera on board the Hubble Space Telescope that has collected its most celebrated images over the past decade since it was installed by spacewalking astronauts in 1993. While Hubble astronomers are now using a more recently installed successor instrument, scientists continue to pore over the JPL camera's trove of images of dazzling galaxies, crowded star clusters and other celestial objects that have led to numerous scientific discoveries and fired the public's imagination.

Here on Earth, the powerful Keck Interferometer atop Mauna Kea in Hawaii made its debut discovery: a young star ringed by a swirling disc of planet-forming dust. The largest optical



Using near-infrared light, Spitzer pierced through a dark cloud to detect outflow in an object called HH 46/47, a bright, nebulous region of gas and dust.

In this Wide-Field and Planetary Camera 2 image, a dusty spiral galaxy collides with a larger, bright galaxy in the Perseus Cluster.

The Space Interferometry Mission will determine to a high degree of accuracy the distances to stars and nearby galaxies and will seek out extrasolar planets resembling our own.



Light collected by each 10-meter-diameter mirror in the twin Keck telescopes is combined for optical interferometry.

telescope system in the world, the Keck Interferometer combines light from two already enormous telescopes to produce one superfine image. The telescope also made a close-up measurement of a galaxy far beyond our own Milky Way, with a monstrous, churning black hole at its core.

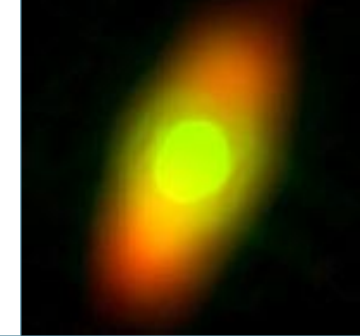
Among future planet-hunting missions, three are in development or planning stages: Kepler, a mission planned for launch in 2007; the Space Interferometry Mission, scheduled to launch in 2009, and the Terrestrial Planet Finder, proposed for launch in the middle of the next decade. JPL was assigned to manage the

Kepler project in 2002, with the science mission led by a principal investigator at NASA's Ames Research Center. The spacecraft will look for the dimming of stars to find planets that may have crossed in front of them.

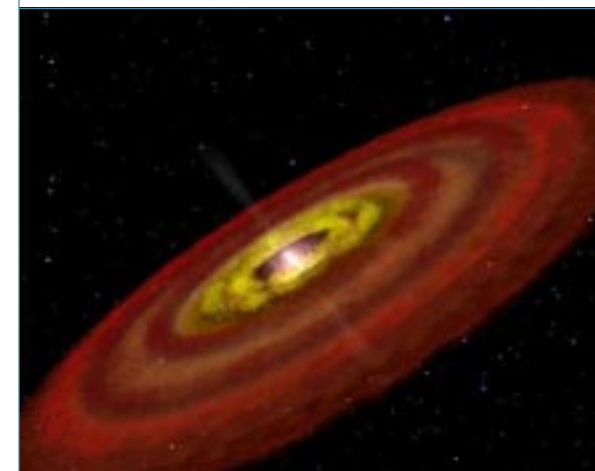
Using technology similar to that of the Keck Interferometer, the Space Interferometry Mission will determine to a high degree of accuracy the distances to stars and nearby galaxies and will seek out extrasolar planets resembling our own. A much more ambitious mission, the Terrestrial Planet Finder, will be able to directly detect Earth-like planets and search for telltale chemical signatures of life.

Under the aegis of JPL's physics program, NASA-funded researchers at the Massachusetts Institute of Technology this year cooled sodium gas to the lowest temperature ever recorded — one-half-billionth degree above absolute zero. Absolute zero is the point where no further cooling is possible.

The JPL physics program also enabled research at Harvard University that was one of 12 projects featured in a special edition of *Scientific American* entitled "The Edge of Physics." The research literally stops light in its tracks, and may someday lead to break-neck-speed computers that shelter enormous amounts of data from hackers.



Spitzer obtained the first infrared images of the dust disc surrounding Fomalhaut, the 18th brightest star in the sky.



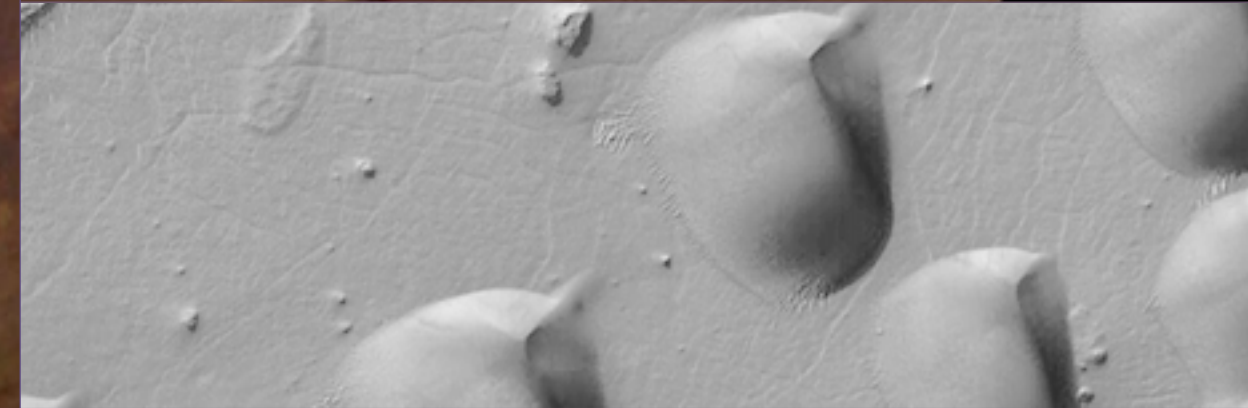
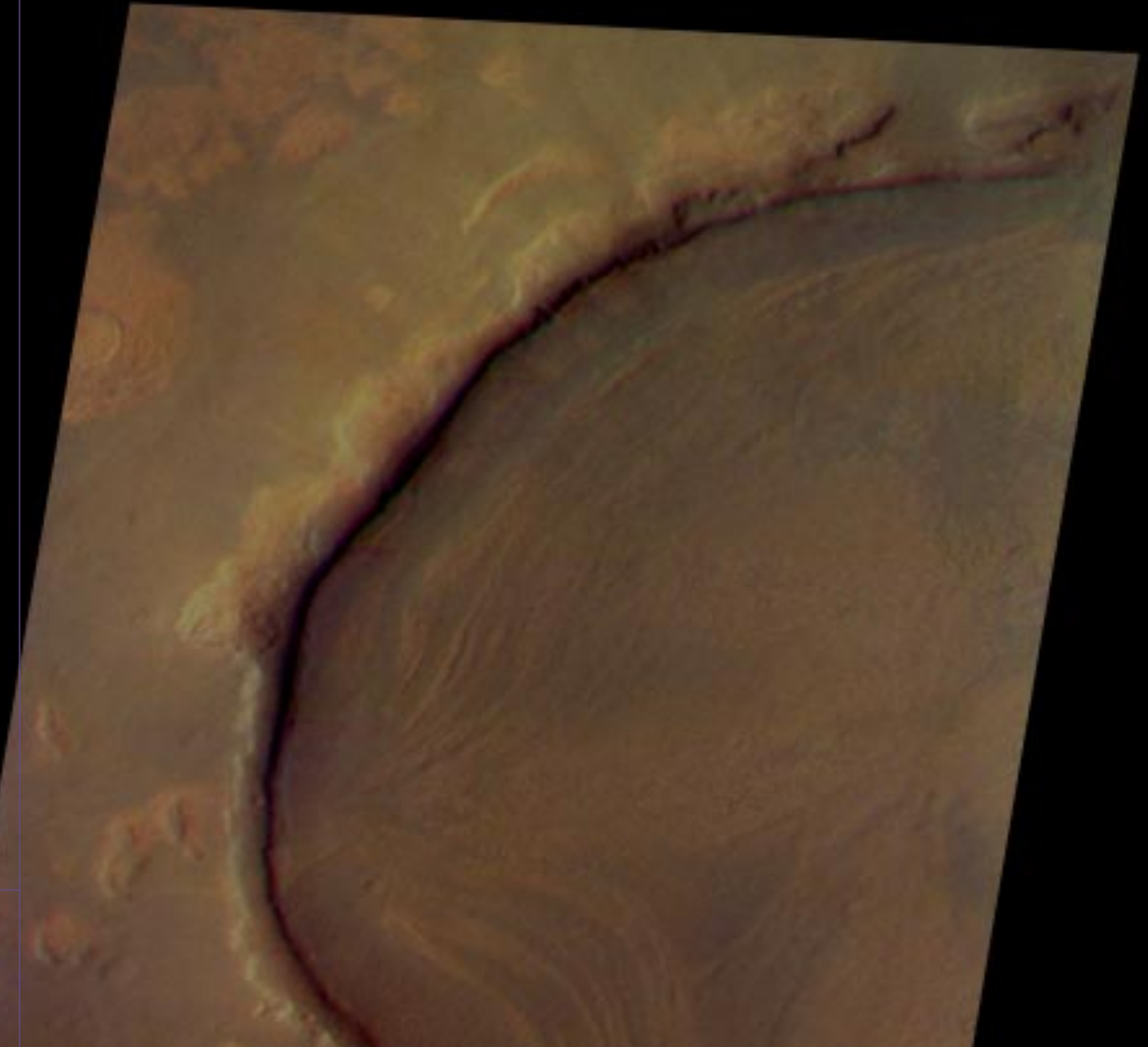
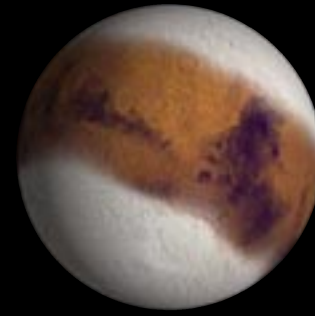
Artist's concept of the Keck Interferometer's debut discovery — DG Tau, a young star with a planet-forming disc.

Mars EXPLORATION

A simulated view of Mars as it might have appeared during a recent ice age. Mars Odyssey's view of a crater in Arcadia Planitia. Sand dunes in Wirtz Crater as seen by Mars Global Surveyor.

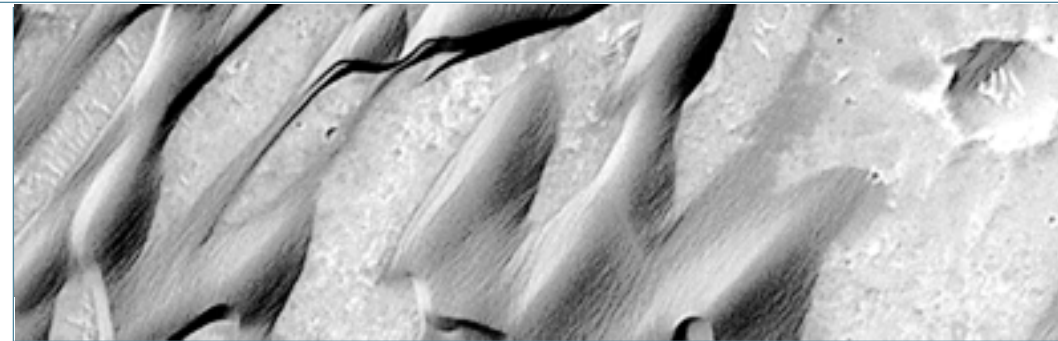
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mere seven years ago, there were no operating spacecraft at our nearest planetary neighbor, Mars. Remarkably, with the imminent arrival of twin JPL rovers, the Red Planet will be attended by four NASA spacecraft — two orbiters and two landers — as well as another orbiter sent by Europe.



Spirit and Opportunity, two robotic field geologists engineered and built by JPL, set off separately from Florida in June and July to arrive at Mars in January 2004. These twin Mars Exploration Rovers can see sharper, explore farther and examine rocks better than anything that ever landed on Mars before. NASA chose to send two both to take advantage of very favorable planetary positions this year — Mars came closer to Earth than it had in more than 50,000 years — and to increase the chances for a successful mission, given the great challenges of landing safely on Mars.

During testing at JPL, technicians take one of the Mars Exploration Rovers for a roll over some precarious terrain.



Mars Global Surveyor imaged these hardened, wind-eroded sand dunes in Herschel impact basin.

In 2003, Mars Global Surveyor discovered a delta-like sedimentary deposit whose details testify that ancient Mars had long-lasting rivers and lakes, not just brief, intense floods.

During the months of Spirit's and Opportunity's passages to Mars, flight-team members at JPL adjusted the trajectories several times and tested the rovers' instruments to see how well they had withstood the severe vibrations of launch.

At year-end, Spirit was just three days away from landing, with Opportunity to follow three weeks later. Both headed for sites selected because of evidence suggesting the locations had been wet in the past. The missions' assignment is to analyze geological clues to learn about past environmental conditions at the sites, particularly the local history of water and conditions that would have been favorable for supporting life.

When the rovers land, they will slip into the planet's atmosphere under a pair of orbital sentinels that have been giving scientists new views of Mars in recent years. Mars Global Surveyor, launched in 1997, and Mars Odyssey, launched in 2001, provided copious information from orbit about several candidate landing sites for the rovers, to aid



Members of the Mars Exploration Rover flight team applaud a successful launch.

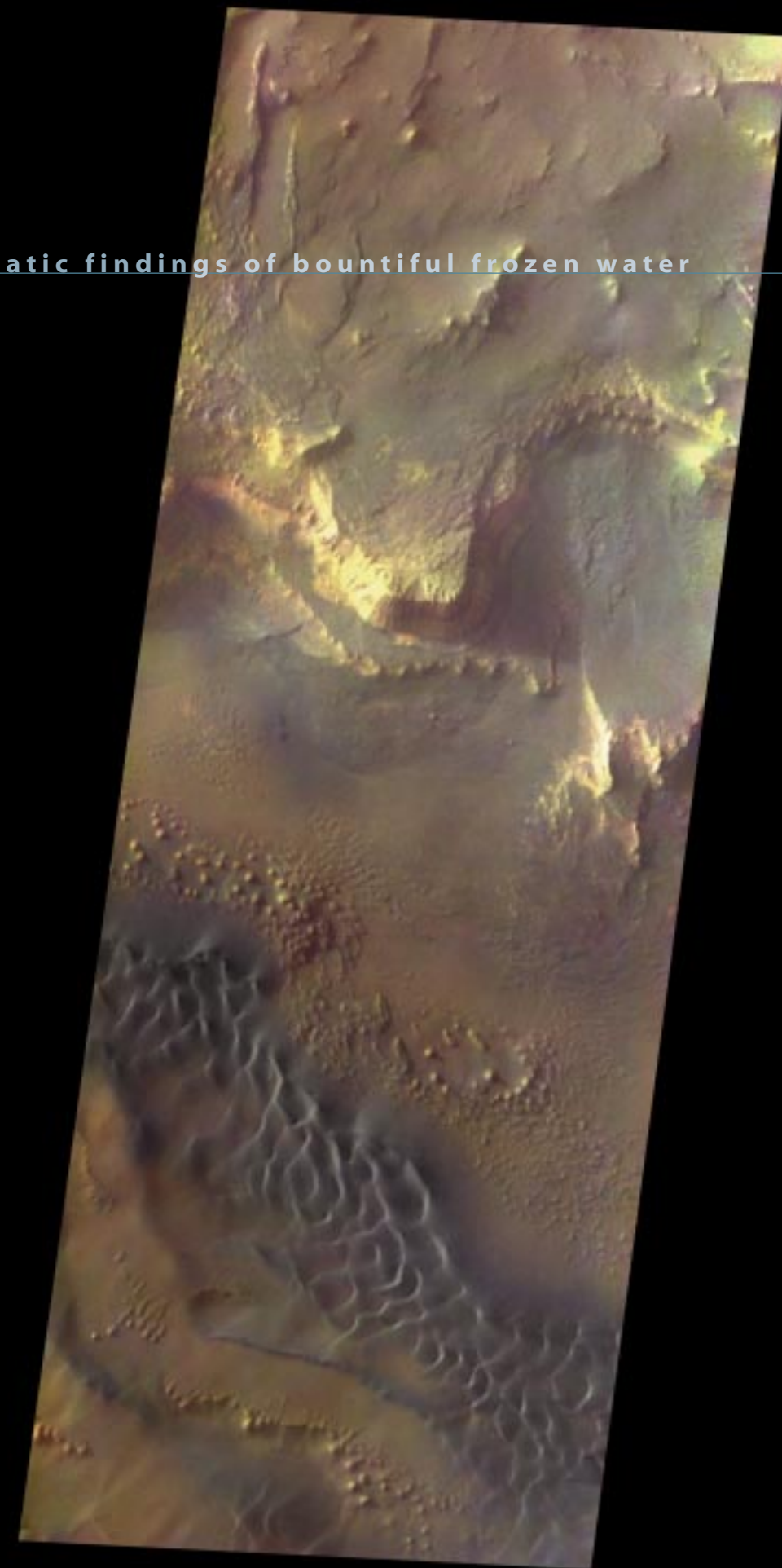
Cliffs and dunes in Melas Chasma are realistically rendered from Mars Odyssey thermal emission imaging system data.

This year, Mars Odyssey added to dramatic findings of bountiful frozen water

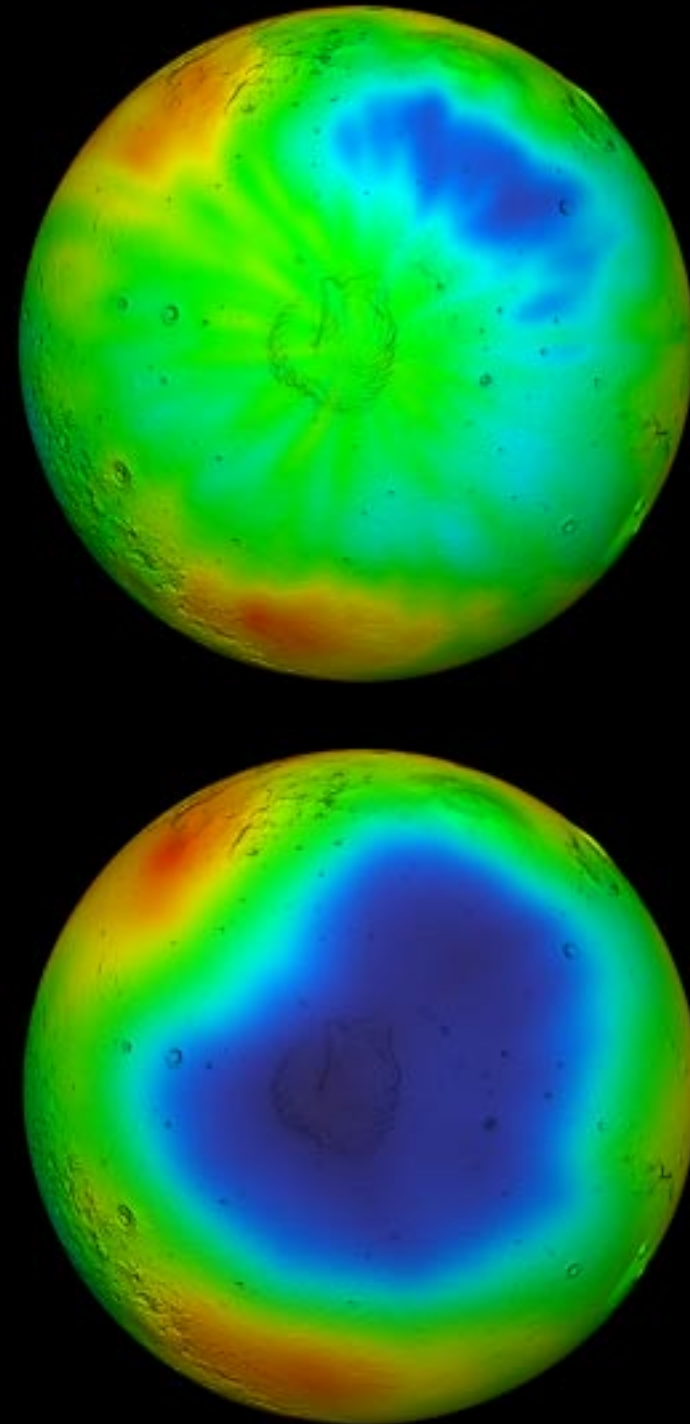
in selection of the final two. Flight teams for both orbiters also prepared to use Global Surveyor and Odyssey for relaying communications from the rovers as a supplement to the rovers' direct-to-Earth communications.

The orbiters also continued making important scientific discoveries of their own. In 2003, Mars Global Surveyor discovered a delta-like sedimentary deposit whose details testify that ancient Mars had long-lasting rivers and lakes, not just brief, intense floods. Also, radio-tracking data from Global Surveyor revealed that Mars has a molten iron core, scientists from JPL and elsewhere reported in March. Pictures from the orbiter's telescopic camera continued to increase the fraction of Mars seen in unprecedented detail. More than 21,000 new images from the camera were released during the year, including the first view of Earth taken from Mars orbit.

This year, Mars Odyssey added to dramatic findings of bountiful frozen water that it began making in 2002. As a covering layer of frozen carbon dioxide vaporized during northern Mars' spring-time, Odyssey's neutron and gamma-ray sensors discovered even more near-surface water ice at high northern latitudes than they had discovered earlier in Mars' southern hemisphere. Paradoxically, Odyssey's infrared and visible-wavelength camera system identified elsewhere on Mars a mineral that is destroyed by liquid water, indicating that region has been very dry for a very long time. Lockheed Martin Space Systems in Denver, Colorado, designed, built and has been operating both Global Surveyor and Odyssey.



Mars Odyssey instruments compared wintertime (above) and summertime maps of hydrogen abundance in the north polar region of Mars.



Mars Express, a European Space Agency orbiter, arrived at Mars in the final week of 2003. Key components of one instrument aboard the spacecraft came from JPL. This radar instrument is designed to check for reservoirs of liquid water deep below Mars' surface.

The next spacecraft NASA plans to send to Mars, the JPL-managed Mars Reconnaissance Orbiter, advanced through major developmental milestones this year in its progress toward a summer 2005 launch. It will examine landscape details as small as a coffee table with the most powerful telescopic camera ever sent to orbit another planet. Some of its other tools will scan underground layers for water and ice, identify small patches of surface minerals to determine their composition and origins, track changes in atmospheric water and dust and check global weather every day.

In August, NASA selected a mission named Phoenix to be the first flight in the Mars Scout program of competitively proposed missions. The mission, to be launched in 2007, will deploy a lander to Mars' water-ice-rich northern polar region, dig for clues about the history of water and check for environmental conditions suitable for microbes. Phoenix, proposed by a team headed by a University of Arizona scientist, is being managed by JPL and will carry a robotic arm and a miniature chemical laboratory built by JPL.



Artist's concept of the Mars Exploration Rover spacecraft during cruise.

The Madrid complex celebrated the completion of a new 34-meter (112-foot) antenna.



Deep Space NETWORK

Beginning in November 2003, the network went into a period of unprecedented demand on its services.



Each of the three complexes consists of several deep space stations equipped with large parabolic reflector antennas and ultrasensitive receiving systems.

The giant dishes of NASA's Deep Space Network, located in three continents around the globe, have known many busy periods over the years — serving as the link with home for many solar system exploration missions from other institutes and other nations, over and above JPL's own. But in 2003 the network had the task of preparing for a communication rush-hour in space.

To ready the system for the coming wave, Deep Space Network engineers mounted preparations on a number of fronts. A new 34-meter-diameter (112-foot) antenna was added at the network's complex near Madrid, Spain. More powerful transmitters were installed on the rest of the 34-meter antennas at each of the sites in California, Spain and Australia.

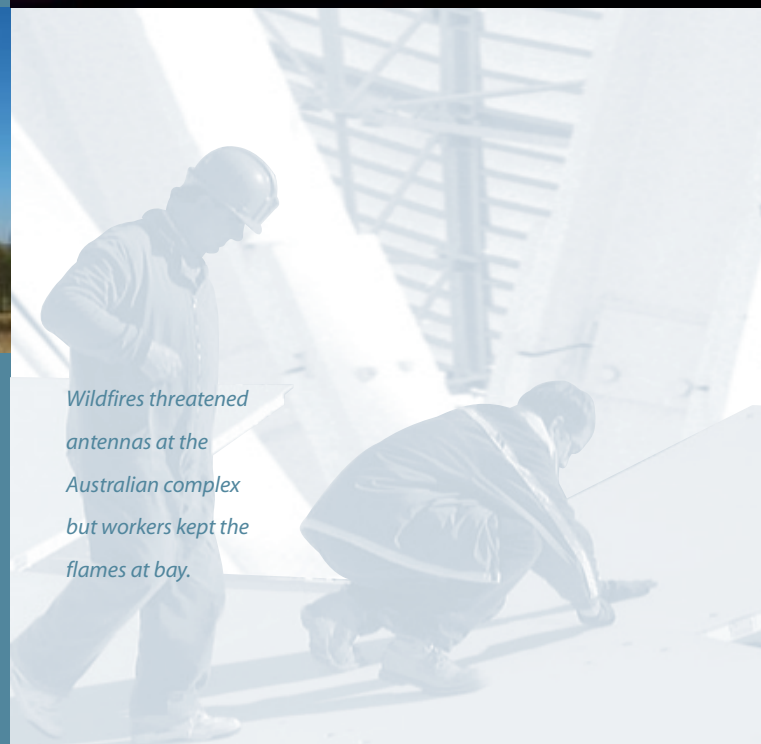
Beginning in November 2003, the network went into a period of unprecedented demand on its services expected to continue for five months. Foremost among those needing service is an international fleet of robotic spacecraft converging on Mars at year's end. In addition to JPL's own twin Mars Exploration Rovers — and the extra demands on the Mars Global Surveyor and Mars Odyssey orbiters to help support the rovers — the Deep Space Network is assisting the European Space Agency's Mars Express mission and Japan's Nozomi. While all this is unfolding, JPL's Stardust spacecraft will execute a comet flyby. During the past year, the network communicated with a total of 31 spacecraft at one time or another.

Engineers sped up a scheduled system-wide upgrade to telemetry, command and tracking systems. New software was developed to more reliably allow one antenna to track two spacecraft. The ability to array together multiple antennas for more sensitive reception — which had been proven in use at the Goldstone facility in California — was extended to the network complexes in Spain and Australia. New hardware and software were created that provide an extra angular measurement to pinpoint the location of spacecraft.

The network also worked with international partners to enhance their mutual capabilities. Upgrades developed by JPL and Australia's Commonwealth Scientific and Industrial Research Organisation were installed at the Parkes Radio Telescope in that country to extend its ability to receive data from spacecraft. An agreement was completed with the European Space Agency to use its new 35-meter-diameter (115-foot) antenna in western Australia as a backup for NASA/JPL missions.



Wildfires threatened antennas at the Australian complex but workers kept the flames at bay.



Enhancements and maintenance on network antennas and equipment ensure first-rate deep space telecommunications.

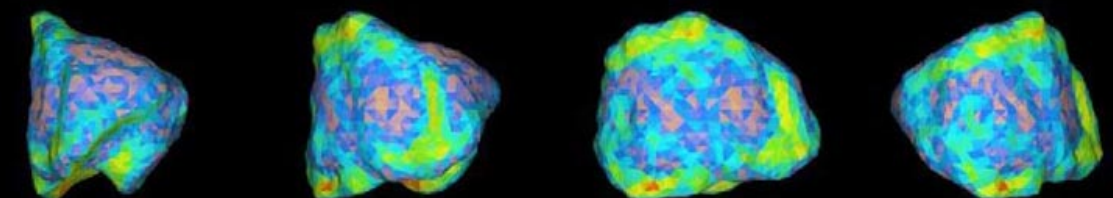


Solar System EXPLORATION

Stardust's aerogel dust collector being prepared for launch. On its way to Saturn, Cassini took this true-color mosaic of Jupiter. A computer-generated model of asteroid Golevka was constructed from radar data.

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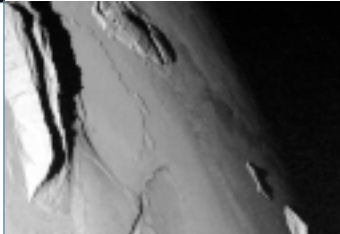
When one door closes, fortune may open another. Nowhere was this truer in 2003 than in NASA's planetary exploration program, where there were fond farewells and also excited hellos.



JPL said farewell to Galileo on September 21, when the intrepid spacecraft reached the end of its odyssey of discovery.



One of the thousands of images returned by Galileo, this one shows topographic details of the Galilean moon Io.



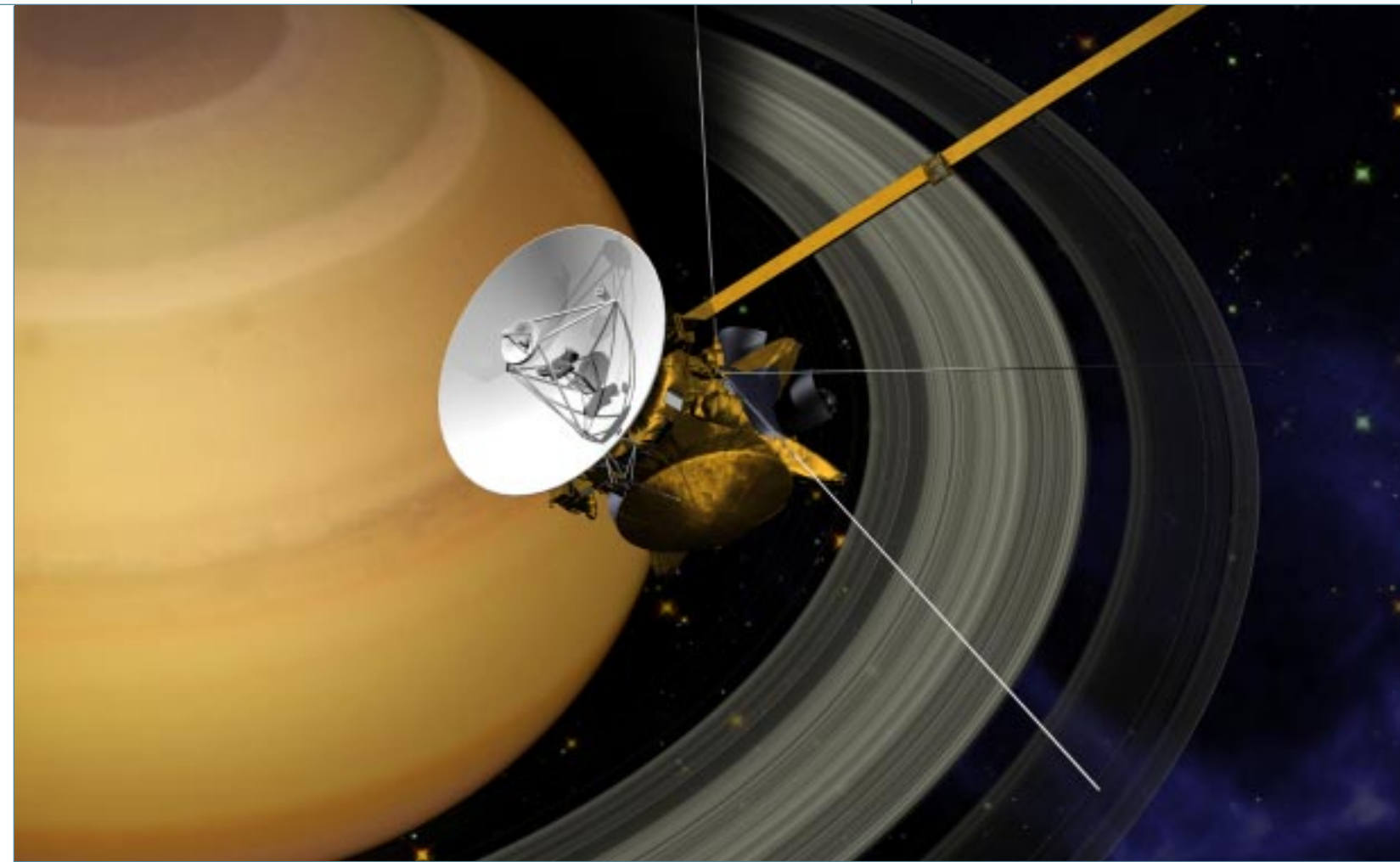
The world bid adieu to one of the most rugged survivors of JPL missions, the long-lived Galileo. This spacecraft capped a remarkable 14-year space adventure, including nearly eight highly productive years making 34 orbits around Jupiter, when it was purposely flown into the giant planet's crushing atmosphere to avoid any possibility of contaminating Jupiter's moons, some of which could possibly harbor life in some form.

During its orbital mission, Galileo extensively investigated the geologic diversity of Jupiter's four largest moons — Io, Europa, Ganymede and Callisto. It found evidence that three of those icy moons — Europa, Ganymede and Callisto — have subsurface layers of liquid saltwater, possibly providing the essential ingredients for life of some kind. It also examined a diversity of volcanic activity on Io. In addition, Galileo was the first mission to measure Jupiter's atmosphere directly with a descent probe, the first spacecraft to fly by an asteroid and the first to discover a moon of an asteroid.

A number of JPL scientists were busy analyzing data from the mission, scrutinizing details from ammonia ice clouds at the giant planet to lava flow on Jupiter's volcanic moon Io.

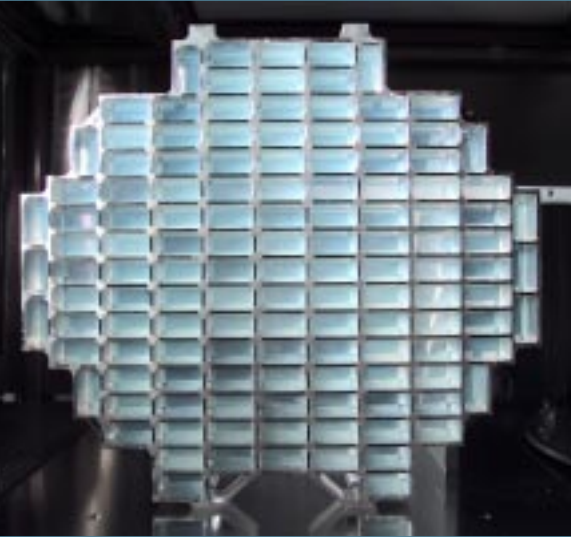
The enthusiastic hellos were for the gem-like, ringed planet Saturn, as the Cassini spacecraft started its final approach before entering orbit in summer 2004. One of the most ambitious missions ever assembled, Cassini is equipped to make special studies of Saturn's large moon

Galileo was the first mission to measure Jupiter's atmosphere directly with a descent probe, the first spacecraft to fly by an asteroid and the first to discover a moon of an asteroid.



Titan, cloaked by an opaque atmosphere containing organic compounds that could offer clues to conditions that led to life on Earth. The mission will explore Titan by way of a probe called Huygens, contributed by the European Space Agency, that will separate from Cassini and descend to the moon's surface in January 2005, perhaps coming to rest on what could be liquid methane oceans. In addition, the Cassini orbiter is equipped with an imaging radar designed to pierce Titan's atmosphere and map its surface. Cassini's Saturn arrival next year will inaugurate a four-year prime mission at the planet. During interplanetary cruise,

The Cassini spacecraft, carrying the Huygens Titan probe, enters Saturn orbit in 2004.



Stardust's sample return collector consists of aerogel mounted in aluminum cells for cometary and interstellar dust capture.

Genesis collects particles of the solar wind in specially designed high-purity wafers of sapphire, silicon, gold and diamond.

Genesis has been collecting tiny particles of material flowing outward from the Sun

scientists have been using radio links between the spacecraft and Earth to search for gravitational waves rippling through the solar system.

Yet other robotic pioneers are the twin spacecraft Voyager 1 and 2, paradigms of reliability and productivity during their 26-year journey past the four large outer planets to the edge of our solar system. The Voyagers owe their longevity to their radioisotope thermoelectric generators. Voyager 1, the most distant of any human-made object, is now billions of kilometers from the Sun. It is expected to provide the first direct sensing of true interstellar space beyond the limit of the solar wind. The Voyagers have enough electrical power to last another 20 years. The mission is managed by a team that also operates the long-lived Ulysses, a European Space Agency–NASA mission to study the Sun.

A more immediate milestone is in store for JPL's Stardust spacecraft, at the end of 2003 just two days away from a flyby of the comet Wild 2 (pronounced "vilt two"). Launched in 1999, Stardust has been collecting interstellar dust during an excursion through the solar system, and likewise will snag comet dust when it flies by Wild 2 in January 2004. It will return those samples to Earth in a novel capsule return over the Utah desert in early 2006.

Utah will also be the rendezvous point next year for another sample return mission, Genesis, which has been collecting tiny particles of material flowing outward from the Sun since its launch in 2001. After they are brought to Earth in September 2004, the samples of "star stuff" could provide scientists with



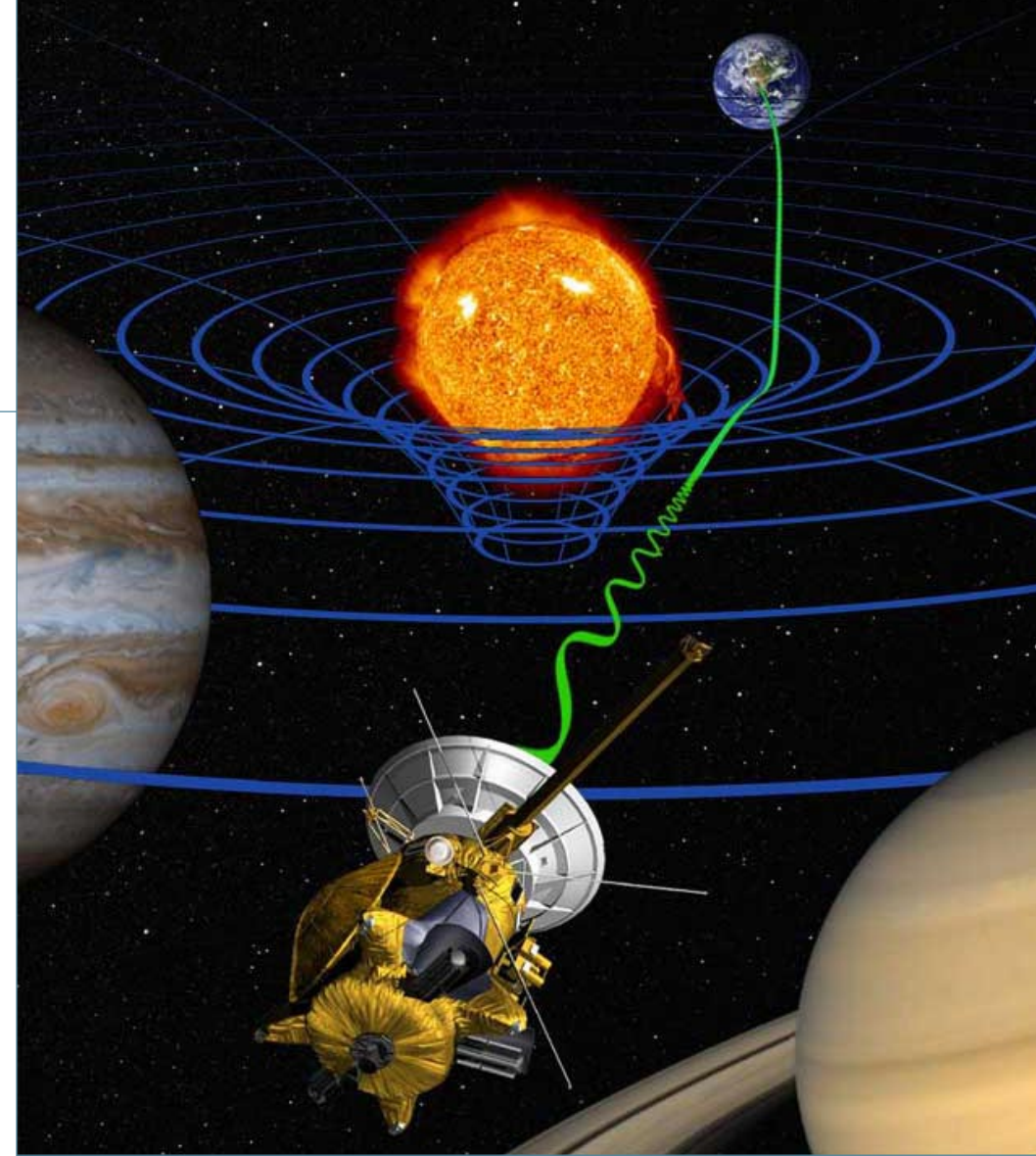
information about the primordial cloud of material that consolidated into the Sun and planets billions of years ago. Both Stardust and Genesis were designed and built by Lockheed Martin Space Systems in Denver, Colorado.

Stardust and Genesis were carried out under NASA's Discovery program of competitively selected, low-cost solar system exploration missions. JPL teams are also at work on two other upcoming Discovery missions. Following launch in December 2004, Deep Impact will fire an impactor into comet Tempel 1 on July 4, 2005, to study material ejected from the comet's interior. Scheduled for launch in 2006, the Dawn spacecraft in 2010 will reach the asteroid Vesta, where it will spend a year before departing and traveling to the solar system's largest asteroid, Ceres.

Galileo's legacy at Jupiter, meanwhile, has prompted an ambitious mission proposal called the Jupiter Icy Moons Orbiter. This spacecraft would solve a longstanding dilemma of how to carry enough propellant to maneuver in and out of orbit around more than one distant world. It would be equipped with a small onboard nuclear reactor to allow it to hopscotch from one moon to the next — a mission that would be impossible to carry out without this technology.

In other solar system ventures, JPL engineers and scientists designed and built a microwave instrument to fly on the European Space Agency's comet-bound Rosetta spacecraft. With

Stardust encounters comet Wild 2 in January 2004 and will return samples in 2006.



A radio science experiment using data from the Cassini spacecraft confirmed Einstein's theory of general relativity with a precision 50 times greater than previous measurements.

launch rescheduled to 2004 due to a launch vehicle issue, Rosetta will enter orbit around comet Churyumov–Gerasimenko in 2014, allowing the JPL instrument to examine the escape of gases from the comet nucleus.

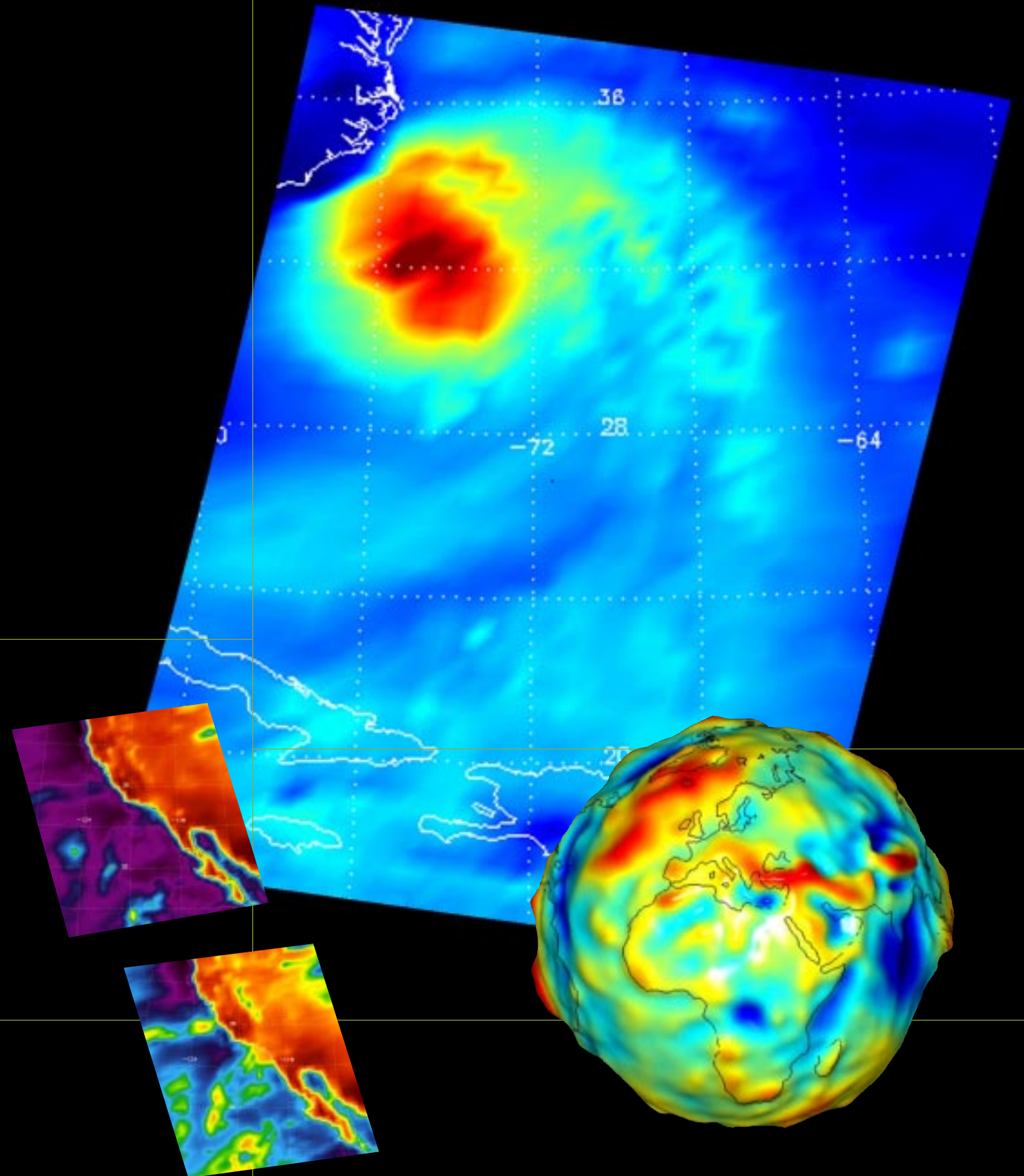
Ground-based activities in 2003 continued to build an important library of knowledge about the asteroids whose orbits come near Earth. The Near-Earth Asteroid Tracking program surveys the sky systematically from Hawaii and Southern California to find space rocks that could be on a collision course with Earth. This program and others have now located approximately 60 percent of the estimated total of near-Earth asteroids greater than one kilometer (about one-half mile) in diameter.

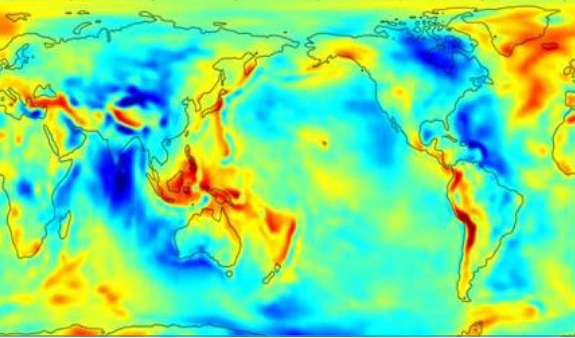
Earth SCIENCE

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As JPL's exploration ventures unfold across the solar system and beyond, another constellation of satellites and instruments is studying our home planet. The year 2003 was a harvest season for the Laboratory's Earth science program, as sophisticated monitors that had been launched over a series of years provided a rich bounty of science data.

Atmospheric water vapor in Hurricane Isabel and two views of a California storm as seen by the Atmospheric Infrared Sounder. Data from the Gravity Recovery and Climate Experiment provided the 3-D view of Earth's gravity field.

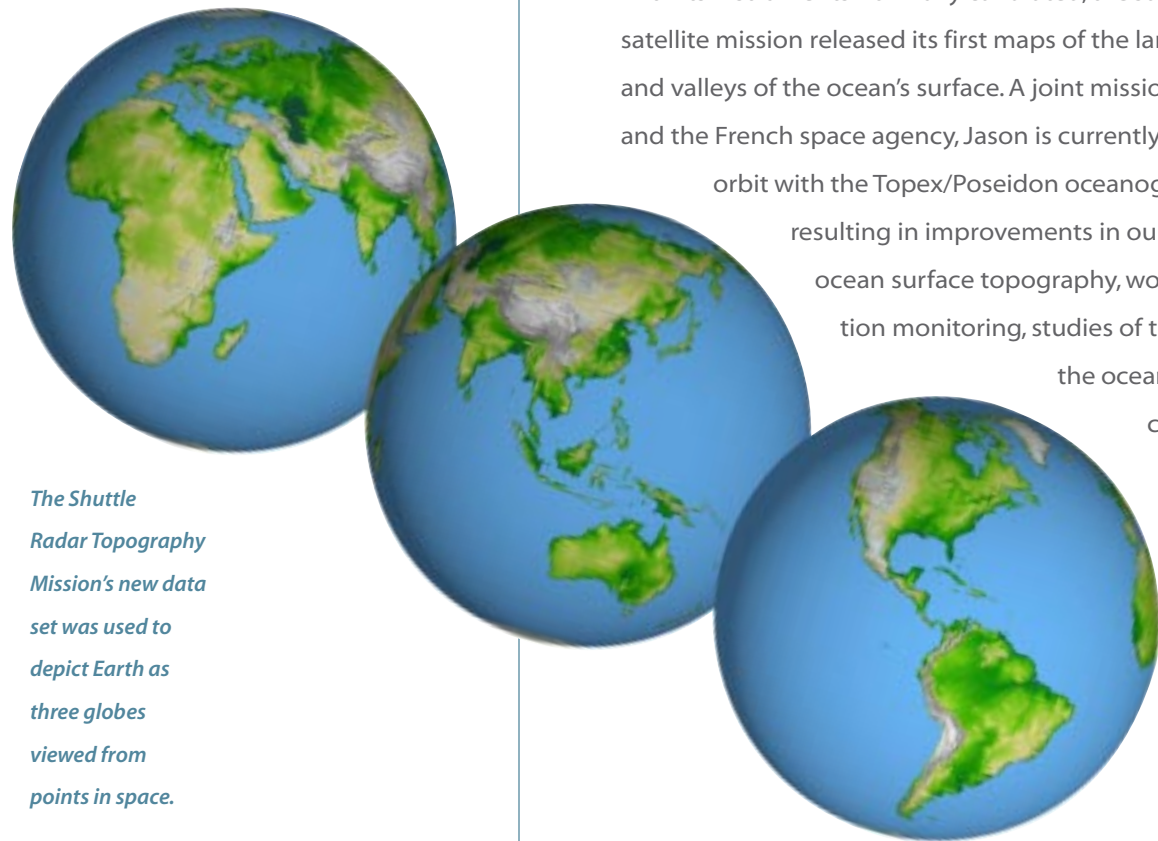




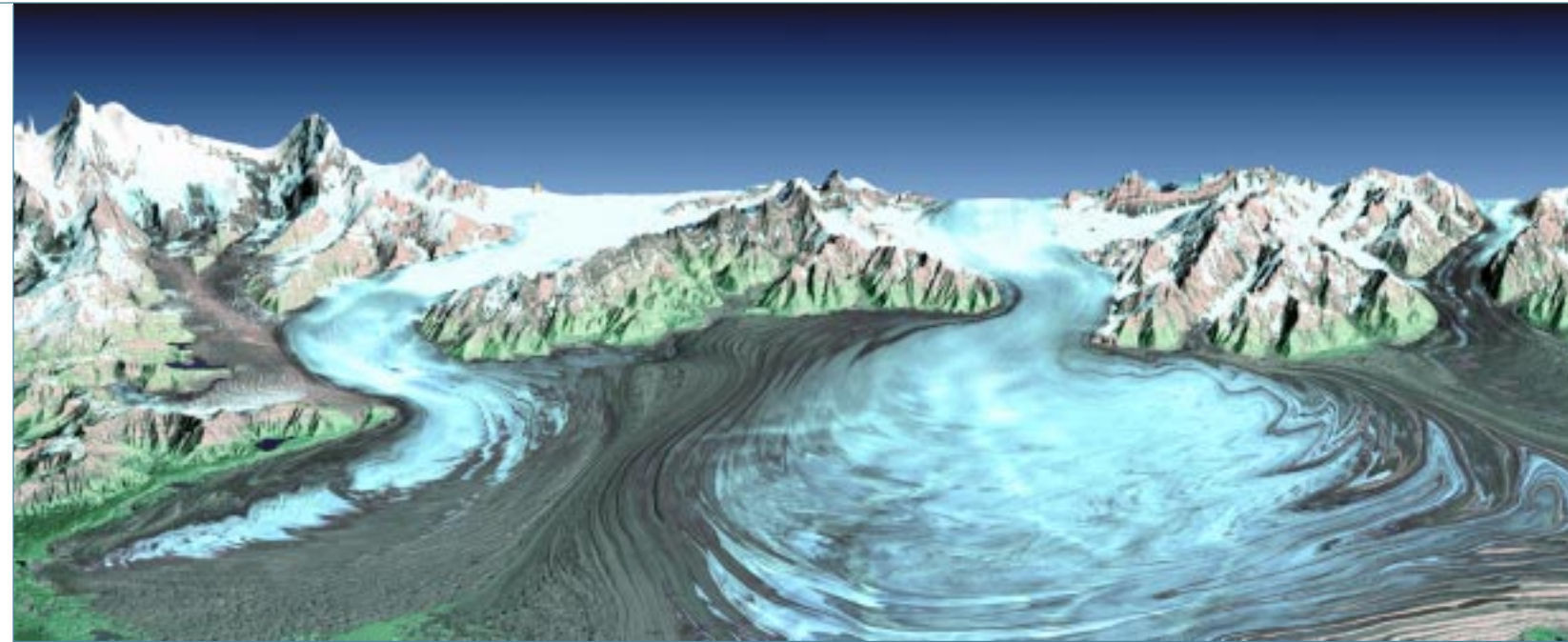
Grace data are providing a more precise definition of the geoid, an imaginary surface defined by Earth's gravity field.

The Gravity Recovery and Climate Experiment, or Grace, released its first science product, the most accurate map yet of Earth's gravity field. This preliminary model improves knowledge of the gravity field so much — by two orders of magnitude — that it was released to scientists months in advance of the scheduled start of routine Grace science operations. The results are already allowing oceanographers to better understand ocean circulation, which has a strong impact on atmospheric weather patterns, fisheries and global climate change. Grace will soon map gravity variations from month to month, reflecting changes that result from the seasons, weather patterns and short-term climate change. The data will help work in ocean circulation and hydrology that is important for climate studies and agriculture. The mission senses Earth's gravity field with a pair of identical satellites provided by Germany.

With its instruments now fully calibrated, the Jason oceanography satellite mission released its first maps of the large and small hills and valleys of the ocean's surface. A joint mission between NASA and the French space agency, Jason is currently flying in a tandem orbit with the Topex/Poseidon oceanography satellite, resulting in improvements in our observations of ocean surface topography, world ocean circulation monitoring, studies of the interactions of the oceans and atmosphere, climate predictions and observations of events such as El Niño.



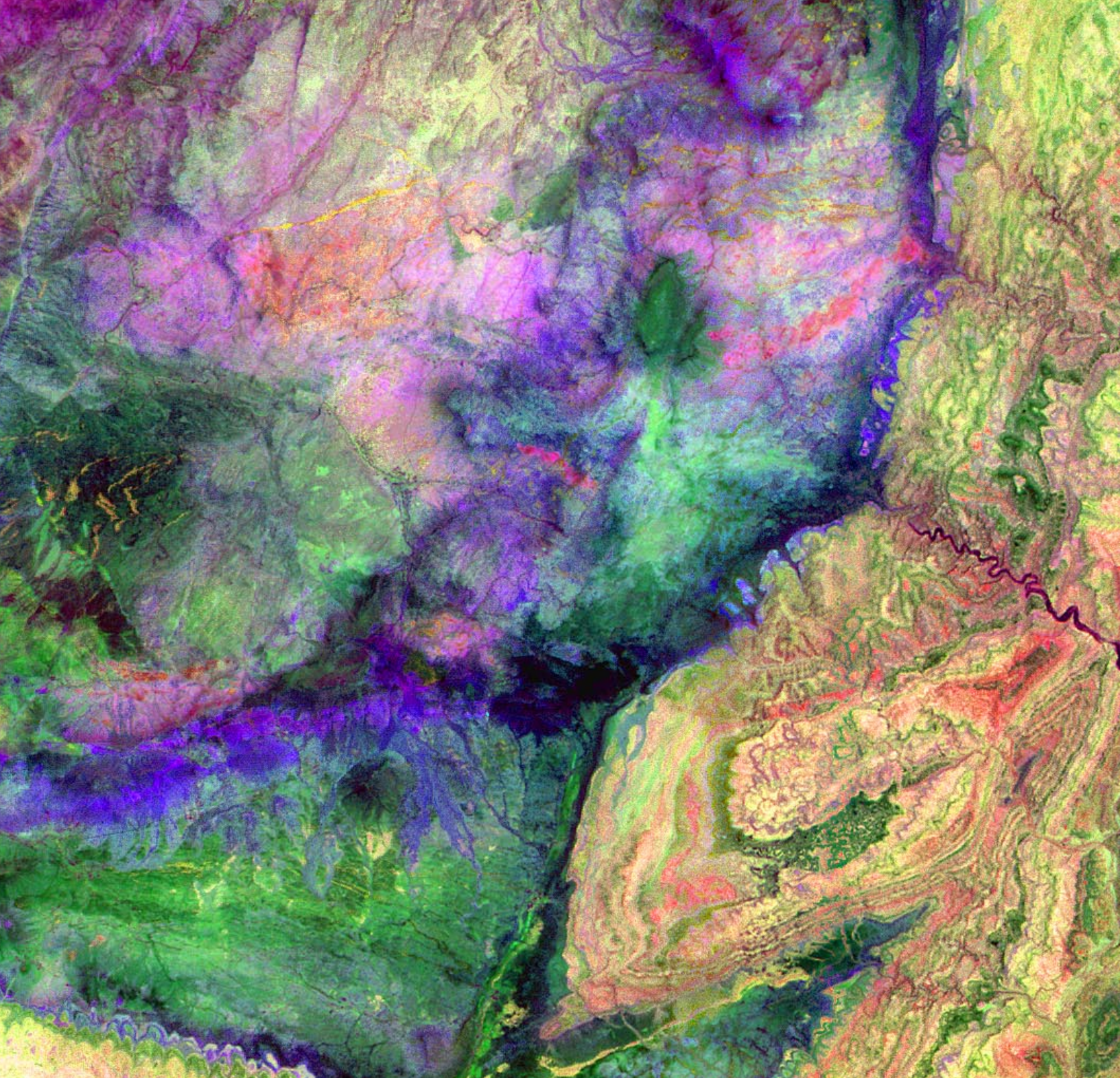
The Shuttle Radar Topography Mission's new data set was used to depict Earth as three globes viewed from points in space.



This highly detailed perspective view of Malaspina Glacier in southeastern Alaska was created from data collected by the Shuttle Radar Topography Mission.

Weather forecasters around the world began receiving data products from JPL's Atmospheric Infrared Sounder experiment aboard NASA's Aqua satellite. These include the most accurate, highest-resolution measurements ever taken from space of the infrared brightness, or radiance, of Earth's atmosphere, as well as profiles of Earth's atmospheric temperatures, humidity levels and many other variables. The new data are expected to eventually allow meteorologists to significantly improve weather forecasts, increasing their useful range beyond the current five days. The data are also expected to improve tracking of severe weather such as hurricanes.

A JPL instrument on NASA's Terra satellite, the Advanced Spaceborne Thermal Emission and Reflection Radiometer, continued to function well, observing a number of special emergency targets such as wildfires, earthquake locales, erupting volcanoes and sites related to national security, in



The year 2003 was a harvest season for the

Laboratory's Earth science program

addition to its regular science work. Another JPL instrument on the Terra satellite, the Multi-angle Imaging SpectroRadiometer, produced unique imagery supporting studies ranging from climate modeling to air quality monitoring.

Ocean winds, meanwhile, are the target for a pair of JPL radar instruments, called scatterometers, flown on two different satellites. Data from NASA's newest SeaWinds instrument aboard Japan's Midori 2 satellite were released to the public, though a malfunction of the Midori 2 spacecraft prematurely ended the mission. The SeaWinds data will continue to be provided by an identical instrument aboard NASA's Quick Scatterometer satellite, or QuikScat, launched in 1999. The instruments provide highly accurate measurements of the direction and speed of near-surface ocean winds, as well as views of the extent of sea ice and properties of Earth's land surfaces, covering 90 percent of Earth's surface each day. Climatologists, oceanographers and meteorologists use SeaWinds data to understand interactions between the ocean and atmosphere, as well as to predict severe weather patterns, climate change and global weather abnormalities such as El Niño. Experts expect data to improve global and regional weather forecasts, ship routing and marine hazard avoidance, measurements of sea ice extent and tracking of icebergs.

The Advanced Spaceborne Thermal Emission and Reflection Radiometer is sensitive to differences in rock mineralogy. This image of the Anti-Atlas Mountains of Morocco highlights the complex geology of the area.



The complex structure of polar clouds is illustrated in this image by the Multi-angle Imaging SpectroRadiometer. The colors represent cloud altitudes, with green being highest.

JPL's Shuttle Radar Topography Mission, a joint project between NASA and the U.S. National Geospatial Intelligence Agency that flew in 2000 aboard Space Shuttle Endeavour, continued in 2003 to release high-resolution digital data that are being used to create the world's best topographic maps. Data from the instrument provide the third dimension — elevation — to maps of features on Earth's surface. For many regions around the planet, the elevation maps created with the data will be 10 times more precise than the best available today. By year end, the project team had released data for all of North and South America as well as Eurasia. Data deliveries for Earth's other land areas mapped by the mission will continue in 2004.

Shuttle Radar Topography Mission data also played a key role in a joint study by NASA and scientists in Chile of the Patagonia ice fields of Chile and Argentina — the largest ice masses apart from Antarctica in the southern hemisphere. Researchers compared conventional topographic data from the 1970s and 1990s with data from the mission that flew on the space shuttle to measure changes over time in volumes of the region's largest glaciers. They found that the ice fields are thinning at an accelerating pace, and now account for nearly 10 percent of global sea-level change from mountain glaciers. The research could yield clues to how climate interacts with glaciers, and may be a good barometer of how the large ice sheets of Greenland and Antarctica will respond to future climate change.

JPL scientists reported considerable progress on several fronts of earthquake research. Working in conjunction with several other institutions, the Laboratory is developing computational models to understand the behavior of earthquake fault systems. The models combine data from Global Positioning System satellites with space radar imagery, giving scientists a view of how land

surfaces deform between and during earthquakes. Researchers reported their initial results on a 10-year experiment attempting to make real-time earthquake forecasts for Central and Southern California. Since 2000, all six earthquakes of magnitude 5 or greater that have struck the region have occurred in regions flagged by the experiment. The work may substantially refine existing hazard maps, allowing federal, state and local agencies responsible for hazard management to make better priorities for retrofitting of buildings and risk mitigation.

Two JPL instruments were completed and shipped to be installed on NASA's Aura satellite, planned for launch in 2004. The Tropospheric Emission Spectrometer is an infrared sensor designed to study Earth's troposphere — the lowest region of the atmosphere — and to look at ozone and other urban pollutants. The Microwave Limb Sounder is an instrument intended to improve our understanding of ozone in Earth's stratosphere, vital in protecting us from solar ultraviolet radiation. Before launch, JPL scientists have been involved in intensive airborne and balloon-borne field campaigns to better understand ozone and climate processes in the atmosphere. In a December issue of Science magazine, JPL scientists reported dramatic progress in understanding atmospheric transport and cloud formation through precise measurements of isotopes of water vapor.



Multi-angle Imaging SpectroRadiometer data were combined with a digital terrain elevation model from the U.S. Geological Survey to create this mosaic of Scandinavia and the Baltic region.

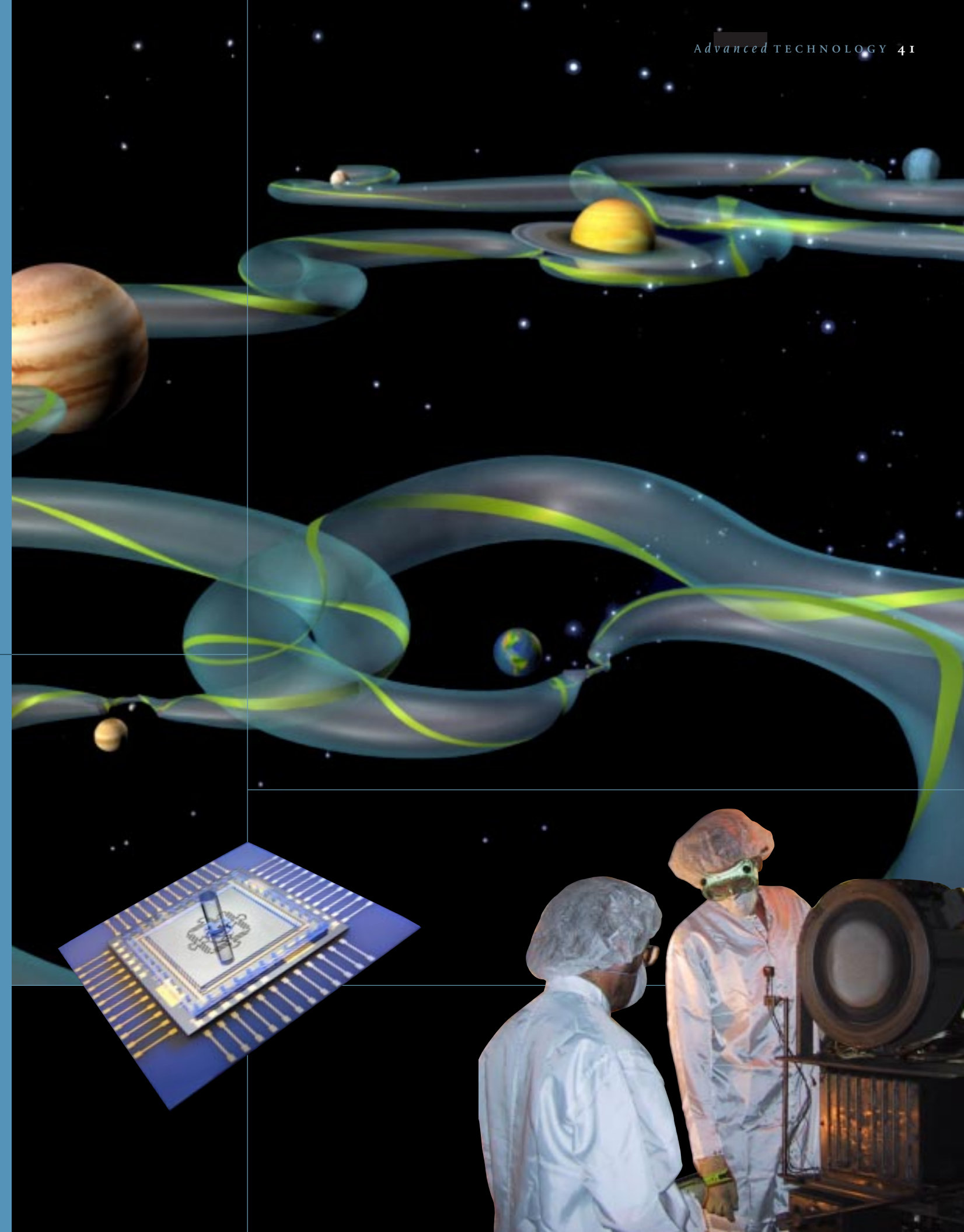
Advanced TECHNOLOGY

An "interplanetary highway" trajectory design would reduce fuel needed by spacecraft to travel through the solar system. Smaller than a shirt button, this microgyroscope may find its way into spacecraft guidance systems. JPL technicians inspect an ion engine that performed flawlessly for 30,352 hours.

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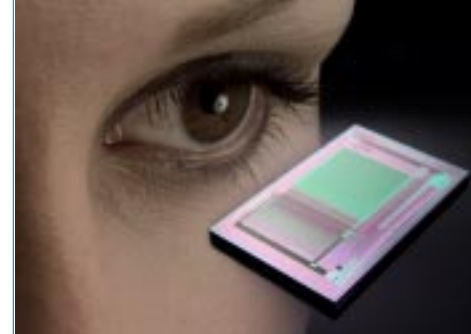
While many of JPL's researchers are engaged in building and flying spacecraft and instruments, others are focused on developing technical innovations that will pave the way for missions of the future. In addition, technologies originally created for space exploration are adapted for earthly uses, both in service of the government and in the commercial sector.



Many missions have benefited from new technologies developed at the Laboratory. The Mars Exploration Rovers, for example, took advantage of many new technologies such as fast three-dimensional terrain mapping with its stereo cameras, collision avoidance software, rover systems design to enable long-range travel and a system that combined hardware and software to measure the lander's horizontal motion as it descended during landing.

Advanced propulsion is another area of focus at JPL. Ion propulsion, which was successfully demonstrated on the Deep Space 1 spacecraft, is being developed further for the Dawn mission to a pair of asteroids and the proposed Jupiter Icy Moons Orbiter. One ion engine was kept running for nearly five years, from 1998 until 2003. Progress was also made in 2003 in such propulsion technologies as ultralight propellant tanks and design refinements for descent engines and onboard thrusters.

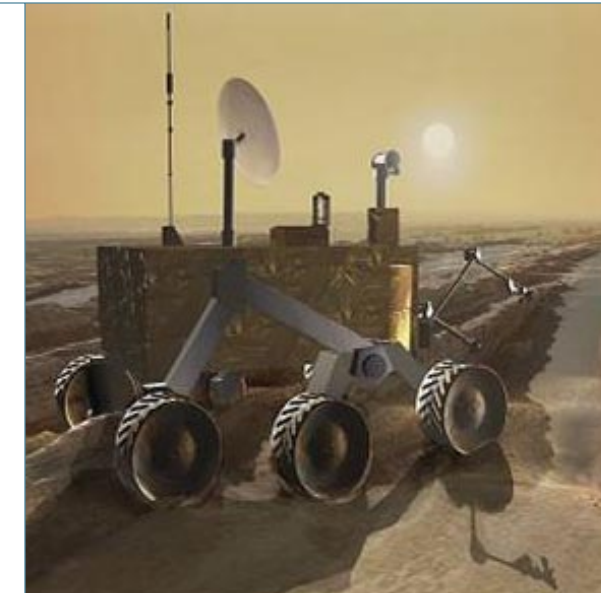
JPL's advanced electron beam lithography system allows researchers to work at the sub-molecular scale.



JPL's work on machine-vision microprocessors contributes to the development of visually intelligent robots for planetary exploration missions.

New technologies that allow science instruments to be enhanced and/or miniaturized are highly prized. New thermopile detectors developed at JPL's Microdevices Laboratory allowed an atmospheric instrument being prepared for the 2005 Mars Reconnaissance Orbiter to be shrunk to one-eighth of its previous weight. JPL technologists are also achieving impressive developments in spectroscopy, which analyzes a spectrum of light to draw conclusions about the makeup of the celestial body from which it came. JPL's New Millennium Program tested and validated designs for small penetrators that would impact the surfaces of planets or other bodies.

In other technology development work at JPL, an advanced eye tracker designed for the U.S. Army could help people with complex physical disabilities. While the Army is interested in the technology as part of sophisticated eye- and voice-operated systems to control military vehicles, it could also allow a disabled person to operate a computer, telephone or appliances entirely with the eyes. A team of JPL scientists and engineers formatted the eye tracker system to help diagnose children with learning and reading challenges.



Future Mars rovers will need to drive long distances and maximize science return. Onboard autonomous science investigation software being developed at JPL would enable these capabilities.

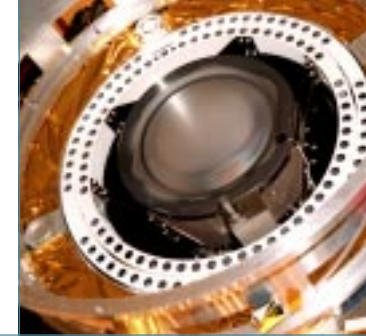
In 2003, JPL recorded about \$60 million in contracts to develop technologies on behalf of the Defense Department and other federal agencies, including the Department of Homeland Security.



New technologies that allow science instruments to be

enhanced or miniaturized are highly prized

JPL's "spider-bot" is a micro-robot explorer that has potential to function in environments where wheeled robots cannot go.



A close-up view of the solar-powered ion engine used on Deep Space 1, which successfully validated the experimental propulsion system.

In 2003, JPL recorded about \$60 million in contracts to develop technologies on behalf of the Defense Department and other federal agencies, including the Department of Homeland Security. The Laboratory also initiated 23 new tasks for commercial customers, entering into agreements with 18 new companies.

A number of JPL technologists and scientists benefited from a new initiative called the Research and Technology Development Program, which uses discretionary funds from JPL's Director's Office to underwrite promising investigations. In 2003, 73 projects shared a total of \$25 million in funding. They reported their results or progress in a poster session in December attended by a significant percentage of the Laboratory's technical staff.



Bacterial growth records are part of development of a prototype device that continuously monitors the air for the presence of spores.

Engaging THE PUBLIC

To inspire the next generation of explorers ... as only NASA can.



Future spacecraft engineers show off models of their designs.



Visiting Girl Scouts get a personalized science lesson.



Space enthusiasts of all ages are inspired by concepts and images from JPL missions.



Hands-on projects always draw a crowd of excited participants.

JPL's past is legendary, and its future is full of great promise. One way that the Laboratory works to ensure a bright future is by embracing NASA's mission statement, which calls on the agency "To inspire the next generation of explorers ... as only NASA can." In 2003, inspiration flowed in many directions, ranging from the formal education setting of the classroom to the informal education opportunities in a variety of public outreach programs.

On the formal education front, JPL reached more than 24,000 teachers through a combination of workshops, Web activities and conferences. More than 73,000 students were engaged by face-to-face interactions of various kinds. Among key programs, JPL participated in a summer teacher institute sponsored by the Chancellor's Office of the California State University system, offering NASA programs and materials training to CSU faculty from 18 campuses. JPL began working with the University of Southern California's Joint Education Project to provide teacher professional development to underserved schools in the downtown Los Angeles area. This project also involves working with university students that serve as mentors in those schools. JPL also created a Space Grant internship program with 40 participants in 2003.

America's museums, planetariums and science centers have proven a highly meaningful way to engage the public in JPL's missions. The Laboratory produced "RingWorld," a wide-screen story of Cassini's journey to Saturn, that has been shown in more than 200 planetariums across the nation. In preparation for the Mars rover landings in early 2004, JPL created an alliance with 100 museums and other institutions to deliver daily images and data from the mission.

In 2003, JPL expanded its Solar System Ambassador program, which recruits space enthusiasts around the country to bring programs about NASA's space science missions to their local communities. Some 295 ambassadors in all 50 states held nearly 2,000 events, reaching a total audience of 23.8 million — almost two and a half times the program's reach the previous year.

More new external partnerships were forged when JPL created a Night Sky Network that links the laboratory to amateur astronomy clubs around the country. The network serves as a conduit for JPL to distribute hands-on activities related to NASA missions to 177 clubs in 47 states. The Laboratory also established a new long-term collaboration with the Girl Scouts of America.

JPL supported NASA's agency-wide communication effort by developing and managing a Web portal that hosts NASA's home page. As the year closed, its infrastructure was enhanced to prepare for the expected high public demand during the Mars rover landings and other events early in 2004. JPL also had the distinction of being the first NASA center to adopt the agency's standardized graphic look for its own center Web site. The JPL home page attracted more than 300,000 unique visitors and 1 million total visitors each month through the year.

In 2003, nearly 18,000 visitors toured JPL. An additional 30,000 visitors attended the Laboratory's annual Open House. Some 4,400 members of the public attended JPL's monthly Theodore von Kármán Lecture Series.

Institutional ACTIVITIES

From modest beginnings in 1944, the Laboratory has grown to occupy 177 acres. Director Charles Elachi describes research results to a visiting member of Congress. Space Flight Awareness representatives joined in Columbia recovery efforts in Texas.



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PL is not content to aim high only in its engineering and science activities. To match that level of excellence, it strives to provide a first-rate institutional and business environment. In 2003, the Laboratory strengthened its business practices in a number of areas.



An Optical Communications Telescope Laboratory was installed at Table Mountain, Wrightwood, California. The facility will conduct research in technology areas that benefit future deep space missions.



One focus during the year was the transition to a new five-year contract governing JPL's relationship with its federal sponsor. In late 2002, NASA awarded the California Institute of Technology a contract to manage JPL beginning October 1, 2003. The new contract required JPL to make many changes in its business procedures, which were smoothly carried out on schedule.

In support of President Bush's Management Agenda for improving the performance of the federal government and ensuring that resources are wisely used, the Laboratory began implementing a

new approach to business management. This approach, which incorporates full-cost accounting, will ensure cost control by standardizing and integrating the monitoring of schedule and cost performance over the entire life cycle of a project. JPL also assisted NASA Headquarters and other field centers as they worked toward reengineering NASA's business infrastructure to improve the management of financial, physical and human resources.

JPL strives to provide a first-rate institutional and business environment

Located at the foot of the San Gabriel Mountains, JPL has been managed by Caltech for NASA since 1958.



The Laboratory conducted and hosted several multi-agency emergency response exercises involving local law enforcement and fire departments.

JPL's Urban Search and Rescue Team trains volunteers for coordinated response to major disasters.



JPL received a top rating from its third-party auditor, National Quality Assurance, for continuing its certification under the International Organization for Standardization, also known as ISO 9001–2000. This assures that JPL's quality management system continues to meet widely recognized standards.

In 2003, JPL reaffirmed its strong commitment to the health and safety of its personnel and surrounding communities by integrating its environmental, health and safety programs. JPL achieved significant reductions in energy usage as measured against established baselines and was the first NASA center to receive a "green" or positive rating for its conservation of energy and water. JPL also achieved a major reduction in targeted chemical emissions and has become one of the benchmark NASA centers for its recycling/rubbish program, exceeding the state government landfill-use reduction goal. As a result, JPL was recognized by the California Integrated Waste Management Board.

In the area of emergency preparedness, JPL continued to take a leading role. It updated its multihazard emergency response plan, which covers a wide range of potential emergencies, including fires, floods, earthquakes, explosions, hazardous material incidents and terrorism. The Laboratory conducted and hosted several multi-agency emergency response exercises involving local law enforcement and fire departments and established mutual aid agreements with surrounding communities. In support



JPL cut the opening ribbon for a new facility that will efficiently transfer residual flight hardware to future projects.

of emergency preparedness, JPL established a Web-based emergency operations center, which is being considered by NASA Headquarters as the West Coast center of excellence for emergency response.

During the year, JPL sustained its support of small and disadvantaged businesses. In acknowledgment of its contributions in this area, the Laboratory received the Dwight D. Eisenhower Award for Excellence from the U.S. Small Business Administration, which recognizes large contractors that have excelled at using small businesses as suppliers and subcontractors. In addition, JPL set attendance records for three key supplier outreach functions: the 15th annual High Technology Small Business Conference, the seventh annual Science Forum for Small Business and the fifth annual Small Business Round Table.

In other institutional achievements, JPL completed a new facilities master plan, which creates a vision for Laboratory infrastructure development over the next decade. It also initiated a new staffing process, including an online applicant tracking tool and streamlined policies and procedures.

selected Awards & HONORS

DR. CLAUDIA ALEXANDER
Emerald Honor for Women of Color in Research and Engineering, Career Communications Group

DR. JAMES BRECKENRIDGE
George W. Goddard Award, International Society for Optical Engineering

DR. ANDREA DONNELLAN
Outstanding Achievement Award, Women in Aerospace

THOMAS GAVIN
Named fellow, American Astronautical Society

DR. ROBERT GREENE
Honorary Directorate, Universidad Extremadura, Caceres, Spain

DR. DAVID HALPERN
Elected life member, International Academy of Astronautics

DR. GERARD HOLZMAN
Thomas Alva Edison Patent Award, Research and Development Council of New Jersey

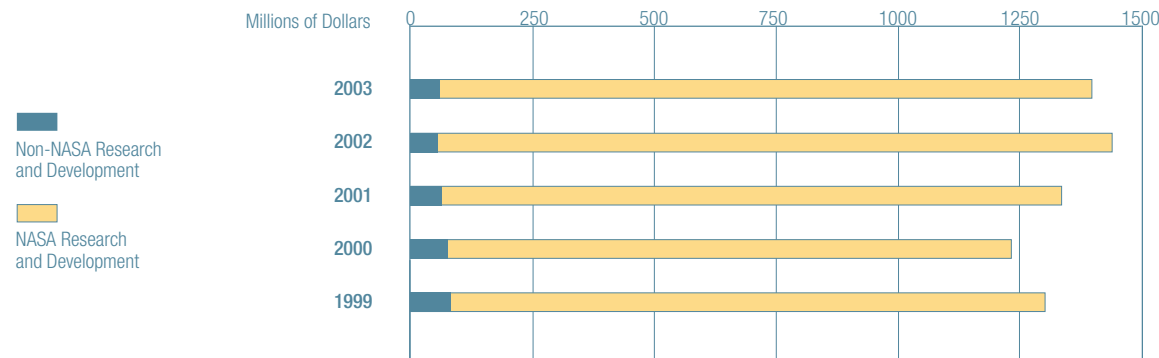
DR. HWANG LEE
America's Outstanding Young Researcher Award, Association of Korean Physicists

DR. MICHAEL PELLETIER
Charles Mann Award, Federation of Analytical Chemistry and Spectroscopy Societies

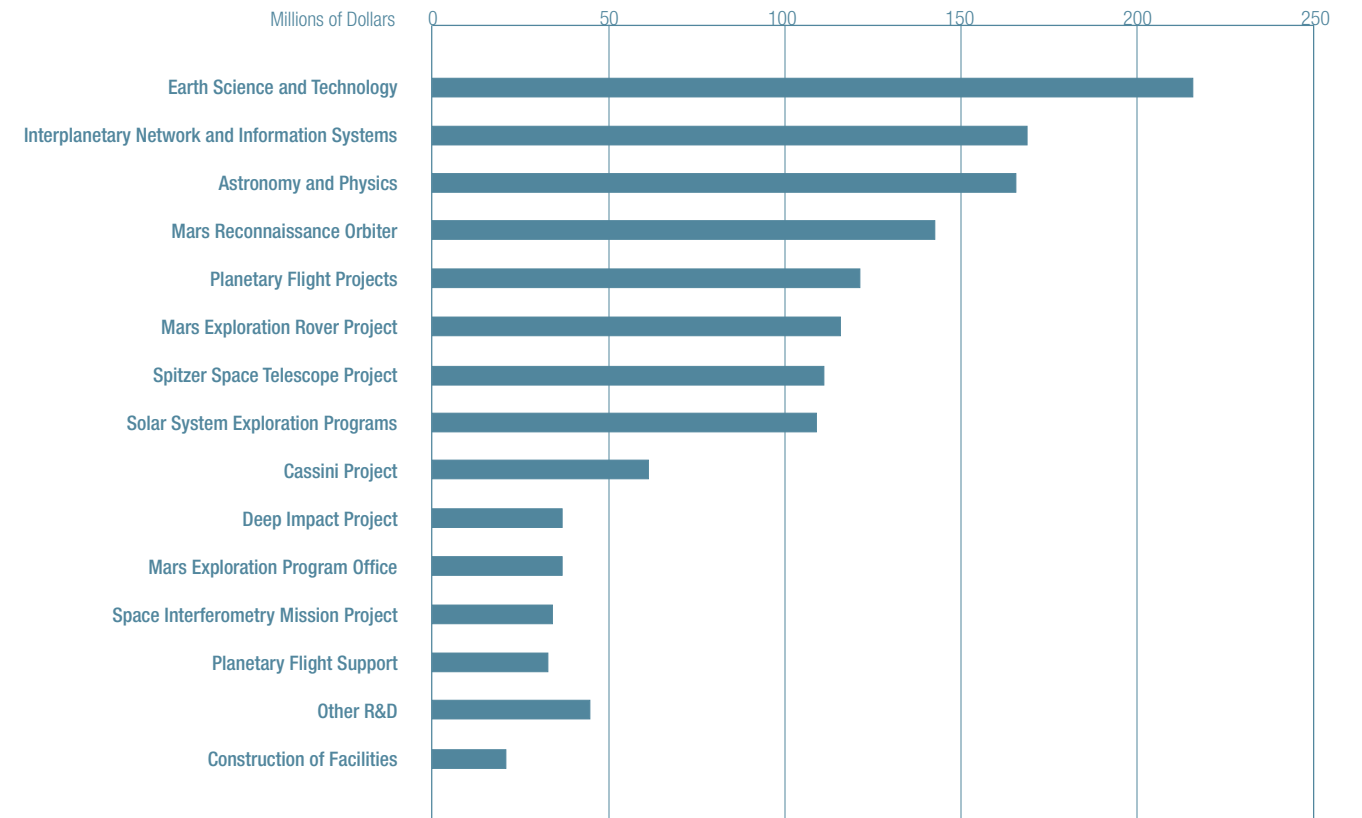
DR. GILLES PELTZER
William Bowie Medal, American Geophysical Union

DEEP SPACE I TEAM
Space Systems Award, American Institute of Aeronautics and Astronautics

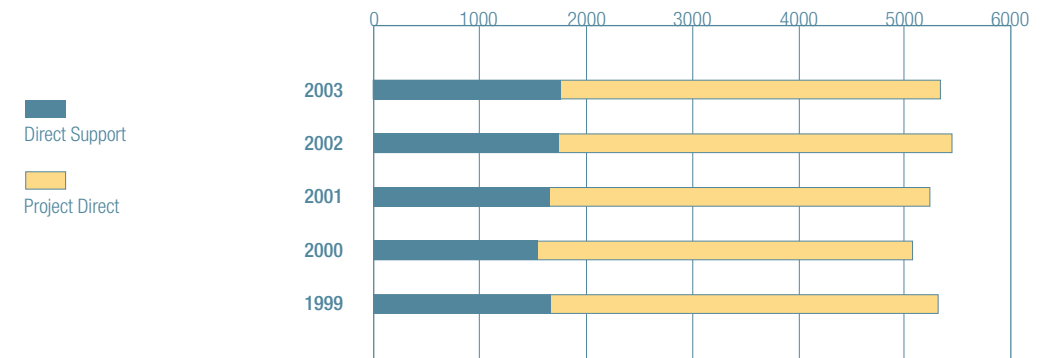
Total COSTS



Fiscal COSTS 2003



Total PERSONNEL



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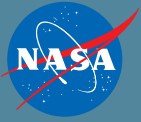
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JPL 400-1156 5/04