Each would illuminate its designated ground target with the light of 30 to 50 full Moons for up to 40 minutes of each orbit. Nikolai N. Sevastionov, Noviy Svet's general director, claims such artificial illumination will not alter the local environment. But its effects on animals' circadian rhythms have yet to be studied.

While the orbiting spotlights would be directed onto small local areas, observers adjacent to the ground track would see bright cones of twilight in an otherwise dark sky. Huge urban skyglows could rise up from the target cities should the artificial light bounce skyward off bare or snow-covered ground. Astrophotography would be compromised worldwide by a nightly parade of Venus-bright tracers. Washington amateur Dale Ireland saw the jettisoned reflector flare from magnitude 0 to –5 as it slowly tumbled toward reentry. "It was dazzling even in the 6:40 a.m. twilight," Ireland reports. The much-larger reflectors envisioned for the Noviy Svet program would gleam several magnitudes brighter still.

Not surprisingly, astronomers have expressed alarm at the Russian light-the-night plan. Peter Boyce, executive director of the American Astronomical Society, admits that the AAS's light-pollution committee doesn't have an official position on Noviy Svet yet. "But when we do," he predicts, "I'm sure we'll be horrified."

Christopher J. Faranetta, an Energia representative in Herndon, Virginia, says at least one more illumination test is planned, involving a reflector with better surface precision and perhaps 10 times more surface area. Faranetta hopes to publicize it well in advance so that teams of observers along and near the ground track can monitor the artificial sunlight. He says the deployment time of February's trial could not be predicted accurately, so a coordinated ground effort was not attempted.

Curiously, the U. S. Department of Defense and NASA briefly looked into a similar scheme during the 1960s. These agencies conceived Project Able as a way to illuminate military operations at night. Technological descendants of the highly visible Echo satellites, Project Able's giant reflectors would have been up to 600 meters across. But no test satellites were ever flown.

MISSION UPDATE

By Jonathan McDowell

EDITOR'S NOTE: Right now an unprecedented number of planetary probes and space telescopes are in orbit, en route to their deep-space destinations, or awaiting launch, with many more planned for launch later this decade. In this new monthly column Harvard astronomer and die-hard space aficionado Jonathan McDowell will provide brief status reports on selected missions. As always, scientific discoveries from these flights will be reported in News Notes, S&T *Newswire, and feature articles.*

Space Infrared Telescope Facility

NASA hopes to launch the Space Infrared Telescope Facility into solar orbit by the turn of the century. The design shown here was unveiled in January. Courtesy the Jet Propulsion Laboratory.

The last of NASA's four planned Great Observatories, SIRTF is the only one still awaiting formal approval. To cut costs, project officials reduced the telescope's aperture from 85 centimeters to 70 and jettisoned some detectors, reducing the weight enough to switch from a Titan IV booster to a less expensive Atlas IIAS (*S&T:* December 1992, page 608). Now a new mission concept will restore the aperture to 85 cm while reducing costs still further. Current plans call for SIRTF to be placed into solar orbit at 1 astronomical unit. The telescope will drift away from Earth, suffering less and less interference from our planet's "waste heat." This means it can use a smaller, lighter tank of liquid-helium coolant. The new design also simplifies many other spacecraft systems. NASA hopes to launch SIRTF by the year 2000 for a three-year mission to obtain high-resolution infrared images and spectra.

Mars Observer

On February 8th Mars Observer used its main engine to trim its course at a distance of 85 million kilometers from Earth and 41 million km from its destination, the red planet. After a smaller adjustment using auxiliary thrusters on March 18th, the probe was on course for arrival in Mars orbit on August 24th (*S&T:* October 1992, page 373). Mars Observer was launched last September 25th by a Titan III rocket.

Magellan

Magellan has been orbiting Venus for four Venusian years and is now mapping the planet's gravitational field (*S&T:* January 1993, page 11). On May 25th it will begin an ambitious series of aerobraking experiments to change its high elliptical orbit to a low circular one by using the upper atmosphere of Venus instead of rocket firings to slow down. The craft will then make extremely precise gravity measurements. This phase of the mission will be carried out with a small budget and a much-reduced staff that calls itself the Lean Mean Gravity Team.

Compton Gamma Ray Observatory

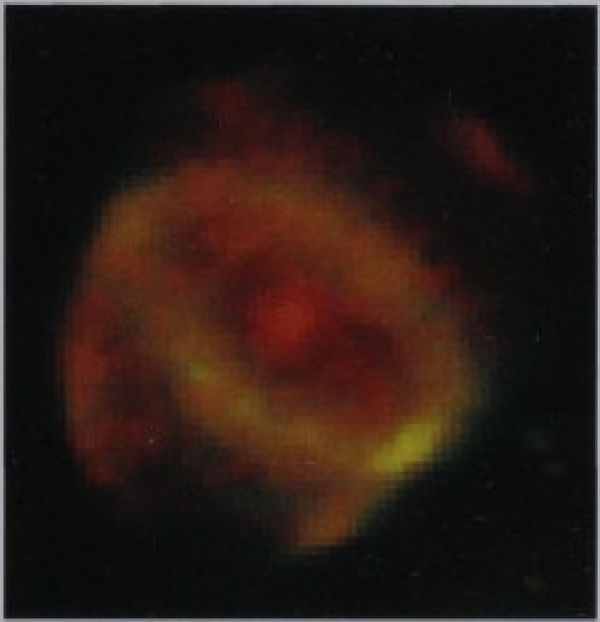
The Compton Observatory completed its all-sky survey last November and is now carrying out studies of specific targets for "guest observers." Since the failure of its onboard tape recorders in early 1992 (*S&T:* December 1992, page 634), the spacecraft has been able to send data to Earth only part of the time. NASA is building a new receiving antenna at Tidbinbilla, Australia, which will enable Compton to relay data through the elderly TDRS 1 satellite. Another important milestone is due in June with the first raising of the spacecraft's orbit, from 350 km to between 420 and 450 km. Problems with gas bubbles in the propulsion system were detected soon after launch in April 1991, so the first calibration firing of Compton's engines in May will be a tense moment for project members.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.

era specifically designed to search for faint objects of large angular size.

The planetary nebula the astronomers unveiled is one of the largest, and therefore among the oldest, yet discovered. It measures about 13 arc minutes across (corresponding to a diameter of 17 light-years), and it probably took approximately 150,000 years to reach this size (planetaries are typically 10,000 to 30,000 years old). The nebula's age and size, in conjunction with the star's pulsations, clearly connect the central stars of planetaries to precursor white dwarfs.

At the opposite end of planetary-nebula evolution is Henize 1357, which not long ago was just an ordinary hot star in the southern constellation Ara. However, over the past 30 years or so gas



Little was known about young planetary nebula Henize 1357, located in the southern sky, before the Hubble Space Telescope observed it. The spacecraft revealed fine detail, including a tilted ring of gas, as well as clumps of material in turbulent motions. This is a composite of several images made in oxygen and hydrogen light. Courtesy Matthew Bobrowsky and NASA.

around the star began to glow, revealing a young planetary nebula. The gas itself may have been released from the star in its red-giant phase thousands of years earlier, but only now has the star grown hot enough to make the gas radiate.

The planetary nebula around Henize 1357 has been fully resolved for the first time by the Hubble Space Telescope's Wide Field and Planetary Camera. It is one of many such nebulae Matthew Bobrowsky (CTA Inc.) has studied to understand the early evolution of planetaries.

MISSION UPDATE

By Jonathan McDowell

ASCA

Japan's Advanced Satellite for Cosmology and Astrophysics has performed flawlessly since its February 20th launch (May issue, page 8). Its X-ray spectrometers and cameras have been turned on and all appear in good health. The first calibration images of celestial high-energy sources were obtained in late March, paving the way for scientific observations to begin in earnest. Among the earliest targets was Supernova 1993J in spiral galaxy M81 in Ursa Major.

A Mu-3S II rocket carrying the ASCA X-ray satellite lifts off from Japan's Kagoshima Space Center. Courtesy the Institute of Space and Astronautical Science.

Hiten

Meanwhile, the mission of another Japanese probe, Hiten, ended on April 10th when it crashed into the Moon near the crater Furnerius at 55°.3 N, 34°.0 S. The 195-kilogram probe was launched in January 1990 and dropped a 12-kg satellite, Hagoromo, into lunar orbit two months later (*S&T:* July 1990, page 14). Hiten then made several close flybys before entering orbit itself on February 15, 1992.

Hubble Space Telescope

In mid-February spacecraft controllers encountered a problem with one of three Fine Guidance Sensors that keep HST pointed at celestial targets, when a small, movable mirror within the instrument partially jammed. The loss of one sensor makes it harder to find suitable guide stars for some observations. Another problem occurred in late March, when electronics failed in the system that points the solar-cell arrays toward the Sun. Although the panels can still be moved, a subsequent failure of the backup electronics could leave the solar cells pointed away from the Sun, starving the spacecraft for power. Mission planners quickly changed HST's observing schedule to reduce the need for large movements of the arrays and to prevent the observatory from pointing more than 145° away from the Sun's direction. Even so, HST's pointing flexibility still exceeds that of other spacecraft with fixed arrays.

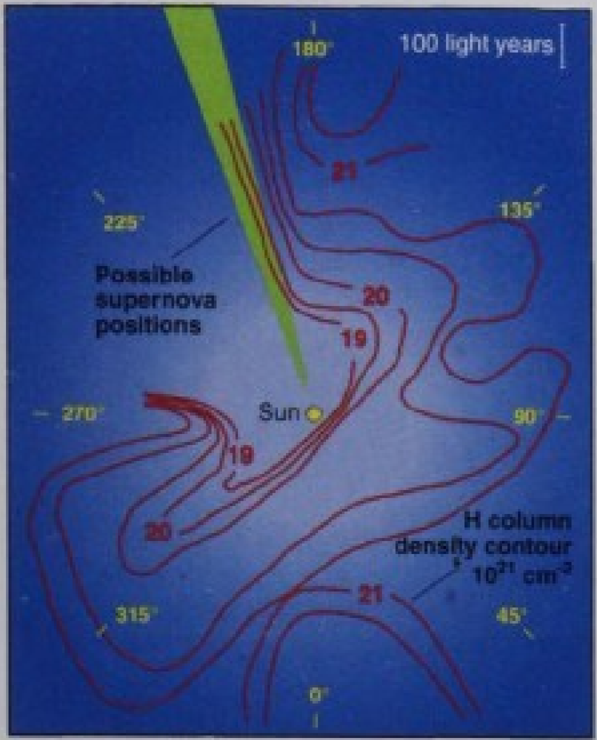
SPARTAN 201

The April mission of the Space Shuttle *Discovery* was devoted mainly to studying the ozone layer, but it also carried a SPARTAN (Shuttle Pointed Autonomous Research Tool for Astronomy) satellite. The SPARTANs are simple spacecraft released by the shuttle's manipulator arm and then retrieved after two days of free flight. One flew in 1985 to study X-ray emissions from extragalactic sources. Another was intended to observe Halley's comet but was lost along with *Challenger* in January 1986. The newest one, designated SPARTAN 201, carried two instruments to study the Sun's visible and ultraviolet corona.

Mars Observer, Galileo, and Ulysses

Between March 21st and April 12th three interplanetary spacecraft carried out the most sensitive search to date for gravitational waves. Rare, catastrophic events such as the collapse of a massive star or the merger of two black holes would be required to give a detectable signal. This spring's experiment monitored radio transmissions from Mars Observer, Galileo, and Ulysses, to search for Doppler shifts that would signal changes in the light paths between the spacecraft and the Earth. Detection of an effect by all three would rule out a spurious signal caused by local interference; ground-based detectors have often been confused by vibrations from terrestrial sources. No results have yet been reported from this latest experiment.

Jonathan McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.



Density contours of the interstellar medium in the solar neighborhood are featured in this slice through the plane of our galaxy. The Sun is at the center, and the shaded band shows where the Geminga supernova may have occurred some 300,000 years ago to create the Local Bubble of low-density interstellar gas at galactic longitude 225°. Adapted from *Nature*.

rels and Wan Chen (NASA-Goddard Space Flight Center) combine the pulsar's age (some 330,000 years) with the proper motion of G" to trace Geminga back to its position at the time it exploded.

Gehrels and Chen find that the supernova was well placed to create the Local Bubble — as long as it was within 200 light-years of the Sun. The resulting shock wave and its effect on the interstellar medium could also explain the observed structure of the bubble and its environs. Where the interstellar medium was of low density (galactic longitude 225°) the shock front expanded relatively quickly. The denser region toward the Sun was less successfully breached.

At 200 light-years, the cataclysm would have rivaled the full Moon in brightness. An intense burst of high-energy radiation would have temporarily depleted the Earth's ozone layer by some 10 to 15 percent, giving our ancestors a yearlong sunburn.

Now fleeing the site of the blast at a velocity exceeding 250 kilometers per second, Geminga lies some 500 to 1,300 light-years away. The void it left behind allows astronomers to make extreme-ultraviolet observations of nearby stars and to get a tantalizing glimpse of the more distant universe.

MISSION UPDATE

By Jonathan McDowell

INTEGRAL

Managers of the European Space Agency (ESA) have selected a new astronomy project, the International Gamma-Ray Astrophysics Laboratory, for development at a cost of about $600 million. INTEGRAL is targeted for launch in 2001 and will carry four scientific instruments. Two will conduct high-resolution gamma-ray imaging and spectroscopy while the others monitor the sky at X-ray and visible wavelengths. INTEGRAL will be an order of magnitude more capable than the Compton Gamma Ray Observatory and the Russian Granat spacecraft.

INTEGRAL, the International Gamma-Ray Astrophysics Laboratory, will be launched around 2001 for a two- to five-year investigation of celestial sources of high-energy radiation. Courtesy the European Space Agency.

ALEXIS

The Array of Low-Energy X-ray Imaging Sensors was boosted into a 750-kilometer-high polar orbit by a Pegasus air-launched rocket on April 25th. Unfortunately the $17 million satellite did not survive the launch. At least one solar-cell panel tore off, and flight controllers failed to establish communication with the spacecraft. The 109-kilogram ALEXIS satellite was conceived at Los Alamos National Laboratory; it was intended to make an all-sky map of the interstellar extreme-ultraviolet background at ½° resolution and to monitor transient sources.

Rosat

The Rosat X-ray observatory, a joint project of Germany, Great Britain, and the United States, has now been in orbit for three years. The next six months will see the final observations with the Position Sensitive Proportional Counter. The PSPC uses a gas supply that must be continually replenished, and it tapped into its last tank of gas in March. After December, X-ray observations will be carried out for six months with the High Resolution Imager, which makes X-ray images that show finer detail than those from the PSPC (3 arc seconds compared with 30) but don't contain as much information about the energies of the X-ray photons. If enough gas can be saved, a final batch of PSPC observations will be made in late 1994.

SEDS 1

On August 4th last year, Italy's Tethered Satellite System was deployed from the Space Shuttle in the first use of a space tether since the Gemini experiments in 1966. Unfortunately the tether snagged when only 256 meters of it had reeled out. On March 30th this year, a much simpler and less costly experiment was successfully carried out using the Small Expendable Deployer System (SEDS) developed by NASA, Tether Applications of San Diego, and the Harvard-Smithsonian Center for Astrophysics. The tether was attached to the second stage of a Delta rocket. After the third stage and its payload (a navigation satellite) separated, the tether was unreeled downward to a length of 20 km, with sensors on the end mass relaying measurements of the string's oscillations. Back on the Delta the string was then severed, leaving the end mass in an orbit whose perigee was 50 km underground; it reentered the atmosphere over Mexico a half hour later.

In addition to his work at the Harvard-Smithsonian Center for Astrophysics, Jonathan McDowell prepares a weekly electronic newsletter on the space program.

the IAU's Working Group for Planetary System Nomenclature; they will receive final approval at the IAU General Assembly next year.

Proxima Centauri: Just Passing Through?

For nearly 80 years astronomers have believed that Proxima Centauri, the star nearest our Sun, orbits Alpha Centauri, a binary star 2° 11' to the northeast (April issue, page 70). Now two British researchers claim this may not be true after all.

Proxima, a red dwarf glowing dimly at 11th magnitude, is separated from its 1st-magnitude neighbors Alpha Centauri A and B by 0.21 light-year, about 330 times the radius of Pluto's orbit. Although this is a rather large physical separation for a multiple system, all three stars do appear to move through space together. If Proxima is in a circular orbit, it rounds Alpha once every million years.

In the March 15th *Monthly Notices* of the Royal Astronomical Society, Oxford amateur Robert Matthews and Cambridge University theorist Gerard Gilmore argue that the association of Proxima with Alpha is mere speculation. A million years, they say, is too long a time span for astronomers to determine unequivocally an orbit for Proxima.

Their own calculations, based on published data, show that Proxima may be traveling too fast for the Alpha Centauri pair to hold onto it gravitationally. The velocities of Proxima and Alpha should agree to within 1 percent if the stars are dynamically related. Some data do meet this criterion, but just barely. Matthews and Gilmore recommend suspending judgment until more accurate velocity measurements are obtained.

They also point out another problem. Alpha Centauri shows signs of being older than our Sun's 4.6 billion years. Proxima, on the other hand, is an active flare star, which implies an age of less than a billion years, according to current thinking about such objects. Perhaps Proxima is an exceptional flare star, or perhaps it is a normal one captured by Alpha in the last billion years. But the simplest explanation is that Proxima just isn't bound to Alpha.

MISSION UPDATE

By Jonathan McDowell

Galileo

The next step in Galileo's odyssey through the solar system is an encounter with minor planet 243 Ida. After trimming its course on August 13th and 26th, the probe will fly within 2,400 kilometers of the asteroid at 16:52 Universal Time on August 28th. But scientists will not see any images from the flyby for about a month. Because Galileo's main communication antenna remains stuck partly open, the craft can only dribble information back to Earth through a smaller antenna. More Ida pictures will be transmitted in 1994.

The crippled Galileo spacecraft flew past the asteroid Gaspra in October 1991 en route to Jupiter. The probe encounters another asteroid, Ida, on August 28th. Courtesy Michael Carroll.

Orbiting 2.9 astronomical units from the Sun in the main asteroid belt, Ida is an estimated 33 km across and spins every 4.6 hours. It is believed to be an S-type asteroid similar to 951 Gaspra, which Galileo flew past on October 29, 1991. Ida was discovered in 1884 by prolific Austrian asteroid hunter Johann Palisa. Unfortunately, 16th-magnitude Ida will lie within 45° of the Sun during the encounter, preventing most Earthbound observers from following it.

ALEXIS

On June 2nd scientists at Los Alamos National Laboratory made contact briefly with the ill-fated ALEXIS X-ray observatory. One of ALEXIS's solar panels was damaged during launch on April 25th (August issue, page 14), and controllers feared that the satellite was a washout. It now looks as if the craft is alive but can operate only when the angle between it and the Sun is favorable. This raises some hope that part of the mission may yet be salvaged.

International Ultraviolet Explorer

Scientists at the June meeting of the American Astronomical Society in Berkeley, California, were outraged to learn that NASA might shut down the IUE satellite on September 30, 1994. This drastic action, by no means certain, is being contemplated in response to steep cuts in the space agency's budget for mission operations and data analysis.

IUE recently marked its 15th anniversary in orbit and is one of the world's most productive observatories (see page 30 of this issue). NASA's chief of science operations, Guenter R. Riegler, has asked a committee led by astronomer Yervant Terzian (Cornell University) to identify key projects for what could be IUE's final year of operations. At an open meeting in Berkeley on June 8th, one experienced IUE observer after another insisted that a better use of time would be to fight to keep the telescope alive. The aging spacecraft continues to return useful data, but it is becoming more difficult to use due to problems with its guide camera.

Sakigake

The Japanese Sakigake (Pioneer) space probe, launched in 1985, made the second of four annual Earth flybys on June 14th. With each pass the probe gets a gravitational assist in preparation for its February 1996 encounter with Comet Honda-Mrkos-Pajdusakova. Sakigake carries instruments to measure charged particles and electromagnetic fields and was a precursor to the Suisei (Comet) probe to Comet Halley in March 1986.

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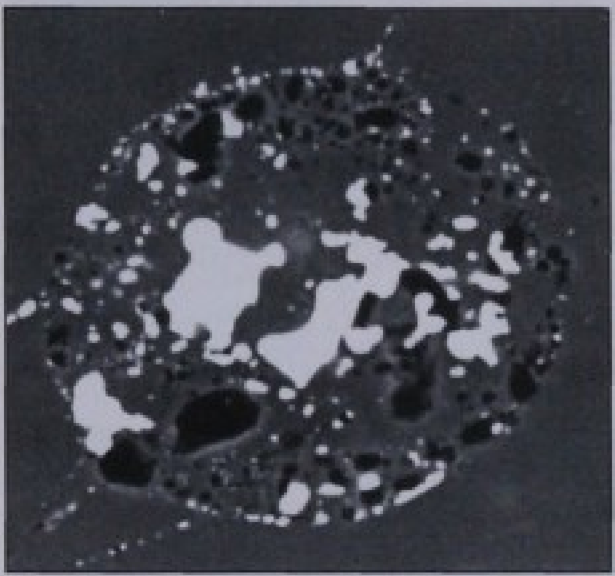
NEWS NOTES

Primordial Lightning?

Researchers probing the interiors of ancient meteorites have uncovered indirect evidence that powerful electromagnetic surges may have continually ripped through the solar system as it was forming.

Don D. Eisenhour and Peter R. Buseck (Arizona State University) base this conclusion on their study of meteorites called chondrites, which are thought to have formed along with the planets 4.5 billion years ago. They have discovered small flecks of very dark minerals (metals, sulfides, or oxides) in the ancient meteorites that were flash melted without disturbing the more transparent silicate material around them. Because of this incongruous pairing, Eisenhour and Buseck believe the minerals were melted by intense pulses of electromagnetic energy, much of it in the form of visible light, which only the darker materials would absorb.



A "dirty snowball" formation, 45 microns across, within a larger meteorite body. Bright areas denote minerals that may have been melted by intense electromagnetic pulses possibly similar to lightning. The surrounding gray areas, transparent silicate minerals, absorb visible-light energy inefficiently and therefore were not melted. Black areas are holes. Courtesy Don Eisenhour.

The two scientists simulated the creation of these "dirty snowballs" to determine the necessary strength and duration of the ancient energy bursts. Their laboratory tests suggest two possible sources of these pulses: magnetic storms, like the ones that trigger auroras but much stronger, and very powerful lightning discharges within the primordial solar nebula.

MISSION UPDATE By Jonathan McDowell

European Retrievable Carrier

Plucked from space after 11 months in orbit, the European Retrievable Carrier dangles from the Space Shuttle *Endeavour's* robot arm. Courtesy NASA.

After almost a year in space, the European Space Agency's European Retrievable Carrier (Eureca) was snatched from orbit by the Space Shuttle *Endeavour* on June 24th and returned to Earth the following week. As well as materials-science experiments, Eureca carried the Watch X-ray burst experiment. Developed at the Danish Space Research Institute, Watch has discovered several X-ray novae, the brightest being EU 1737–132 in October 1992. In April 1993 it found a bright gamma-ray burst. It also monitored flares in known sources such as Cygnus X-2 and Aquila X-1. Three similar Watch detectors continue in orbit aboard the Russian Granat satellite.

Compton Gamma Ray Observatory

The reboost of the Compton Observatory into a higher orbit was interrupted on June 15th when one of four attitude-control thrusters failed, almost sending Compton into a spin. The spacecraft successfully entered a safe mode, and science operations resumed on June 19th while the problem was analyzed. The attitude-control thrusters were being used instead of the main orbital-adjustment thrusters because of earlier problems encountered in the propulsion system's plumbing.

At the beginning of May Compton was in a 346-kilometer-high orbit; a test firing on May 4th raised this by 4 km, but by mid-June it was back down to the earlier height. The aborted reboost raised it once more to 350 km, 100 km below the altitude it had after its deployment by the Space Shuttle in April 1991. In early July spacecraft controllers decided that they will have to try using the orbital-adjustment thrusters after all.

ALEXIS

Flight controllers at Los Alamos National Laboratory restored full communications with the ALEXIS satellite on July 5th (see last month, page 15). The magnetometer is not working, making the satellite difficult to orient properly, but by July 11th flight controllers were able to command the start of science observations. If all goes well, ALEXIS (Array of Low-Energy X-ray Imaging Sensors) will study extreme-ultraviolet line emission from the interstellar medium.

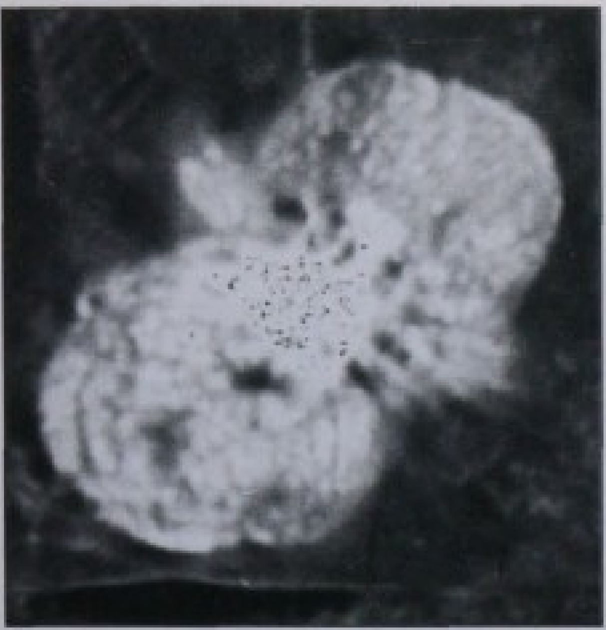
GAUSS

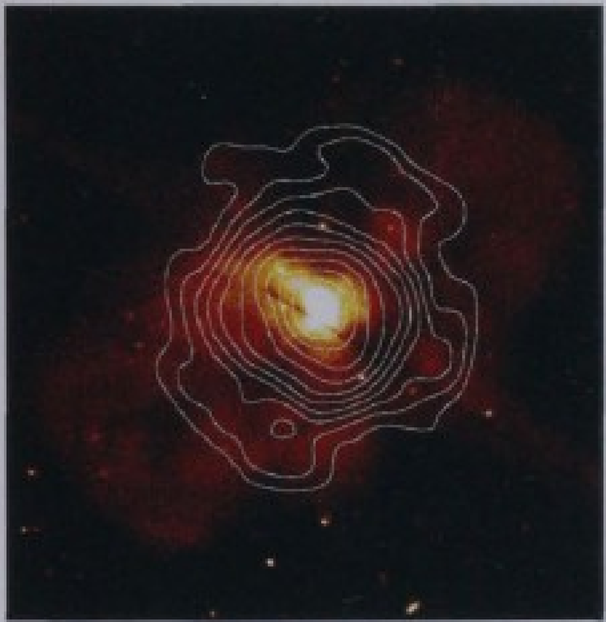
In April the German Spacelab D2 mission flew in space aboard *Columbia*. Among its many experiments was a single astronomical payload: the Galactic Ultrawide Angle Schmidt System (GAUSS) Camera. This instrument, developed at Ruhr University in Bochum, is unusual because of its enormous field of view — 145°. More than 100 images were taken through various ultraviolet and visual filters, covering half the sky. They will be used to study the large-scale structure of the gas and stars in the Milky Way.

Hubble Space Telescope

During June the HST operations team worked with astronauts in the water tank at NASA-Marshall Space Flight Center in a simulation of the space-walk repairs to be carried out in December. Space Shuttle *Endeavour* is now in the Orbiter Processing Facility at Cape Canaveral being readied for the flight. Meanwhile the orbiting telescope's computer was loaded with a completely new version of the operating system for the first time since launch, and Fine Guidance Sensor 2 began a series of tests to requalify it for use alongside the other two guiders.

Jonathan McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.





At the heart of the Carina nebula, 8,000 light-years from Earth, lies the massive star Eta Carinae. Intensity contours of a recent radio map (*above*) are concentric about Eta's location; the innermost contours are extended in roughly the same directions as jetlike features noticeable farther away from the star in a visible-light image from the Hubble Space Telescope (*top*). Radio image courtesy Stephen White; HST image courtesy Jeff Hester, Caltech, and NASA.

wind, perhaps the most intense of any star in the galaxy. The radio maps also provide a puzzling surprise: clumpiness in the material being expelled by the wind within a few arc seconds of the star. Although the star's radiation field, which powers the wind, is presumably uniform at the surface of the star, White's team believes that instabilities in Eta's upper atmosphere have somehow led to asymmetrical mass loss.

At the June meeting of the American Astronomical Society, White expressed hope that he and his colleagues will find an explanation with further studies of the star, particularly the velocity pattern of gas near it.

MISSION UPDATE

By Jonathan McDowell

Astro 2

Astronomer-astronaut Tamara Jernigan has been selected as payload commander for the Astro 2 Spacelab mission, scheduled for November 1994 aboard shuttle flight STS-67. The instrument suite, consisting of the Hopkins Ultraviolet Telescope, the Wisconsin Ultraviolet Photo-Polarimeter Experiment, and the Ultraviolet Imaging Telescope, flew as Astro 1 aboard *Columbia* in December 1990 (*S&T:* June 1991, page 591). On that flight it was accompanied by the Broad Band X-Ray Telescope (BBXRT), but Astro 2 will carry instead a service pallet to enable the shuttle to stay up longer. Astro 1 astronomers Ronald A. Parise and Samuel T. Durrance will probably also fly on Astro 2; additional crew members will be selected later.

The Astro 1 telescopes probe the ultraviolet sky during the STS-35 mission in December 1990. Courtesy NASA.

Ulysses

The European Space Agency's Ulysses probe is now higher in heliocentric latitude than any other human-made object. By early November it will be at 35° south ecliptic latitude, and in September 1994 it will reach a record 80° en route over the Sun's south pole. The Voyager 1 probe, now escaping the solar system, is 33° above the ecliptic; Voyager 2 is slowly heading to extreme southern latitudes but is now only 14° below the plane. Most planetary probes remain within a few degrees of the ecliptic.

Magellan

The Magellan Venus mapper's historic aerobraking maneuver is now complete. During the so-called transition experiment from May 25th to August 3rd, Magellan altered its orbit from a 170-by-8,460-kilometer ellipse to a more circular 197 by 540 km. The orbit change used only a small amount of fuel, most of the work being done by drag in the Venusian atmosphere. The trajectory was carefully calculated to ensure that the spacecraft would not overheat. Magellan now begins a more detailed mapping of Venus's gravitational field. The success of this experiment, and that of a less ambitious one carried out in Earth's upper atmosphere by the Japanese Hiten probe in 1991, make it likely that aerobraking will become standard practice in future missions, just as the gravity-assist flybys first done by Mariner 10 and Pioneer 11 are now part of virtually every planetary mission.

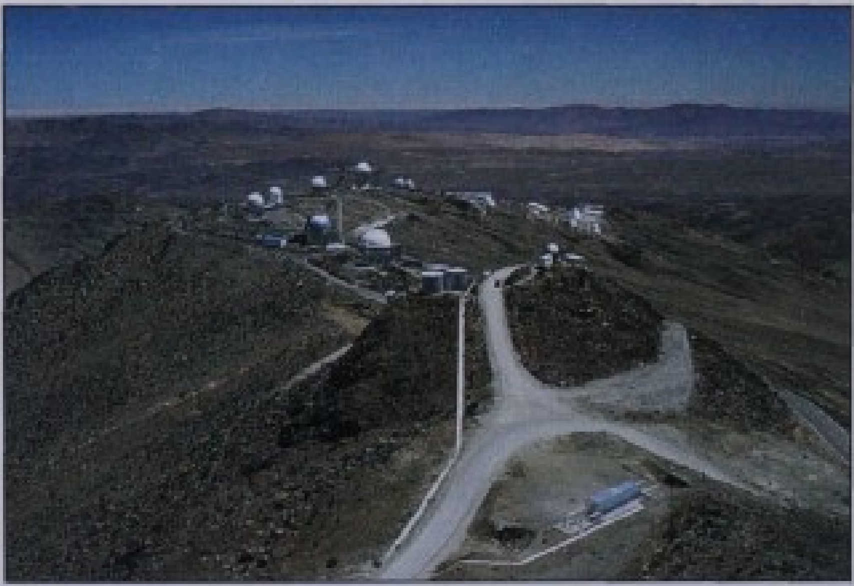
Funding Cutbacks

A statement issued by NASA's astrophysics division in early August warned that the 15-year-old International Ultraviolet Explorer is not the only ongoing mission under threat of termination. A new policy proposes to turn off all space-astronomy missions after a limited period and allow only one extra year for data analysis. Among the scenarios being considered are ending funding for the Rosat X-ray observatory next year and abandoning the Compton Gamma Ray Observatory in 1996. Rosat currently is the only instrument that can make images in the soft (low-energy) part of the X-ray spectrum, while Compton's gamma-ray capabilities will not be even partly replaced until the European Integral mission after the turn of the century. Nevertheless, if there are no increases to NASA's budget for mission operations and data analysis, it seems likely that at least one mission will be axed before its time.

The author studies quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics. Asteroid 4589 was recently named McDowell to honor his efforts to identify the "mystery object" 1991 VG with artificial-satellite debris.

Compromise in Chile

For almost three decades the Republic of Chile and the European Southern Observatory (ESO) have worked hand in hand to run one of the world's leading astronomical facilities on La Silla in the Andes mountains. Despite the long history of collaboration, relations recently became strained when Chilean astronomers began pressing for a guaranteed percentage of observing time as well as wages and working conditions comparable to those enjoyed by their European counterparts.



The European Southern Observatory operates 15 telescopes at La Silla in Chile, ranging in size from 0.4 meter to 3.6 meters. Recent changes in the original treaty between ESO and the host government will mean guaranteed observing time and improved working conditions for local astronomers. *Sky & Telescope* photograph by Dennis di Cicco.

MISSION UPDATE

By Jonathan McDowell

ALEXIS

The heart-stopping saga of the ALEXIS satellite continues. Originally given up for lost after its launch last April 25th, the $17 million spacecraft has one damaged solar-cell panel and wobbles as it spins. Flight controllers lost contact with ALEXIS for two weeks in August and feared the worst. But the spacecraft recovered again, and by early September it had enough electrical power to operate all of its experiments. Scientists at Los Alamos National Laboratory have now verified that ALEXIS, whose full name is Array of Low-Energy X-ray Imaging Sensors, is indeed capable of observing celestial X-rays. Each of its six telescopes has a 30° field of view and measures radiation at energies between 50 and 100 electron volts, on the boundary between the extreme-ultraviolet and soft-X-ray regions of the spectrum.

A technician inspects the ALEXIS satellite before its April 1993 launch. Courtesy LeRoy Sanchez, Los Alamos National Laboratory.

Hipparcos

The Hipparcos astrometry satellite stopped transmitting data on June 24th, and the European Space Agency (ESA) abandoned the craft on August 15th after failing to restart its onboard computer. But in contrast with the Mars Observer, which fell silent *before* beginning its science mission (November issue, page 8), Hipparcos was a major success. The satellite observed two regions of the sky at once, precisely measuring the angular distance between them. Like ALEXIS, Hipparcos had a shaky start: launched on August 8, 1989, it was meant to enter geostationary orbit but ended up in a highly elliptical loop instead when its rocket motor failed to fire. The spacecraft was able to carry out astrometric measurements anyway, and in a few years ESA expects to publish the most accurate star catalog yet. Astronomers are especially excited about Hipparcos's success at measuring trigonometric parallaxes for many more stars than ever before, which promises to strengthen the foundation of the cosmic distance scale.

Edison

Even as it was closing the books on one space-science mission, ESA was already looking ahead to the next. The agency recently invited proposals for a medium-size project to launch early in the next century. One idea submitted by a team of European and U. S. astronomers is a large infrared telescope called Edison. The 1.7-meter reflector would be launched by an Atlas IIAS rocket into a special orbit around the Lagrangian point some 1½ million kilometers from Earth in the direction opposite the Sun. Edison would have eight times the collecting area of ESA's forthcoming Infrared Space Observatory and would be the first mission to use radiative cooling instead of short-lived liquid helium to reach the low temperatures needed for far-infrared astronomy.

Extreme Ultraviolet Explorer

The EUVE satellite completed its sky survey earlier this year and is now making observations of specific objects for a wide range of observers. On August 16th the schedule was interrupted so that EUVE could swing its telescopes toward the dwarf nova SS Cygni; some 8 hours earlier, amateur astronomers discovered that the star had begun one of its outbursts. Most of EUVE's targets are hot stars in our galaxy, but a handful of quasars have also been detected through the interstellar murk, which is almost opaque to extreme-ultraviolet radiation.

The author studies quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics. He also publishes "Jonathan's Space Report," an electronic newsletter.

an abundance is tiny compared with the number of comets lost to interstellar space when the Oort Cloud formed. And since then even more comets have been stripped away by passing stars and giant molecular clouds.

Assuming that other stars formed in a manner similar to the Sun, astronomers think that the space between stars should be teeming with comets. One study determined that in the past 150 years we should have detected as many as six interstellar comets passing through the solar system (*S&T:* March 1990, page 254). An interstellar comet would be distinguished from an ordinary one by its velocity, which would be large enough to allow escape from the Sun's gravitational pull — probably by a huge factor. So why haven't we seen any such objects?

Many solutions to this problem have been suggested, including a revised model of the Oort Cloud's formation. However, A. K. Sen and N. C. Rana (Inter-University Centre for Astronomy and Astrophysics, India) propose that the frequency of detectable interstellar comets is actually much smaller. In the August (I) *Astronomy and Astrophysics* they explain that the large discrepancy in predictions follows from different assumptions concerning the number of stars that have Oort-type clouds.

The astronomers argue that stars in binary or multiple systems cannot have comet clouds like the Sun's, so only single-star systems contribute significantly to the interstellar-comet population. They calculate that a third of all stars in the solar neighborhood fall into this category, with the result that in a 200-year period at most one interstellar comet should be detected. This is consistent with observations to date.

MISSION UPDATE

By Jonathan McDowell

ORFEUS-SPAS

Germany's first astronomical shuttle-pallet satellite (SPAS) recently flew a successful six-day mission. Deployed last September 13th from the Space Shuttle *Discovery*, the free flyer carried two ultraviolet telescopes. The main payload was the Orbiting Retrievable Far and Extreme Ultraviolet Spectrograph (ORFEUS). Its 1-meter telescope fed ultraviolet light to two spectrometers, one developed at the University of California, Berkeley, and the other in Germany. Together they covered the wavelength interval from 400 to 1250 angstroms. The Berkeley instrument successfully measured celestial radial velocities to better than 100 kilometers per second, but the German spectrometer ran into some problems with stray light. A secondary payload was Princeton University's Interstellar Medium Absorption Profile Spectrograph (IMAPS), which covered only the far-ultraviolet spectral region longward of 900 angstroms but with a much higher resolution of about 1 km per second. ORFEUS-SPAS observed mainly galactic objects, but about 5 percent of its first mission was devoted to a study of the BL Lacertae object PKS 2155−304 in Piscis Austrinus.

The astronomical shuttle-pallet satellite with its ORFEUS (center) and IMAPS (top right) spectrographs dangles at the end of *Discovery*'s robotic arm before being set loose for six days last September. Courtesy NASA.

Compton Gamma Ray Observatory

After encountering thruster problems during an earlier attempt to raise its orbit, the Compton Gamma Ray Observatory gingerly climbed to a higher altitude and is now out of danger of premature reentry into the atmosphere. The first part of the operation was carried out from October 4–17, with a second part scheduled to begin on November 22nd and last 10 days. At its lowest point, Compton's perigee was only 333 km, down more than 100 km from the height at which the satellite was deployed from the shuttle *Atlantis* in April 1991. Between reboost operations, the spacecraft was scheduled to continue with a series of pointings at targets in the Virgo region and to study Nova Cygni 1992 and the Geminga pulsar.

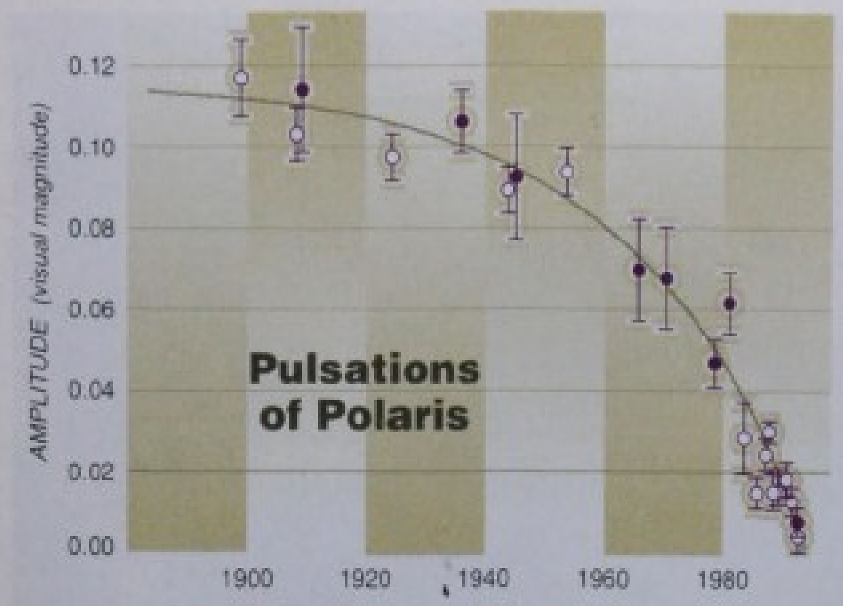
Small Explorers

NASA is getting ready to pick two new Small Explorer (SMEX) projects for launch in 1997–98. The four missions on the shortlist will be given 10 months to show that their scientific promise matches the inventiveness of their acronyms. TRACE (Transitional Region and Coronal Explorer) is a solar physics observatory. POEMS (Positron Electron Magnetic Spectrometer) is designed to measure the ratio of matter to antimatter in cosmic rays. The cryogenically cooled WIRE (Wide-Field Infrared Explorer) would study the evolution of galaxies. Finally, JUNO (Joint Ultraviolet Night Sky Observer) would carry out an all-sky survey at ultraviolet wavelengths.

Galileo and Mars Observer

The Galileo probe, fresh from its successful encounter with asteroid 243 Ida, has made its first targeting maneuver to refine its approach to the planet Jupiter. The spacecraft made five rocket burns between October 4th and 8th. It is due to reach Jupiter in December 1995, and all systems except its main communication antenna are functioning well. The same cannot be said for Mars Observer, which is still lost with little hope of recovery. Planetary scientists had hoped to mount a replacement mission in late 1994, but NASA funding won't support such an attempt before 1996.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.



The declining amplitude of Polaris's pulsations from 1899 to 1992. Solid circles are actual photoelectric measurements of the difference between maximum and minimum brightness. Open circles are values derived indirectly from the amplitude of the star's radial-velocity variations. Also drawn is the exponential curve that best fits the points. Adapted from the *Astrophysical Journal*.

Polaris remains well inside what is called the "instability strip" on the Hertzsprung-Russell diagram, the area where every star ought to pulsate as a Cepheid variable. In fact the astronomers point to RT Aurigae as a virtual twin of Polaris in terms of their temperature and luminosity, but it varies by a hefty 0.8 magnitude. "It seems that we simply do not know what sets a Cepheid's amplitude of pulsation," they conclude. Polaris, they note, seems destined to become "the first incontrovertible case of a nonvariable star in the instability strip."

MISSION UPDATE

By Jonathan McDowell

Advanced X-ray Astrophysics Facility

AXAF is the third of NASA's Great Observatories, the X-ray counterpart to the Hubble Space Telescope and the Compton Gamma Ray Observatory. After a successful test of AXAF's prototype X-ray mirrors in 1991, the planned spacecraft was split into two parts, AXAF-I (imaging) and AXAF-S (spectroscopy). In a cost-cutting move last September, the Senate appropriations subcommittee chaired by Maryland's Barbara Mikulski canceled the AXAF-S satellite, which was to be built at NASA's Marshall Space Flight Center in Alabama. Subsequently a House-Senate conference committee saved the single AXAF-S X-ray instrument, a spectrometer to be constructed at NASA-Goddard. If Japan's Institute for Space and Astronautical Science agrees, the spectrometer will fly aboard the Astro E satellite around the turn of the century.

The remaining AXAF satellite is optimized for X-ray imaging. It will have an angular resolution of about 1 arc second, comparable with that of most ground-based optical telescopes. In addition, its spectral resolution will be even better than that of the ASCA satellite (see the next item). Work on AXAF-I is proceeding on schedule for a launch in 1998.

NASA's next Great Observatory, the Advanced X-ray Astrophysics Facility (AXAF), started out as a large satellite for X-ray imaging and spectroscopy. To cut costs, NASA later split it into two less complex spacecraft, and now only one — AXAF-I, shown here — remains. Courtesy the AXAF Science Center.

ASCA

Japan's current X-ray satellite, formerly Astro D but now renamed ASCA (Advanced Satellite for Cosmology and Astrophysics), was launched on February 20, 1993. With its test phase now completed, ASCA has begun its "guest observer" phase. A significant portion of the available observing time is being used by Japanese, American, and European astronomers for studies of specific high-energy targets. Although few results have been publicly released so far, the remarkable X-ray spectra shown by ASCA team members at conferences make it clear that the satellite marks a qualitative step forward in X-ray astronomy.

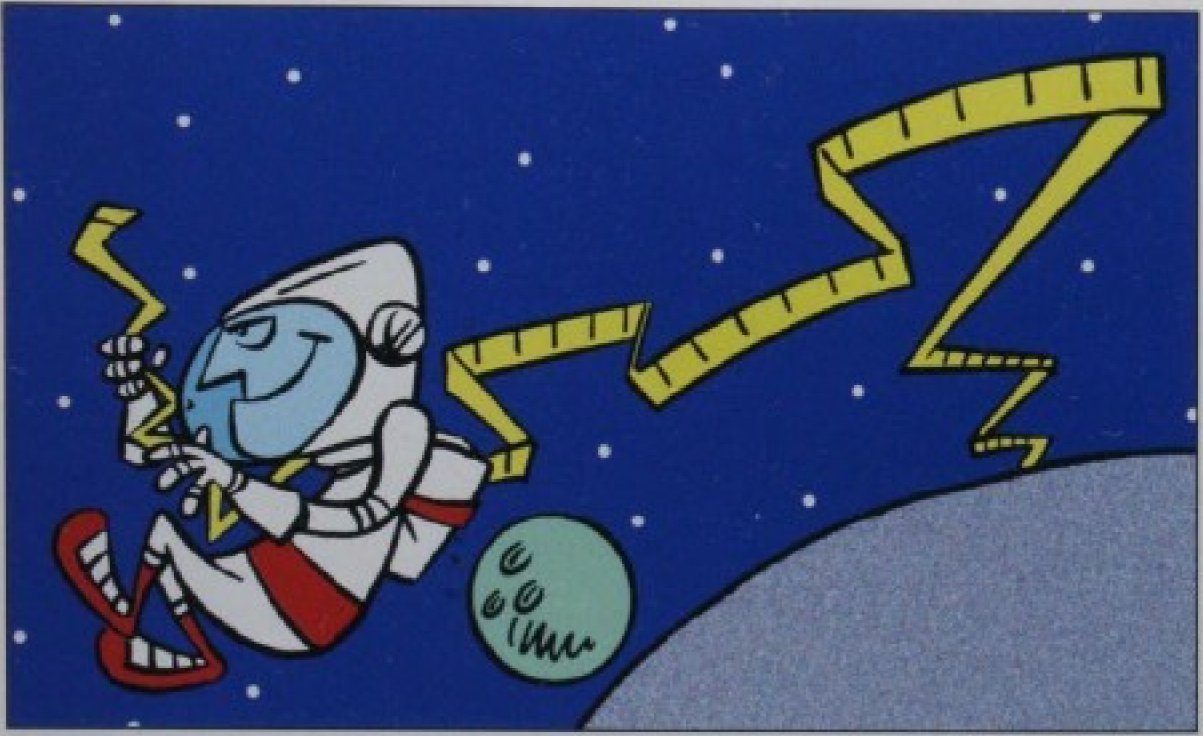
Mars 94

Last fall Russian space officials announced that their Mars-exploration program was running out of funds. The Mars 94 mission, in which the French space agency CNES has already invested substantial development funds, is in danger of cancellation. Even if other nations can supply the money to keep Mars 94 alive, the mission will likely be delayed until the 1996 launch window. Mars 94 is to include the first probe to land on the Martian surface since Viking 2 touched down in September 1976.

Rosetta and FIRST

The European Space Agency (ESA) has selected its next two "cornerstone" science missions. Rosetta will be launched in 2003 to carry out the first long-term rendezvous with a comet. Earlier cometary probes like ESA's Giotto flew past their targets at high speed, but Rosetta will actually land an experiment package on the comet's nucleus — exactly which comet is to be decided later. Originally Rosetta was to return samples of the nucleus to Earth, but cuts in ESA's budget forced the agency to trim the spacecraft's capabilities. The year 2006 should see the launch of FIRST, the 3-meter-wide Far Infrared Space Telescope.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.


KEVIN SARTORIS

In the December 1993 AAS *Newsletter* Bradt reports that nearly half the respondents said they would support a switch to SI units as long as a handful of supplementary measures, including the astronomical unit and the stellar magnitude, could be used as well. Bradt himself now espouses this view. He points out that the International Astronomical Union recommended such an approach in 1988 but that astronomers have largely ignored it.

"I'm not rabid on this issue," Bradt told *Sky & Telescope*. "The point was just to smoke out some discussion and sensitivity." He plans to tabulate and analyze all the comments he has received and pass the results along to the AAS Council.

MISSION UPDATE

By Jonathan McDowell

Clementine

As this issue went to press, an unusual space probe was due for launch from Vandenberg Air Force Base in California. The Deep Space Program Science Experiment, nicknamed Clementine, was developed by the Ballistic Missile Defense Organization, the Naval Research Laboratory, and NASA to expose sensors and other systems to high radiation doses. Interplanetary flight is an easy way to get such exposure, so the small, 225-kilogram spacecraft will orbit the Moon for three months, then in May fly outward to the asteroid 1620 Geographos. This 2-kilometer-wide rock orbits the Sun at distances between 0.8 and 1.6 astronomical units, crossing Earth's orbit twice on each circuit. Clementine will carry infrared, ultraviolet, and visible-light cameras as well as a laser altimeter; the success of scientific observations with these instruments is meant to determine whether they are suitable for the missile-defense applications for which they were originally developed.


After its scheduled January 25th launch the Clementine spacecraft will orbit the Moon before flying past the Earth-crossing asteroid 1620 Geographos. Courtesy BMDO.

Rosat and ASCA

One of the gyroscopes on the Rosat X-ray observatory failed on November 18th, sending the spacecraft into electronic hibernation. The gyros help determine and maintain the direction in which the satellite points. After a week of tests, operations resumed using the two remaining gyros, one of which has behaved erratically in the past. Flight controllers report that any further gyro failures will start to reduce the observing efficiency of the telescope, but software exists to allow continued observations even if both remaining gyros fail. In December the High Resolution Imager became the primary Rosat instrument, with the Position Sensitive Proportional Counter reserving the last vestiges of its gas supply for observations one week every month.

Mysteriously, the Japanese X-ray astronomy satellite ASCA encountered a gyro problem the same day Rosat did. Its observations resumed in December using a spare unit.

Compton Gamma Ray Observatory

The final phase of the reboost of the Compton Observatory ended successfully on December 17th. In all, the thruster firings raised the spacecraft's orbit by 100 km, back to the 450-km altitude it had initially after launch in April 1991. A 10-year-old Tracking and Data Relay Satellite in geostationary orbit has been moved over a recently completed ground station in Australia to increase the fraction of time that Compton's instruments can transmit their data to Earth. Compton continues to make observations of gamma-ray bursts, quasars, and other high-energy sources.

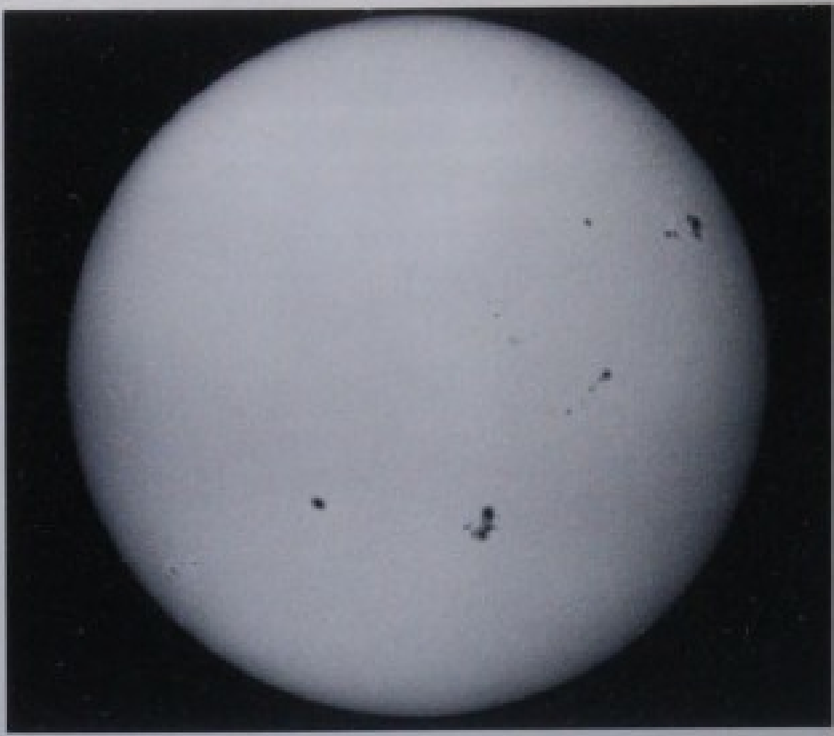
Cosmic Background Explorer

Its scientific mission complete, NASA's Cosmic Background Explorer (COBE) has ceased operations. Launched in November 1989, COBE made two of the most dramatic observations in the history of space astronomy when it confirmed the blackbody spectrum of the cosmic microwave background radiation and found indications of minuscule fluctuations in its temperature. The liquid helium supply for the satellite's far-infrared spectrometer ran out in September 1990. The remaining instruments continued to operate until December 23, 1993, when they were switched off by ground controllers.

Jonathan McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

carbon, oxygen, and nitrogen in nearby nebulae are below the solar values. In a recent issue of *Astrophysical Journal Letters* Steigman writes, "Perhaps the Sun is *anomalous*."

In a related paper in *Astronomy and Astrophysics*, Bengt Edvardsson (Uppsala Astronomical Observatory) and his colleagues find cause for reassurance in a 10-year survey of *F*- and *G*-type stars. They examined 189 dwarfs at very high spectral resolution and detected significant trends in their chemical compositions. When the Sun's age, distance from the galactic center, and heavy-element content are accounted for, Edvardsson's team finds the Sun to have a normal elemental makeup. Further study may reconcile these discordant results.



Many models of galactic chemical evolution rely on the Sun having a typical composition. A recently published survey of almost 200 dwarf stars strengthens this assumption, just when other research questions it. This white-light image of the solar disk was made with a 130-millimeter Astro-Physics refractor working at f/16 and a 1/500-second exposure on Kodak Technical Pan 2415 film. Courtesy Gordon Garcia.

MISSION UPDATE

By Jonathan McDowell

Near Earth Asteroid Rendezvous

NASA has begun development of its next planetary mission, the Near Earth Asteroid Rendezvous (NEAR). The first close-up views of minor planets were obtained by the Galileo spacecraft when it sped past the main-belt objects 951 Gaspra and 243 Ida en route to Jupiter (*S&T*: December 1993, page 9). After its February 1996 launch, NEAR will swing by another such object, 2968 Iliya. But more important, beginning in December 1998, it will match its course with that of 433 Eros for a year-long study of this body's surface, structure, and composition. Eros has an unusual Amor-type orbit that carries it near the Earth. Some Amors might be extinct comet nuclei, but Eros seems to be an ordinary asteroid perturbed out of its original orbit.

The Near Earth Asteroid Rendezvous (NEAR) probe will approach within 24 kilometers of minor planet 433 Eros. Courtesy the Johns Hopkins University.

NEAR, to be built and operated by the Johns Hopkins University's Applied Physics Laboratory, is the first in a proposed series of low-cost planetary missions known as the Discovery program. In the 1960s NASA had two regular planetary series, Mariner and Pioneer, whose last descendants are the Voyager and Galileo probes, respectively. Their successors, the Planetary Observer and Mariner Mark II series, were abandoned after only one mission of each kind was funded (Mars Observer and the Cassini Saturn orbiter, respectively). It remains to be seen whether the Discovery series will fare better.

Mars Observer

The review panel studying the loss of the Mars Observer has concluded that a fuel leak probably caused the spacecraft to tumble out of control. Timothy Coffey (Naval Research Laboratory) and his colleagues suspect that the leak occurred when the probe tried to pressurize its fuel tanks prior to firing its engine to brake into Martian orbit last August. NASA now plans to launch a new mission to the red planet in 1996 if funding permits, and Russia hopes to dispatch its Mars 94 probe this year.

Infrared Space Observatory

The stunning success of the Infrared Astronomical Satellite (IRAS) in 1983 marked the opening of the far-infrared frontier. Scientists continue to produce exciting new results using data in the IRAS archive. Despite years of work on a planned successor called the Space Infrared Telescope Facility, NASA has not yet won approval to build it. The European Space Agency (ESA) will fill the gap with its Infrared Space Observatory (ISO), now scheduled for launch in September 1995. While IRAS surveyed the whole sky, ISO will study individual targets in detail and obtain high-resolution images and spectra. It carries an array camera, long- and short-wavelength spectrometers, and a multiband photometer. These will cover the infrared spectrum from 2.5 to 200 microns. ISO's supply of liquid-helium coolant is expected to last 18 months.

Some observing time will go to the European scientists who built the instruments, but two-thirds of it will be available to astronomers worldwide on a competitive basis. Thanks to a recent agreement between NASA and ESA, U. S. astronomers will also have special access to ISO for an average of 30 minutes each day in exchange for ISO's use of a NASA ground station. Part of this extra time will be devoted to four large projects to study stars, galaxies, protoplanetary disks, and quasars.

Jonathan McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

When it rounded the Sun in late 1992 Periodic Comet Swift-Tuttle exhibited a strong infrared emission believed due to the organic compound methanol, which apparently comprises about 7 percent of the comet's gaseous exhalations. This visible-light image, acquired by James V. Scotti with the 0.9-meter Spacewatch telescope, shows how Swift-Tuttle's coma appeared on October 18, 1992, two months prior to perihelion. At the time the comet was 7th magnitude. Stephen M. Larson and Scotti (University of Arizona) tracked the movement of distinct jets and found that the nucleus rotates every 2.8 days, as had been deduced from observations made during the comet's previous visit in 1862. Courtesy Scotti.

but is also responsible for much of the broader peak centered on 3.4 microns. Details appear in *Icarus* for October 1993 and in *Monthly Notices* of the Royal Astronomical Society for December 15th.

For years a comet's volatiles were thought to be 80 percent water, with the remainder carbon monoxide, carbon dioxide (CO_2), and little else. But Susan Hoban (Hughes STX and NASA-Goddard Space Flight Center), who participated in both Swift-Tuttle observations, says all the newly found CH_3OH implies that hydrogen played a bigger role than once thought in comet-forming regions of the primordial solar system. "Methanol," she says, "appears to be an equal partner in carbon chemistry that should not be ignored."

MISSION UPDATE

By Jonathan McDowell

Mars Surveyor

The Clinton administration's proposed fiscal 1995 budget includes money to develop Mars Surveyor, a series of small probes to orbit around and land on the red planet. If approved by Congress, the initial pair of orbiters will probably carry backup experiments built for the lost Mars Observer. The first of these will head off in November 1996, as will the Mars Environmental Survey (MESUR) Pathfinder, which had been planned as a precursor to a more ambitious series. Future MESUR spacecraft will likely be superseded by Mars Surveyors.

The new plan calls for two launches in every Mars window. This return to 1960s' practice means that a single failure will not ruin the program, as it did for Mars Observer. In addition, each spacecraft will be launched on Deltas or smaller rockets, so the cost of the probes and their launchers will be manageable.

The 1996 Surveyor will send data from Martian orbit for up to five years and operate independently of Pathfinder, which will land on the planet in 1997. The 1998 and 2001 Mars windows will also see the launch of orbiter-lander pairs.

Duplicates of some instruments on the ill-fated Mars Observer (shown here) could orbit the red planet beginning in 1997 as part of NASA's new Mars Surveyor program. Courtesy General Electric Astro Space.

Rosat

The Rosat X-ray observatory was beset by attitude-control problems in late 1993 and early 1994. Repeatedly in December and early January the German-American-British spacecraft drifted from its intended pointing direction and automatically entered the electronic hibernation state called safe mode. Eventually telescope controllers put the craft in an extended safe mode while they attempted to understand the problem.

Rosat would lose its aim when its intended target in the sky was blocked by the Earth while the satellite passed through the planet's shadow. At such times, with Sun sensors rendered useless, magnetometers are used to supplement attitude information from the gyroscopes; by finding the local direction of the Earth's magnetic field the onboard computer can guess where the telescope is pointing. Previously unrecognized problems with this approach were resolved in early February, and partial operations resumed shortly thereafter.

ALEXIS

When contact was lost with the Array of Low-Energy X-ray Imaging Sensors after its launch in April 1993, the project's future looked bleak — especially after dramatic video images transmitted from the Pegasus rocket showed a solar-cell panel break loose during the ascent to orbit. But ALEXIS has gained a reputation as the Comeback Kid of space astronomy, and at the American Astronomical Society meeting in January, Jeff Bloch (Los Alamos National Laboratory) presented the first astronomical observation from the satellite. He and his colleagues were able to reconstruct where the spacecraft was pointing well enough to obtain an extreme-ultraviolet image of the Moon. ALEXIS's small telescopes have such low angular resolution that the Moon appears as a point source to them, but the image is an encouraging sign and suggests that eventually the wobbly motion of the damaged satellite will be understood well enough to create useful sky maps.

Jonathan McDowell studies quasars and space-program history at the Harvard-Smithsonian Center for Astrophysics.

Halley Halfway Out

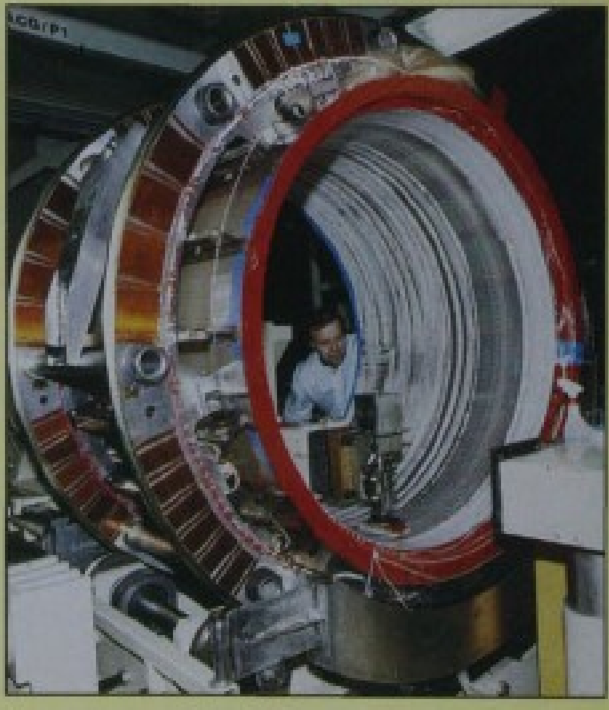
Although it wouldn't win a prize for Best Picture, this CCD image of Comet Halley is, nonetheless, historic. It captures the comet amid star trails at a record distance of 18.8 astronomical units from the Sun — about as far away as Uranus. Since it rounded the Sun in February 1986, the comet has traveled more than halfway toward the farthest point in its orbit. Olivier Hainaut (European Southern Observatory) and an international team of astronomers successfully identified the 26.5-magnitude speck on CCD images made last January 11th through the ESO's 3.5-meter New Technology Telescope. Shown here is a composite of nine 25-minute exposures. The apparent absence of a coma suggests the comet's surface is entirely frozen. Halley will reach aphelion 30 years from now, when it will be 5.3 billion kilometers from the Sun and 15 times (3 magnitudes) fainter. However, for the first time in history, it should be within range of earthly telescopes.

MISSION UPDATE

By Jonathan McDowell

Advanced X-ray Astrophysics Facility

AXAF will be the first dedicated U. S. X-ray astronomy observatory since the Einstein mission of 1978–81. Still on schedule for a 1998 launch, AXAF will build on the research carried out by the European- and Japanese-built spacecraft Exosat, Rosat, and ASCA. The first of its grazing-incidence mirror assemblies passed a critical design review in February; all four mirror pairs have now been ground, and polishing will continue over the next year. A special X-ray test facility at NASA's Marshall Space Flight Center in Alabama will be used to check out the assembled telescope and its instruments starting in 1997. AXAF will carry a high-resolution camera, a CCD imaging spectrometer, and two spectroscopic gratings. It will return the sharpest X-ray pictures and most detailed X-ray spectra of high-energy celestial sources to date.



An automated grinder-polisher figures the largest of AXAF's grazing-incidence mirrors. Courtesy Hughes Danbury Optical Systems.

Koronas I

The fledgling Russian Space Agency's first astronomy satellite was launched on March 2nd from Plesetsk in northern Russia. Koronas I carries a diverse set of solar-physics instruments provided by scientists from nine countries. Among them is a copy of the Terek solar X-ray spectrometer first flown on the failed Phobos 1 probe. Koronas I is the first of two similar satellites and is the latest incarnation of a small-satellite design that dates back to Kosmos 1 in 1962.

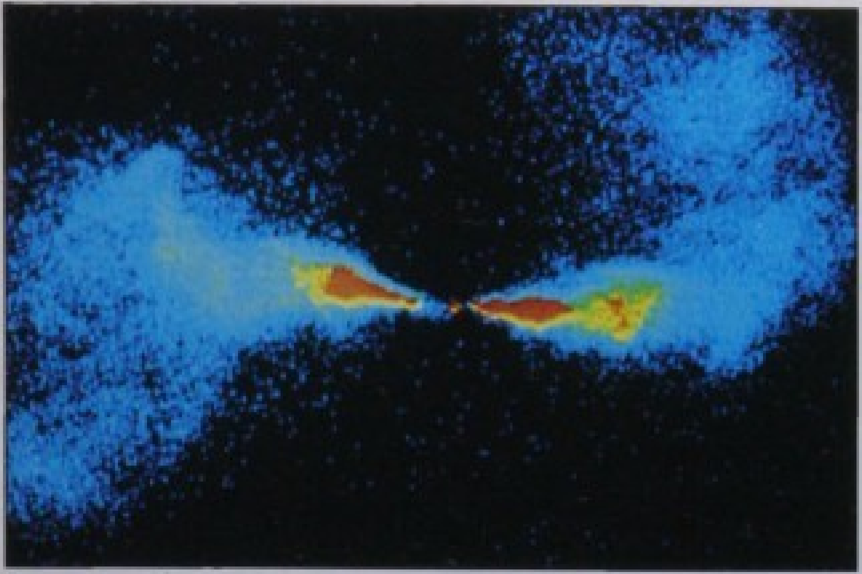
Hubble Space Telescope

The Hubble Space Telescope has resumed science observations following last December's successful repair mission. The lengthy post-repair checkout, called Servicing Mission Observatory Verification (SMOV), went extremely smoothly and was essentially complete by the end of March. During SMOV, observations were made to locate precisely the scientific-instrument apertures that had been altered by the addition of corrective optics. Other observations were made to measure the instruments' sensitivities. One highlight of SMOV was the successful turn-on of the Goddard High Resolution Spectrograph's short-wavelength detector, which had been inoperative for two years. The reactivation was made possible by new wiring installed by the astronaut repair crew.

Magellan

The Magellan Venus mapper continues operating in a low-altitude orbit around the planet. NASA's Jet Propulsion Laboratory is conducting the mission on a shoestring budget. The project's limited funding was recently extended until September, which will permit scientists to map the gravity field over 90 percent of the planet. Magellan was launched in 1989 from the Space Shuttle. After four years spent making a radar map of Venus's surface, the probe used aerobraking last year to lose altitude and begin measuring local variations in gravity.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.



Cosmologist Ruth Daly has devised a new way to measure the mass density of the universe using observations of high-redshift, double-lobe radio sources. This false-color radio image, made at a wavelength of 6 centimeters with the Very Large Array, shows the twin jets and radio-bright lobes in M84, a relatively nearby galaxy in the Virgo Cluster. Courtesy NRAO/AUI.

arguments that the universe is precisely balanced between eternal expansion and eventual recontraction.

Another recent attempt to use the angular sizes of radio sources to infer the cosmic density came up with a number more in line with theorists' expectations (*S&T:* September 1993, page 12). But, as usual, many astronomers refused to believe it because of likely confusion by evolutionary effects. It remains to be seen whether Daly's result will fare better. She cautions that she won't feel too confident in it herself until it incorporates data on at least 100 galaxies.

MISSION UPDATE

By Jonathan McDowell

Relativity Mission

Lockheed Missiles and Space Co. has begun building the Relativity Mission satellite, designed to make the first test of a subtle effect predicted by Einstein's general theory of relativity. A massive, rotating body such as the Earth should cause the space-time around it to rotate slightly as well — a phenomenon known as *frame dragging* — and this should cause the delicate gyroscopes on the satellite to precess (*S&T:* October 1990, page 367). The effect is minuscule, and to detect it the gyroscopes must operate near 0° Kelvin in an ultrapure vacuum and a negligible magnetic field. Formerly called Gravity Probe B, the Relativity Mission was developed by researchers at Stanford University. The 3-ton payload is scheduled for launch in 1999 on a Delta rocket. Gravity Probe A, in June 1976, was a suborbital flight of an atomic clock to test the equivalence of gravitational and inertial mass, another key element of Einstein's theory of gravity.

In 1999 the Relativity Mission, formerly known as Gravity Probe B, will perform a new, highly precise test of Einstein's theory of gravity. Courtesy NASA.

Magellan

Flight controllers at the Jet Propulsion Laboratory have once again lowered Magellan's orbit around Venus. With several thruster firings in March and April, the probe dropped from an average altitude of 360 kilometers to only 305 km. This will allow more detailed mapping of the planet's gravitational field. After Magellan completes its mission at the end of this year, it will burn up in Venus's atmosphere.

Wind

NASA has postponed the launch of its Wind spacecraft to study the solar wind. Part of the International Solar-Terrestrial Physics program, the satellite will fly past the Moon twice and then settle into orbit at the L_1 Lagrangian point 1½ million kilometers from Earth in the direction of the Sun. A similar orbit was used by the International Sun-Earth Explorer 3 in 1978, before it was renamed the International Cometary Explorer and sent off to chase Periodic Comet Giacobini-Zinner. Manufacturer Martin Marietta is making some last-minute changes to Wind following the losses of three of the company's spacecraft last year. NASA officials have threatened to cancel the mission if it cannot be completed within its current budget.

Astro 2

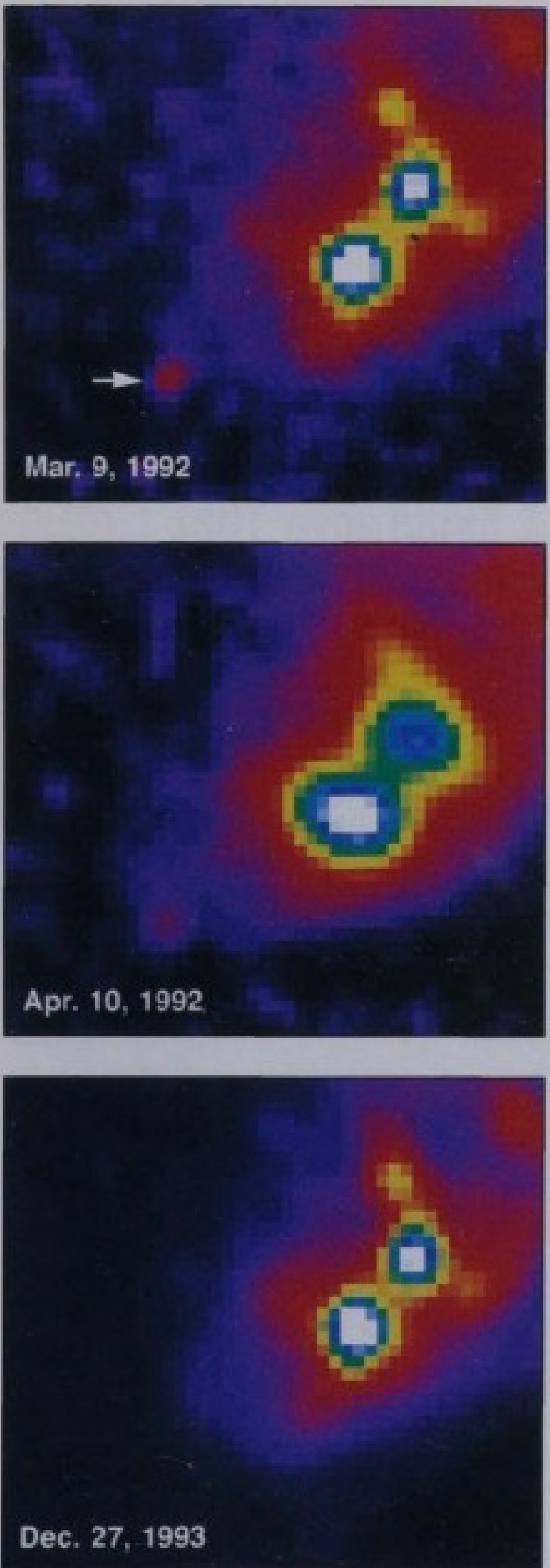
The Astro 2 Spacelab flight has been bumped from December 1994 to January 1995 and switched to the Space Shuttle *Endeavour.* The shuttle *Columbia,* which was to have carried the mission's ultraviolet telescopes, is being taken out of service for a seven-month refurbishment. Astro 2 will extend the studies of hot stars, nebulae, and galaxies begun on Astro 1 in December 1990 (*S&T:* June 1991, page 591).

Mars

The Russian government has decided to delay the planned Mars 94 mission to 1996, and Mars 96 to 1998, because of funding problems. The planetary program's budget was used up in an unsuccessful attempt to keep the Mars 94 effort on schedule for launch in October. Mars 94 (now 96) will circle the red planet and release several small landing probes. The Soviet Union launched 16 spacecraft to Mars between 1960 and 1988, and nearly all of them failed.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.

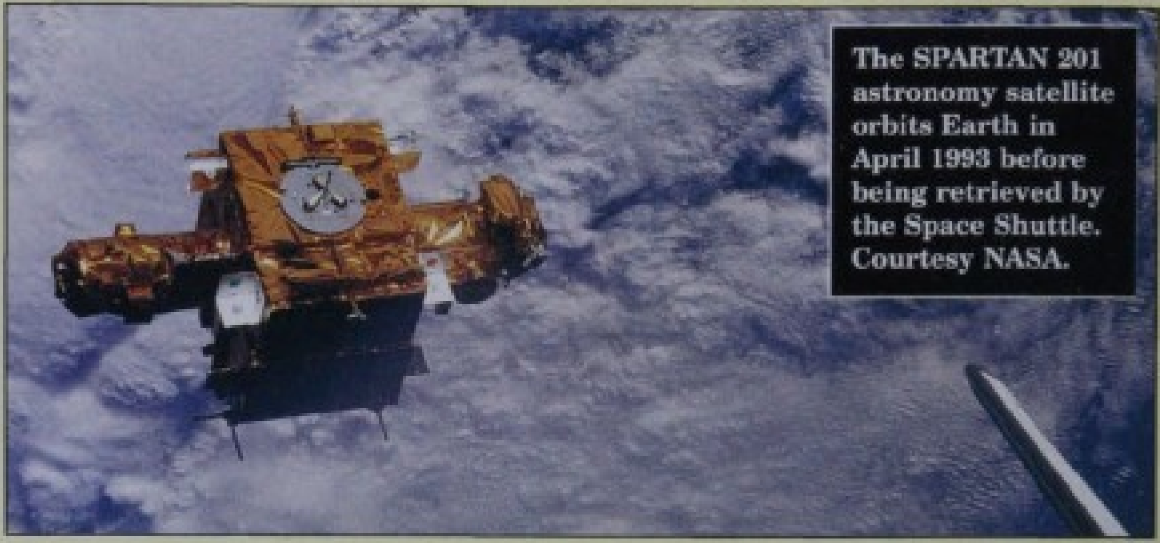
NGC 3690 in 1993 by researchers at the University of California, Berkeley. Two supernovae in two years from the same galaxy lends credence to the starburst theory, though this experiment can't rule out the existence of black holes at these galaxies' centers.



Two infrared images taken a month apart in 1992 reveal a supernova (arrowed) near the core of the starburst galaxy NGC 3690. However, at magnitude 16.6 the exploding star was so faint that its identity was suspect. A December 1993 image made with a more powerful camera showed that the source had completely faded, thus confirming its supernova nature. Courtesy Caltech and the Jet Propulsion Laboratory.

MISSION UPDATE

By Jonathan McDowell



The SPARTAN 201 astronomy satellite orbits Earth in April 1993 before being retrieved by the Space Shuttle. Courtesy NASA.

SPARTAN 201

NASA's SPARTAN 201 satellite is due to make its second flight in September. It will be released from the Space Shuttle's cargo bay to fly solo for several days, making ultraviolet measurements of the Sun. Its first mission was in April 1993. The new flight is specially timed to coincide with the study of the Sun's south pole by the European Ulysses spacecraft. SPARTAN will make detailed spectroscopic measurements while Ulysses senses the properties of the polar wind. SPARTAN, which stands for Shuttle Pointed Autonomous Research Tool for Astronomy, is a program designed to modify simple sounding-rocket experiments for use in orbit. This launch will be the fourth in the series.

SROSS C2

India's space program took a step forward on May 4th with its fifth successful satellite launch. The small SROSS C2 (Stretched Rohini Satellite) spacecraft rode the fourth Augmented Satellite Launch Vehicle on its first fully successful flight. SROSS C2 is similar to SROSS C, which was stranded in a low orbit and reentered the atmosphere after only two months in space in 1992. Two earlier SROSS satellites were lost in the Bay of Bengal shortly after leaving their Sriharikota Island launch pad. Reflecting the strong tradition of astronomy in India, one of the two experiments aboard SROSS C2 detects celestial gamma-ray bursts. While it does not match the sophistication of detectors aboard NASA's Compton Gamma Ray Observatory, it offers Indian scientists a chance to gain experience operating a space-astronomy instrument.

Fast Auroral Snapshot Explorer

The Fast Auroral Snapshot (FAST) Explorer is due for launch this fall aboard a winged Pegasus booster, which will be dropped from a converted Lockheed L-1011 airliner. One of NASA's Small Explorer series, FAST will carry four instruments to study electrons and ions in the Earth's auroral oval. Many spacecraft have studied the polar ionosphere and magnetosphere; FAST is distinguished by its ability to record extremely rapid changes in charged-particle flux and the structure of auroral electromagnetic fields.

Cassini

NASA has decided that the Cassini mission to Saturn will be lofted on a Titan 4 Centaur rocket after all. Earlier this year the agency looked at the possibility of using two shuttle launches instead. One would carry an Inertial Upper Stage, and the other would carry Cassini; the payloads would be joined in orbit. But the study concluded that this approach would be riskier than launching everything on a single Titan. The first two launches of the Titan 4 Centaur were successful this spring after nearly two years of delays. Cassini will orbit Saturn early next century and deliver the European-built Huygens probe to the surface of Titan.

Jonathan McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

temperatures of 600° Kelvin and higher. Instead, the JPL team found that much of the infrared radiation comes from broad areas spanning thousands of square kilometers. These regions, which do not correspond to known topographic features, average 300° K and are some 100° warmer than Io's average daytime temperature.

The new data help explain a long-standing mystery about Io's response when eclipsed by Jupiter. The moon exhibits a sharp drop in infrared emission as it enters shadow and a steep rise when it reemerges into sunlight. To explain this behavior, theorists had proposed a surface covered with a fluffy layer of dust, which would not retain the Sun's warmth for very long. But Veeder notes that broad areas actually stay warm well into each eclipse and remain hotter than predicted by the fluffy-dust model.

Veeder suggests that the steep infrared light curves are due to a previously overlooked contribution from the volcanic calderas: though already hot, the nearly black lavas inside them readily absorb sunlight at all wavelengths during the day, raising their temperature and thus Io's total infrared output. As soon as the moon enters shadow, this contribution vanishes. The Sun's reappearance raises the heat level once again.

All evidence points to a solid surface for Io, but one made of what? More than a decade ago some Voyager scientists interpreted the moon's colorful, variegated surface as evidence for outpourings of liquid sulfur. But liquid sulfur can't match the highest eruption temperatures observed subsequently from Earth. Nor is there likely to be enough sulfur on or within Io to account for the estimated 550 cubic kilometers of volcanic material that spews onto the surface each year.

Instead, the JPL team believes the lavas must be predominantly molten silicate rock. Calculations by Michael Carr (U. S. Geological Survey) on the energy released by cooling silicate lavas, when combined with Io's rate of volcanism, are roughly consistent with the total heat output observed. And a sudden infrared outburst witnessed in early 1990, presumably due to a fresh eruption, cooled from 1,200° to 700° K in about three hours — almost exactly the rate Carr predicted.

MISSION UPDATE

By Jonathan McDowell

Compton Gamma Ray Observatory

The Compton Observatory has begun its fourth year in orbit with all instruments functioning well. On May 27th the Burst and Transient Source Experiment (BATSE) recorded its 1,000th gamma-ray burst, an event celebrated in Minneapolis a few days later at a meeting of the American Astronomical Society. At the same gathering the Energetic Gamma Ray Experiment Telescope (EGRET) team distributed a CD-ROM filled with images and tabular data from its survey of the gamma-ray sky at energies above 100 million electron volts.

The Gamma Ray Observatory, later renamed to honor high-energy physicist Arthur Holly Compton, begins its mission with deployment from the Space Shuttle *Atlantis* on April 7, 1991. Courtesy NASA.

Pluto Mission

Despite early, optimistic pronouncements by NASA administrator Daniel Goldin, hopes for a robotic mission to Pluto and its moon Charon have waned due to deepening cutbacks in the space agency's budget. Now there is talk that NASA and the Russian Space Agency could undertake such an exploration together. The Planetary Society has paid a Russian firm to study using a Proton rocket to launch a 100-kilogram U. S. craft. It would reach Pluto in just seven years, perhaps dropping off a small Russian probe while zipping by at a range of 20,000 kilometers. NASA managers are taking an independent look at prospects for bilateral and multilateral missions.

Infrared Space Observatory

The European Space Agency's Infrared Space Observatory (ISO) reached two important program milestones in June: the completion of the instrument module and the call to astronomers worldwide to submit observing proposals. ISO is equipped with a 60-centimeter, liquid-helium-cooled telescope. During its 18-month mission it will take images and detailed spectra of astronomical targets at wavelengths from 2.5 to 240 microns. Launch is targeted for September 1995, with a backup opportunity the following spring. Because the satellite's highly elliptical orbit will precess only slightly, Earth will continuously block part of the sky. If ISO is launched on schedule, this "hole" will fall in Orion; if the launch is delayed until spring 1996, ISO will instead be unable to observe the galactic center in Sagittarius.

Solar and Heliospheric Observatory

The European Space Agency and NASA are preparing the Solar and Heliospheric Observatory (SOHO) for launch next year. SOHO will be the most ambitious solar-physics mission for NASA in many years. It will orbit at the L_1 Lagrangian point about a million kilometers from Earth in the direction of the Sun, where terrestrial and solar gravity balance. SOHO will carry ultraviolet and visible-light telescopes, particle detectors, and an experiment to measure small oscillations in the Sun's radius. The main solar observatory currently in space is Japan's Yohkoh, which takes X-ray images of the solar corona.

In addition to his research at the Harvard-Smithsonian Center for Astrophysics, McDowell prepares a weekly electronic newsletter on the space program.

NEWS NOTES

A New Piece of the Moon

The latest lunar meteorite, recovered last year in Antarctica, is approximately 2 inches long and weighs 0.75 ounce. Its salt-and-pepper interior is visible at lower left, where the fusion crust is broken. Courtesy Marilyn Lindstrom, NASA-Johnson Space Center.

The 13th known lunar meteorite was discovered December 11, 1993, by a team from the Antarctic Search for Meteorites (ANSMET) project. It was found near the top of the Beardmore Glacier about 750 kilometers south of McMurdo Station. All lunar meteorites except one (from Calcalong Creek, Australia) have been found in Antarctica.

Only 5 by 2 by 2 centimeters in size, the meteorite weighs 21.4 grams and is a fragment of a larger body. In the field it exhibited characteristics of a lunar sample. "We knew what it was by the salt-and-pepper texture of its interior and its frothy green fusion crust," said team member John Schutt. This identification was later confirmed at the Smithsonian Institution in Washington and the NASA-Johnson Space Center in Texas.

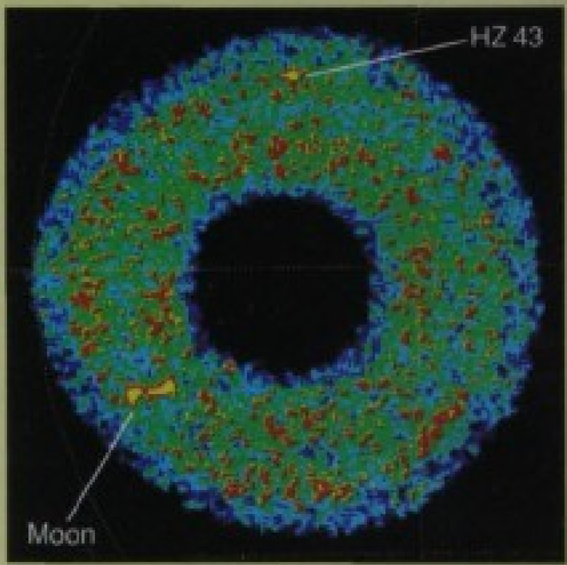
The new lunar specimen, technically called an anorthositic breccia, is one of 858 meteorites collected in Antarctica last season by ANSMET. According to co-principal investigator Ralph P. Harvey (University of Tennessee), "it is similar in most respects to two lunar specimens found in 1989 at the MacAlpine Hills about 80 km away. If the falls are paired, they may indicate that a shower of lunar rocks occurred over Antarctica sometime in the past." Searching will continue under the ANSMET program, headed by Harvey and William A. Cassidy (University of Pittsburgh).

MISSION UPDATE

By Jonathan McDowell

ALEXIS

Despite a pronounced wobble caused by a damaged solar-cell panel, the ALEXIS satellite continues to return data on the extreme-ultraviolet sky. But the 800 megabytes recorded so far will be useful to scientists only if they can figure out where the telescopes have been pointing. In May the ALEXIS team took a crucial step forward by reconstructing an image of a swath of sky that includes the white dwarf HZ 43 and the Moon. The computer program used to generate this view should eventually produce a coarse map of the whole sky.



As the ALEXIS satellite wobbles, its low-energy X-ray telescopes sweep out 30°-thick doughnuts on the sky. This view from April 1994 includes the Moon and the white dwarf HZ 43. Courtesy Los Alamos National Laboratory.

Ulysses

After a four-year odyssey that took it out to Jupiter and back toward the Sun, the European Space Agency's Ulysses spacecraft has begun its primary science mission. The study of charged particles and magnetic fields emanating from the Sun's south polar region officially began on June 26th, when the craft reached an ecliptic latitude of 70°. By September it was slated to reach 80°. Although Ulysses remains more than one astronomical unit from the Sun, its unique vantage provides a rare opportunity to examine energetic phenomena associated with regions of the Sun unobservable from Earth.

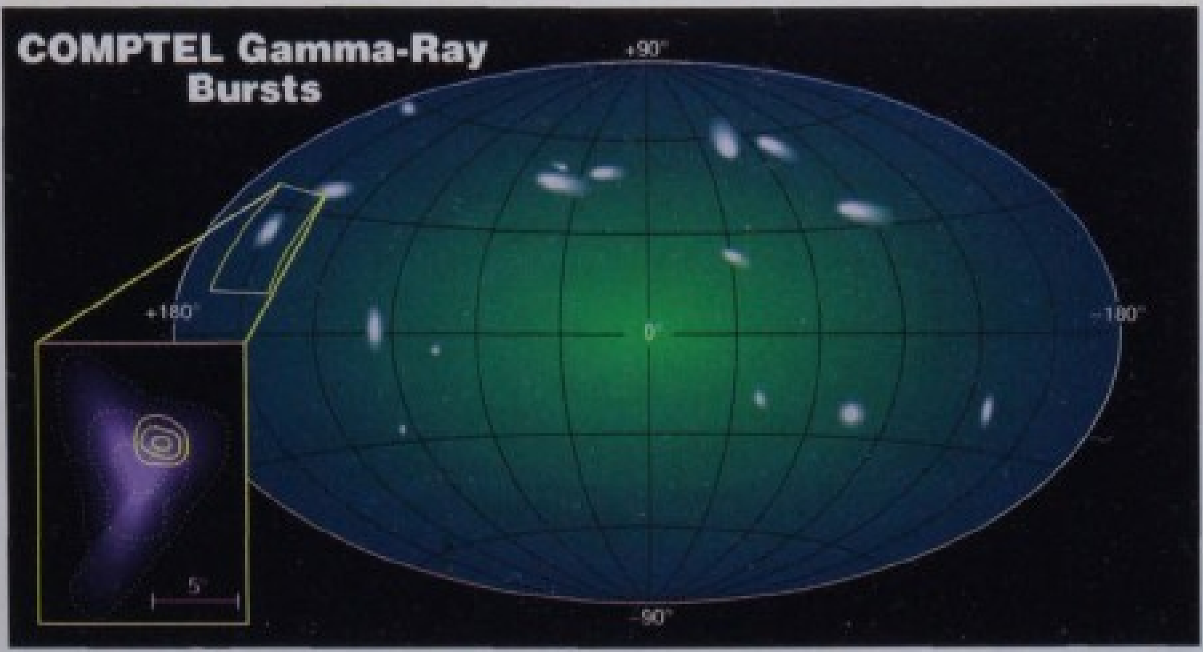
Hubble Space Telescope

The Hubble Space Telescope, in high gear since its repair by shuttle astronauts last December, shifted into neutral on July 5th. In the middle of a camera exposure a memory unit in the main computer failed, causing the observatory to point away from the Sun and await further instructions. After idling for 2½ days while controllers reconfigured the computer to use coprocessor memory added during the repair mission, Hubble suddenly closed its aperture door in response to a signal that it had lost all its pointing-control gyroscopes. But the gyros were fine; the problem was traced to a bug in the program that monitors their health, which caused a mathematical error after exactly 2½ days. The bug was fixed, and the telescope resumed normal science observations on July 9th, one week before beginning its intensive study of Comet Shoemaker-Levy 9's crash into Jupiter.

Scout, Pegasus, and DC-X

Many small astronomical satellites were lofted in recent decades by Scout rockets, the last of which flew in May. Scout's successor is the air-launched Pegasus, which first flew into orbit in 1990 from under the wing of a B-52 bomber. The prototype of an improved version, the Pegasus XL, was released from an L-1011 airliner on June 27th but went off course and had to be destroyed. With delays in the Pegasus XL program and no more Scouts, the Small Explorers and other astronomy payloads may have to wait longer than expected for their tickets to ride. Meanwhile, the DC-X experimental reusable rocket survived a dramatic midflight explosion on June 27th and landed safely in the New Mexico desert with a gaping hole in its side.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.



A strong burst of gamma rays on March 1st was nearly coincident with another from the previous year, implying that some bursts repeat. Courtesy Marc Kippen.

nomical phenomena. Astronomers have also known for some time that below a certain brightness the number of bursts abruptly falls off.

So far two possible explanations have been developed, but both have shortcomings. The burst sources could be as uniform in brightness as they appear, so that beyond a certain distance bursts are simply too dim to detect. Or there may be a repulsive gravitational force at work in the cosmos, something Albert Einstein proposed and later rejected. If such a force did exist the universe's rate of expansion would be accelerating, having the effect of "dropping off" what can be seen at the farthest reaches of the universe.

MISSION UPDATE

By Jonathan McDowell

Submillimeter Wave Astronomy Satellite

NASA's next Small Explorer, the Submillimeter Wave Astronomy Satellite (SWAS), is now assembled and ready for testing. SWAS will point at dense molecular clouds in the Milky Way to detect telltale radiation from gas clouds that are just beginning to collapse under their own weight. Such clouds should warm up as they contract, eventually reaching a stable configuration. Yet apparently they keep collapsing to form protostars.

Astronomers believe the clouds cool by emitting submillimeter radiation from atoms of carbon and molecules of water, carbon monoxide, and oxygen. But these emissions cannot be observed from the ground because Earth's atmosphere blocks them. SWAS carries a half-meter-wide mirror to concentrate radiation from a 4-arc-minute patch of sky onto two receivers that will measure the intensities and shapes of five key spectral lines at wavelengths between 540 and 625 microns. The relative strengths of the emissions from the atomic and molecular "coolants" will not only test star-formation models but also will provide crucial new data on chemical processes in molecular clouds. In addition, gas motions inducing Doppler shifts as small as 1 kilometer per second will be detectable in the spectra. Built by Ball Aerospace and the Smithsonian Astrophysical Observatory, SWAS is scheduled for launch next spring aboard a Pegasus XL rocket.

From an orbit 600 kilometers above Earth, the Submillimeter Wave Astronomy Satellite will probe chemical processes in galactic molecular clouds. Courtesy Ball Aerospace and Scott Kahler.

Solar, Anomalous, and Magnetospheric Particle Explorer

NASA's first Small Explorer, the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX), recently passed its second anniversary in orbit. Launched aboard a Scout rocket in July 1992, the satellite carries four experiments to detect high-energy particles from cosmic rays, solar flares, and the Earth's magnetosphere. In May 1993 the SAMPEX team reported finding a belt of so-called anomalous cosmic rays — oxygen, helium, and other light nuclei — trapped by our planet's magnetic field.

Fast Auroral Snapshot Explorer

The Fast Auroral Snapshot (FAST) Explorer was to be NASA's second Small Explorer, but its launch has been delayed one year because of the loss of the first Pegasus XL rocket (October issue, page 16). The booster will be ready to fly again later this year, but FAST has to be launched in the summer, so SWAS (see above) will be launched first. The apogee of FAST's elongated orbit must be over the Northern Hemisphere at the time of a ground-based auroral-monitoring campaign scheduled to take place in the dark Arctic winter. FAST will study auroral electric and magnetic fields and energetic electrons and ions. Its four extendable equipment booms will measure 60 meters tip to tip.

Clementine

The Clementine spacecraft has completed its lunar-mapping mission and is now orbiting the Sun. Following the accidental loss of attitude-control fuel, the planned flyby of an asteroid had to be canceled (August issue, page 20). Instead, Clementine made one last lunar flyby on July 20th — the 25th anniversary of the Apollo 11 Moon landing — and entered solar orbit.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

Using Planetary Nebulae to Weigh a Galaxy

Astronomers have discovered a new use for planetary nebulae, the shells of dust and gas cast off in the death throes of low-mass stars. These objects can be used as a sort of cosmic bathroom scale for distant galaxies.

Taking advantage of the special properties of planetaries, Magda Arnaboldi Gnidica and Kenneth C. Freeman (Mount Stromlo Observatory) led an international research effort to find the mass of the giant elliptical galaxy NGC 1399, some 50 million light-years away in the Fornax cluster of galaxies. Many giant ellipticals reside near the center of galaxy clusters, and astronomers have always suspected that these galaxies are extremely massive. But because they are so far away (NGC 1399 is one of the closest), mass measurements have been next to impossible.

The light from planetary nebulae has offered new hope. At NGC 1399's distance, planetaries are exceedingly faint — challenging detections for even the largest telescopes. But most of their radiation is the characteristic green light given off by doubly ionized oxygen atoms. Viewed through a filter that isolates these emissions, the planetaries are more easily identified. It then becomes possible to measure the Doppler shifts of the oxygen ions as they orbit their parent galaxy.

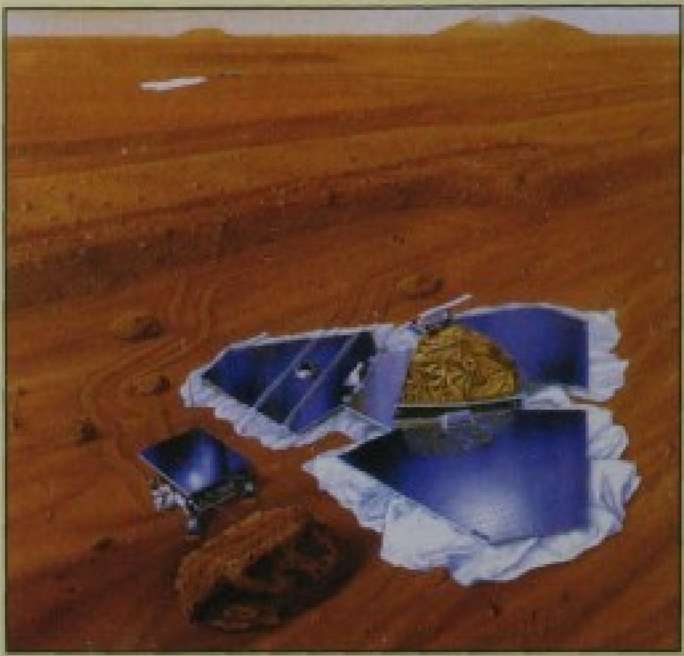
Arnaboldi and Freeman used the multi-object spectrograph on the European Southern Observatory's 3.5-meter New Technology Telescope in Chile. A metal mask allowed the planetary nebulae in NGC 1399's outskirts to shine through but blocked most of the other light coming from the galaxy. Two 5-hour exposures allowed the observers to determine the velocities of 37 planetaries. The objects are moving so quickly that they would fly off into intergalactic space unless NGC 1399 contains about 10 times more mass than we see as stars and bright gas.

This discovery fortifies the growing evidence that our universe consists largely of invisible "dark matter" that continues to elude detection or easy explanation. Arnaboldi, Freeman, and their colleagues plan to apply their new technique to more giant ellipticals to see if they too contain much more mass than meets the eye.

MISSION UPDATE

By Jonathan McDowell

Mars Pathfinder



After landing on the red planet in July 1997, Mars Pathfinder will deploy a small robotic rover to explore the Ares Vallis floodplain. Courtesy NASA and the Jet Propulsion Laboratory.

NASA's Mars Pathfinder is slated to touch down in the red planet's Ares Vallis region in July 1997. The landing site, selected by scientists at the Jet Propulsion Laboratory in September, is an ancient, sediment-covered floodplain located at 33° west longitude, 19½° north latitude, 850 kilometers southeast of the Viking 1 site in Chryse Planitia. It lies at the mouth of the Ares Vallis, a large canyon that stretches southeast all the way to the equator. To be launched on a Delta rocket in November 1996, Mars Pathfinder will sample atmospheric gases as it parachutes to the planet's surface. Once on the ground it will deploy a 63-centimeter-long, 9-kilogram "microrover" carrying a multispectral camera and an X-ray spectrometer to determine the composition of rocks.

Magellan

The Magellan orbiter, its Venus-mapping mission complete, performed a "windmill" experiment in September. Beginning on August 25th Magellan was lowered into a 172-by-390-km orbit, causing it to dip into the planet's upper atmosphere at periapsis. Then the spacecraft was turned to face its solar-cell panels "into the wind." The resulting pressure on the panels was then measured by the force needed to stop the spacecraft from spinning like a windmill. This information will be used in designing future probes to Venus. After some final measurements of the planet's gravity field, Magellan was lowered deeper into Venus's atmosphere — and to a fiery end — on October 11th.

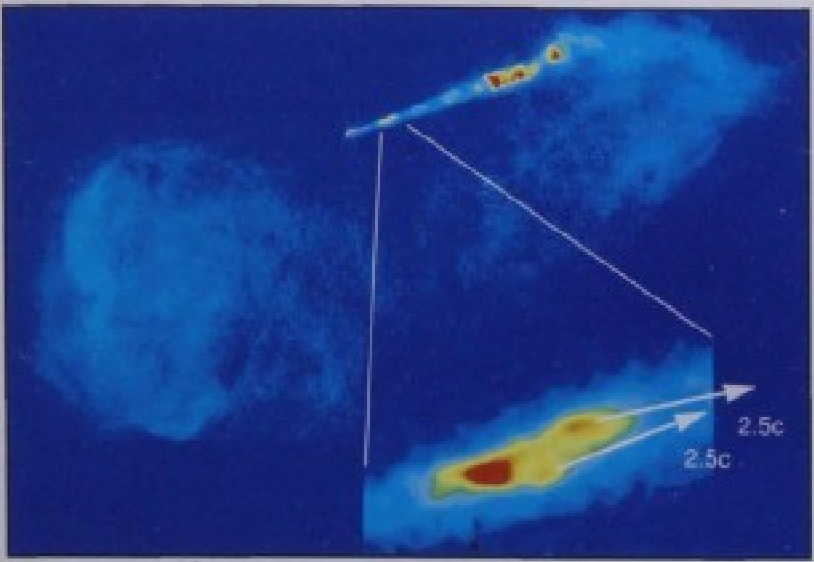
Far Ultraviolet Spectroscopic Explorer

The Far Ultraviolet Spectroscopic Explorer (FUSE) faces a drastic redesign in an effort to lower its cost. FUSE was to be the last of the large Delta-class Explorer satellites, which NASA managers want to ax in favor of a new line of midsize Explorers (MidEx). FUSE was to have a 0.64-meter-wide telescope and a high-resolution spectrograph for observations in the spectral region defined by the hydrogen atom's Lyman continuum (912 angstroms) and Lyman-alpha line (1216 angstroms). Principal investigator Warren Moos (Johns Hopkins University) says he is optimistic that a large fraction of FUSE's science could be accomplished within a new, much smaller budget for the program.

Lidar In-space Technology Experiment

Flown aboard *Discovery* during Space Shuttle mission STS-64 in September, the Lidar In-space Technology Experiment (LITE) bounced laser light off particles suspended in Earth's upper atmosphere and back up to a telescope in the shuttle's cargo bay. This so-called lidar (optical radar) system made use of a 96-cm Cassegrain receiver telescope originally built as the engineering model for the Goddard Experiment Package on Orbiting Astronomical Observatory B. Launched in November 1970, OAO B failed to reach orbit due to problems with its Atlas-Centaur rocket. The prototype telescope languished forgotten for two decades until it was refurbished for *Discovery*'s mission.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics who writes a weekly electronic newsletter on the space program.



At radio wavelengths the giant elliptical galaxy M87 in Virgo consists of two faint lobes and a bright jet squirting more than 20 arc seconds (5,000 light-years) from the nucleus. The two knots identified in the expanded view of the jet appear to be moving 2½ times faster than light. This Very Large Array image was made at 2 centimeters wavelength. Courtesy the National Radio Astronomy Observatory.

ly in all directions — including toward Earth — as it flows out from the galaxy's nucleus.

For Biretta, the most surprising feature of the discovery is M87's relative proximity. Past cases of superluminal motion have involved high-redshift galaxies and quasars, but M87 is the second-closest galaxy with a radio-bright jet. "Here we see superluminal motion that is, in cosmic terms, right in our living room," he says. "This suggests that the phenomenon may be more common than we thought."

Many astronomers believe that jets like M87's are composed of electrons and other subatomic particles accelerated by supermassive black holes in the centers of galaxies. Imaging and spectroscopic observations with the Hubble Space Telescope recently unearthed strong evidence for such a beast in M87 itself (*S&T:* August 1994, page 13). Biretta says that the discovery of superluminal motion supports the black-hole model. "We know of little else," he says, "that could accelerate jet material to relativistic speeds."

MISSION UPDATE

By Jonathan McDowell

Wide-Field Infrared Explorer

In mid-September NASA selected two new Small Explorer missions for astronomy (November issue, page 16). The Wide-Field Infrared Explorer (WIRE), set for launch in October 1998, will carry a 30-centimeter infrared telescope. It will make deep images of the sky at wavelengths of 12 and 25 microns to search for distant galaxies. Unlike the earlier Infrared Astronomical Satellite and Cosmic Background Explorer, which used liquid-helium coolant, WIRE will use solid hydrogen to cool its optics and detectors below 20° Kelvin. Two infrared-detector arrays 128 pixels square will observe the same half-degree patch of sky simultaneously. The survey should reveal more than 30,000 starburst galaxies at redshifts between ½ and 1; WIRE will also seek luminous protogalaxies at much higher redshifts.

After launch on a Pegasus XL rocket in 1998, the Wide-Field Infrared Explorer will probe for high-redshift galaxies. Artwork by Glenn Allred; courtesy Helene Schember.

Transition Region and Coronal Explorer

NASA's other new Small Explorer is scheduled to reach orbit in 1997. The Transition Region and Coronal Explorer (TRACE) will use a 30-cm telescope to make far-ultraviolet images of a thin zone between the Sun's chromosphere and corona in the light of ionized carbon. In this transition region, temperatures rise a hundredfold over just a few hundred kilometers. High-resolution images in the light of ionized iron between 170 and 280 angstroms will show the solar corona, where the gas temperature is several million degrees.

Spartan 201

The Spartan 201 solar observatory (August issue, page 18) successfully completed its second mission. Released from the Space Shuttle *Discovery* on September 13th, it studied the Sun's south pole with an ultraviolet coronal spectrometer and a white-light coronagraph. The observations were timed to coincide with the passage of the Ulysses space probe over the solar pole. After 48 hours astronauts retrieved the satellite with *Discovery*'s robotic arm. The payload will be refurbished for a third mission in mid-1995, when Ulysses will loop over the Sun's north pole.

X-ray Mirror Mission

The European Space Agency plans to launch its X-ray Mirror Mission (XMM) near the end of the century. The 3-ton satellite will carry a trio of X-ray telescopes equipped with CCD cameras to make images with an angular resolution of 30 arc seconds. Two of the telescopes will also contain grating spectrometers to obtain "soft" (low-energy) X-ray spectra. The most unusual feature of XMM is that it will also carry a 30-cm optical-ultraviolet telescope to monitor the same field that the X-ray telescopes are looking at. This will allow observers to correlate optical flares with X-ray outbursts in variable sources, but optical space telescopes are in short enough supply that it may prove useful in its own right. The XMM satellite will be launched by an Ariane rocket into an elliptical orbit with a 24-hour period, making it the first astronomical observatory since the International Ultraviolet Explorer to be geosynchronous.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

ecliptic latitudes are moving much faster than those encountered here on Earth. In other words, they behave just like the solar wind.

Ulysses was launched from the Space Shuttle *Discovery* in October 1990 and passed within 450,000 km of Jupiter in February 1992. The planetary flyby propelled the spacecraft out of the ecliptic plane and back toward the Sun. Ulysses will pass over the Sun's north polar region from June to November 1995, and with any luck it will still be operating in 2000 and 2001 when two more solar polar flybys will take place. These coincide with the next maximum of the sunspot cycle, by which time the coronal holes of 1994–95 will have shrunk dramatically.

Interstellar Laughing Gas

It's no joke. Astronomers have found nitrous oxide (N_2O), commonly known as laughing gas, near the center of our galaxy. (Dentists sometimes use this colorless, sweet-smelling gas as an anesthetic.) This discovery provides an important clue to the evolutionary state of interstellar matter in the Milky Way and allows astronomers to test their understanding of interstellar chemistry.

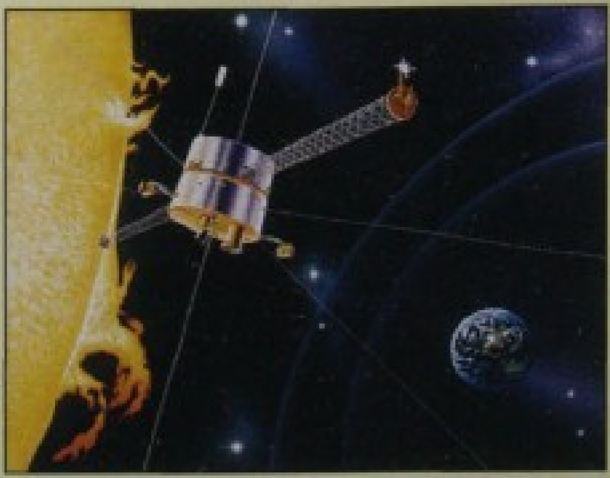
A team led by Lucy M. Ziurys (Arizona State University), Mike Hollis, (NASA-Goddard Space Flight Center), and Lewis E. Snyder (University of Illinois) detected four discrete millimeter-wave emissions from N_2O while pointing the National Radio Astronomy Observatory's 12-meter antenna toward Sagittarius B2, a giant molecular cloud 25,000 light-years away. The team reports its results in *Astrophysical Journal Letters* for December 1, 1994.

Until now the only molecules found in space with a nitrogen-oxygen bond were nitric oxide (NO) and the nitroxyl radical (HNO). The addition of N_2O to the inventory supports chemists' belief that the reactions that produce NO and HNO should also produce laughing gas. Furthermore, it enables researchers to compare the relative abundances of the three species with predictions from chemical models. In Sgr B2, at least, the observed ratios best fit the theory for young clouds whose abundances of chemical species haven't yet stabilized. Observations of N_2O in additional sources will help determine whether the molecule is a reliable indicator of cloud age.

MISSION UPDATE By Jonathan McDowell

Wind

In the predawn hours on November 1st NASA launched its Wind spacecraft to probe the solar wind and Earth's outer magnetosphere. The satellite initially had a 200-by-495,000-kilometer orbit, but it was due to fly past the Moon in late December for a gravitational slingshot farther out into interplanetary space. In 1997 Wind will settle into a halo orbit around the L_1 Lagrangian point, where the gravity of the Earth and Sun balance.



Stationed between the Earth and Sun, Wind will monitor the solar-wind plasma and Earth's magnetosphere during its 3-year mission. Courtesy Martin-Marietta Astro Space.

The probe carries a battery of detectors to measure the velocity, density, temperature, charge, and mass of solar-wind ions and electrons, as well as the properties of interplanetary radio waves and magnetic fields. Wind also carries two gamma-ray instruments: the Transient Gamma Ray Spectrometer (TGRS) and Konus. These will study mysterious gamma-ray bursts and other high-energy transients, such as those associated with solar flares. TGRS will search for gamma-ray emission features at very high spectral resolution, complementing the much larger Compton Gamma Ray Observatory, which detects fainter bursts but with poorer energy resolution. Konus is the first Russian instrument to fly on an American satellite.

Astro 2

The second flight of the Astro Spacelab observatory is scheduled for late February. Astro 2 will carry the Hopkins Ultraviolet Telescope (HUT), the Wisconsin Ultraviolet Photopolarimeter Experiment (WUPPE), and the Ultraviolet Imaging Telescope (UIT). These will remain in the shuttle's cargo bay and be operated by astronauts in the crew cabin as well as by controllers on Earth. UIT takes pictures at the same ultraviolet wavelengths as the Hubble Space Telescope but with a much wider field of view (40 arc minutes compared with 2⅔). WUPPE measures the polarization of radiation from hot stars in the same waveband. The 0.9-meter HUT, largest of the three telescopes, reaches shorter ultraviolet wavelengths.

The nine-day Astro 1 flight in December 1990 included a fourth instrument, the Broad Band X-Ray Telescope (BBXRT). This time BBXRT's place will be taken by an Extended Duration Orbiter pallet that will allow the shuttle *Endeavour* to stay in orbit for two weeks.

Extreme Ultraviolet Explorer

EUVE begins its third year of general observations this month. Launched in June 1992, EUVE first carried out a six-month, all-sky survey in four wavebands between 60 and 740 angstroms, generating an initial catalog of 410 sources (*S&T:* December 1994, page 36). Since then the mission has focused on observations with its spectrometers.

In recent months astronomers have pointed EUVE at stellar coronas, pulsars, white dwarfs, planetary nebulae, and cataclysmic variable stars. CCD detectors like those on Japan's Advanced Satellite for Cosmology and Astrophysics (ASCA) can make out some spectral lines at higher X-ray energies, but they are less successful in the energy range that overlaps with EUVE's spectrometers, which allow many individual "soft" (low-energy) X-ray features to be distinguished for the first time. The EUVE results prove that the soft X-ray spectrometers planned for future missions will enable scientists to probe the physics of hot plasmas in galactic stars and nebulae and in remote active galaxies.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

ship in 1648, or a farmer killed in Kentucky in 1879 — but no event has been authenticated beyond a significant doubt. However, according to Chinese written histories, renown for their reliable accounts of such events as solar eclipses and comet apparitions, meteorites *have* killed humans — apparently a lot of them.

Kevin K. Yau, Paul R. Weissman, and Donald K. Yeomans (Jet Propulsion Laboratory) report in *Meteoritics* for November 1994 that from 700 B.C. onward Chinese scribes recorded more than 300 meteorite falls. Of significance were seven instances of meteorites causing fatalities over a period of 13 centuries. In one incident, on September 5, 1907, a large stone reportedly hit a house, crushing an entire family. Perhaps most alarming is the report of a meteorite shower in 1490 over Ch'ing-yang of the Shansi Province when "stones fell like rain" and killed more than 10,000 people. The event appears in several records, including the official history of the Ming Dynasty — a strong indicator that the shower truly did happen — though the latter report makes no mention of the casualties.

Deadly showers of stones are the stuff of legends — as depicted in this 16th-century woodcut. Illustration from Conrad Lycosthenes' *Chronicles of Prodigies* (1557).

The scientists also note that relatively few falls were reported during the 18th century, when interest in meteorites waned. However, the frequency picks up markedly between 1840 and 1880 — consistent with observed falls in Europe.

MISSION UPDATE

By Jonathan McDowell

X-ray Timing Explorer

NASA is preparing another astronomy satellite for launch this fall. The boxy, 3-ton X-ray Timing Explorer (XTE) will ride a Delta 2 rocket into Earth orbit. XTE's two main instruments are the Proportional Counter Array (PCA) and the High Energy X-ray Timing Experiment (HEXTE). The PCA covers the "traditional" X-ray energy range of 2 to 60 kiloelectron volts (keV), while HEXTE can sense photons with energies up to 200 keV. The mission's main goal is to study the time variability of the brightest and most energetic X-ray sources, including neutron-star binaries, black-hole candidates, and active galactic nuclei.

Unlike the X-ray observatories already in orbit or scheduled for launch later this decade, XTE will not make images of the sky. Instead it will count all the X-rays from a 1° area. This makes it difficult to study faint sources, since more than one is likely to be in the field of view at once. However, XTE's large detectors and specially designed computer will let it obtain well-exposed spectra in just a few minutes and accurately measure variations in the sources' emissions on time scales of a few microseconds.

XTE will also be able to slew rapidly to catch X-ray novae in outburst. And, in contrast with the current generation of X-ray telescopes, it will sport movable solar panels to let it point opposite the Sun, enabling it to observe the same "local midnight" part of the sky that ground-based telescopes are studying.

The X-ray Timing Explorer will monitor changes in high-energy emissions from cosmic sources. Courtesy NASA-Goddard and Advanced Technology & Research Corp.

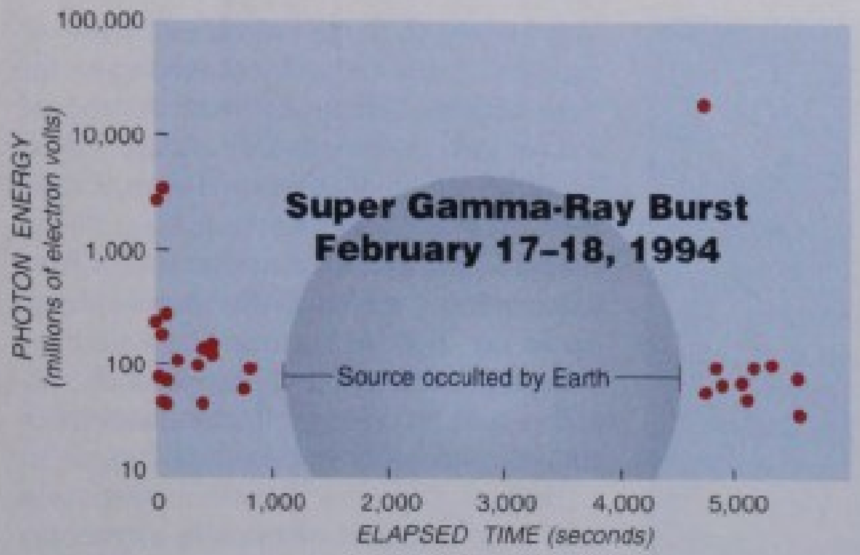
Voyagers 1 and 2

Sixteen years ago this month Voyager 1 made a close encounter with the planet Jupiter, inaugurating a series of spectacular flybys of the outer planets. Although their cameras are now dormant, both Voyagers are still sending back data on energetic stars from their ultraviolet spectrometers. Also functioning are the particle-and-field detectors aboard, which continue to search for the boundary where the solar wind ends and true interstellar space begins. The detectors measure the solar wind, radio and plasma waves, and interstellar cosmic rays. Voyager 1 is now 8.7 billion kilometers from Earth, while Voyager 2 is "only" 6.7 billion km away.

Galileo

The Galileo spacecraft is on the final leg of its 6-year voyage to Jupiter. The last of Galileo's images of the impact of Comet Shoemaker-Levy 9 were transmitted to Earth earlier this year, as the craft closed to within 1 astronomical unit of its target. Now the focus of the mission shifts to Galileo's arrival. The next big event is the separation of the atmospheric probe from the orbiter on July 13th. The orbiter will then alter its course to just miss Jupiter and will fire its braking rocket in December to enter Jovian orbit. (This solid-fueled rocket, a Star 48, has the same basic design as the Delta rocket's PAM-D third stage. It has an extensive flight history but has never been used after such prolonged exposure to the harsh space environment.) On December 7th the probe will have an hour of glory as it plummets through Jupiter's atmosphere.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.



Among the more than 1,200 gamma-ray bursts detected by NASA's Compton Observatory since April 1991, the one on February 17–18, 1994, is unique. Erupting in Pisces, it lasted far longer and packed more energy than any other such event. These data were collected by the Energetic Gamma-Ray Experiment Telescope. Adapted from *Nature*.

rent of gamma rays at energies between 25 and 150 kiloelectron volts splashed over Compton's Burst and Transient Source Experiment (BATSE) and the burst monitors aboard the Ulysses interplanetary spacecraft. Occasional high-energy photons registered in the EGRET detectors for another 10 minutes until the Earth occulted the source. At that point astronomers figured they'd seen the last of the event, but when Compton rounded the Earth and the source popped back into view, EGRET signaled still more hits, including the 18 GeV whopper.

Astronomers have come up with more than 100 theories to explain gamma-ray bursts, and a couple predict delayed high-energy emissions of the type seen on February 17–18, 1994. But it is not yet clear if a high-energy "tail" is common among bursts, or if this event was unique. One problem is that only a small fraction of the bursts picked up by BATSE are also visible to EGRET. Still, the bizarre behavior of GRB 940217 suggests that whatever and wherever the bursters are, some of them may have counterparts that linger long enough to permit their detection at other wavelengths.

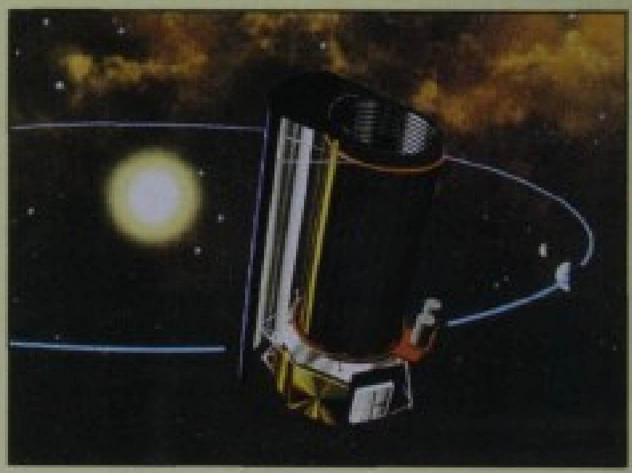
MISSION UPDATE

By Jonathan McDowell

Space Infrared Telescope Facility

The Space Infrared Telescope Facility (SIRTF) has been redesigned again, this time incorporating a major technical advance. During its first few weeks in solar orbit the telescope will passively radiate thermal energy into space, thereby chilling down to about 50° Kelvin. From then on, the optics will be kept cold by gas evaporating from the small amount of liquid helium still needed to cool the detectors themselves. In reducing the size of the cooling system, this strategy saves so much weight that the 85-centimeter telescope can be lofted by a Delta 7920 rocket rather than by the more expensive Atlas launcher envisaged in the previous design (*S&T:* June 1993, page 14).

The SIRTF mission will last 2½ years and will emphasize a handful of "key projects" involving studies of substellar objects, protoplanetary disks, ultraluminous galaxies, and highly redshifted radiation from the early universe. SIRTF will obtain images at wavelengths from 12 to 160 microns, low-resolution spectrophotometry from 50 to 100 microns, and higher-resolution spectra from 4 to 40 microns.



NASA's Space Infrared Telescope Facility is targeted for launch into solar orbit around the year 2001. Courtesy the Jet Propulsion Laboratory.

Infrared Imaging Surveyor

Another significant change to SIRTF is expected to be finalized in the coming months: the third SIRTF instrument, the Infrared Array Camera (IRAC), will fly instead as IRAC-J on a planned Japanese satellite called IRIS (Infrared Imaging Surveyor). IRIS will also boast an 85-cm aperture but, unlike SIRTF, will fly in a 900-kilometer-high polar orbit around the Earth. It will obtain near-infrared images between 4 and 8 microns and conduct a far-infrared survey. Both SIRTF and IRIS could be launched around the year 2001.

Hubble Advanced Camera for Exploration

NASA has selected Ball Aerospace to build the third-generation instrument for the Hubble Space Telescope. The Hubble Advanced Camera for Exploration (HACE) is actually three cameras. The wide-field channel incorporates a huge, 16-million-pixel CCD array with a field of view 3.3 arc minutes square; it will make images in red light. The high-resolution channel operates at near-ultraviolet, visible, and near-infrared wavelengths from 2000 angstroms to 1 micron, while the far-ultraviolet "solar-blind" channel works from 1150 to 1700 angstroms. The high-resolution and solar-blind cameras use 1,024-by-1,024-pixel CCDs with 0.03-arc-second pixels to take full advantage of Hubble's resolving power. All three cameras will be four to eight times more sensitive than the two currently aboard Hubble. Principal investigator Holland C. Ford (Johns Hopkins University) suggests that HACE will detect *all* luminous galaxies along a given line of sight.

On Hubble's second servicing mission, in early 1997, shuttle astronauts will install the Space Telescope Imaging Spectrograph (STIS) and Near-Infrared Camera and Multi-Object Spectrometer (NICMOS), both now being built at Ball. HACE will be sent up on the third shuttle servicing mission, now planned for late 1999. STIS, NICMOS, and HACE will each incorporate corrective optics to compensate for the telescope's spherical aberration.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

recent star formation emit telltale signals.

The 2.17-micron image clearly shows the partial ring recorded previously at radio wavelengths. Several bright "hot spots" probably correspond to associations of young stars and supernova remnants. Emission *inside* the ring is weak, however — there is no evidence for any current star formation in the nucleus of NGC 7552.

And therein lies the rub. Theory and observation suggest that galactic interactions and the presence of bars lead directly to increased activity in a galaxy, and that this activity should be concentrated in the nucleus. Forbes and his coworkers note that NGC 7552 has all the prerequisites for an active nucleus — distorted edges implying a previous interaction, a large-scale bar to transport material toward the nucleus, a sizable pool of molecular gas, and a nuclear bar. Why then is this galaxy's nucleus inert?

Perhaps, as Forbes and his colleagues write in the September 20, 1994, *Astrophysical Journal Letters*, the density of the material inside the nucleus isn't high enough to trigger star formation. Or maybe the inflow of material occurs in cycles and NGC 7552 is in a dormant phase now. A future search for other nuclear bars may reveal the true reason why NGC 7552's active nucleus really isn't.

MISSION UPDATE

By Jonathan McDowell

Advanced X-ray Astrophysics Facility

Opticians at Hughes Danbury Optical Systems finished polishing the four pairs of grazing-incidence mirrors for the Advanced X-ray Astrophysics Facility (AXAF) in January, four months ahead of schedule. Once coated and assembled, the mirrors will be transferred to NASA's Marshall Space Flight Center for calibration tests. AXAF will be launched on the Space Shuttle in 1998, then pushed into a high orbit by an upper stage and its own propulsion module. The observatory will do high-resolution imaging and spectroscopy of cosmic X-ray sources.

The Advanced X-ray Astrophysics Facility uses nested paraboloidal and hyperboloidal grazing-incidence mirrors, one of which is shown here before getting its reflective coating. Courtesy Hughes Danbury Optical Systems.

International Ultraviolet Explorer

The International Ultraviolet Explorer (IUE) satellite continues its extraordinary mission, which passed the 17-year mark in January. IUE is so far the only astronomical observatory to be placed in a 24-hour synchronous orbit, which allows efficient real-time observing. Advances in computer technology now allow astronomers to observe remotely from their home institutions via the Internet, rather than by traveling to a control center in Maryland or Spain. IUE should operate at least until September; next year's funding remains uncertain.

Mir

On February 6th the Space Shuttle *Discovery* made a historic rendezvous with the orbiting Mir complex, paving the way for joint American-Russian missions that will lead to construction of an international space station. Meanwhile, the Mir cosmonauts continued their record-breaking expedition, with 52-year-old physician Valeriy Polyakov having set a new space-endurance mark on January 9th, his 367th consecutive day in orbit. Flight engineer Yelena Kondakova, who has been aboard Mir for more than four months, holds the women's record. No American astronaut has been in space for more than 84 days at a stretch, but in March NASA's Norman Thagard was due to depart for Mir on a mission scheduled to beat that record by 10 days.

Astrid

Sweden's Astrid microsatellite was launched on January 24th on a Kosmos 3M rocket from Plesetsk, Russia. The 28-kilogram spacecraft was designed, built, and launched for only $800,000. It carries a trio of instruments to study atoms and electrons in Earth's magnetosphere and ionosphere.

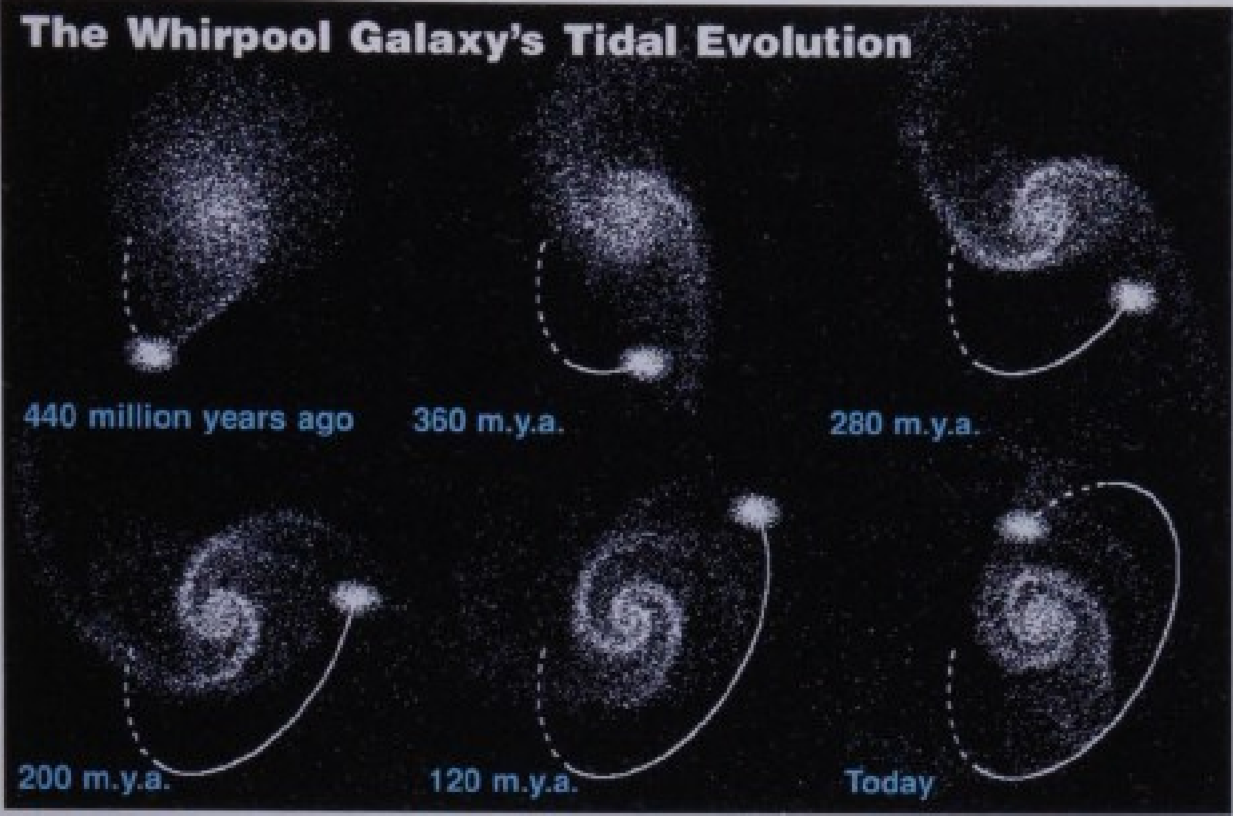
SPARTAN 204

On its February flight *Discovery* carried the latest SPARTAN (Shuttle Pointed Autonomous Research Tool for Astronomy) satellite. SPARTAN 204 was the first in the series to be funded by the Department of Defense rather than NASA; it carried a far-ultraviolet imaging spectrograph built at the Naval Research Laboratory. Optimized for studies of diffuse sources, the instrument observed interstellar gas in the Milky Way as well as in other galaxies. It was recaptured by the Shuttle after a two-day free flight.

Galileo

The orbit-insertion engine on the Jupiter-bound Galileo spacecraft is not a Star 48 solid-fuel motor as reported in my March column (page 16), but rather a German-built liquid-propellant engine.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.



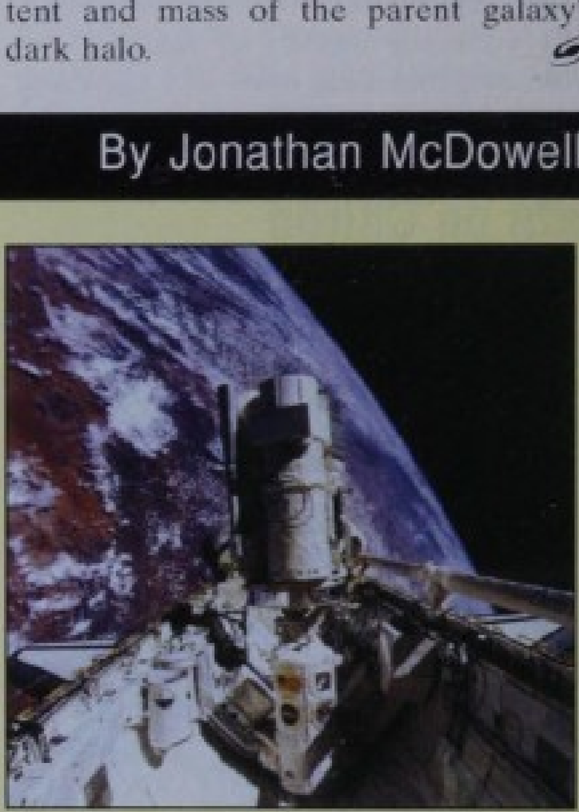
The researchers represented NGC 5194 in their computer codes as a rotating disk of stars and gas clouds embedded in a massive dark halo. They then assessed these components' mutual gravitational interactions as well as their response to the passing companion, NGC 5195, whose orbit was adjusted to best match the system's observed structure and dynamics. Such models had already suggested that NGC 5194's disk has endured at least two encounters with the smaller satellite (*S&T:* October 1990, Page 343). The currently favored orbit, tilted 73° to NGC 5194's disk, dates the latest such event at 56 million years. The researchers hope to exploit the orbital history inferred with the help of their models to better discern the extent and mass of the parent galaxy's dark halo.

MISSION UPDATE

By Jonathan McDowell

Astro 2

The second and final flight of Astro began with the launch of the Space Shuttle *Endeavour* on March 2nd. The observatory's three ultraviolet telescopes were mounted on a special pointing system in the shuttle's cargo bay. During the Astro 1 mission in December 1990, astronomers had trouble aiming the telescopes accurately and revising their complicated observing schedule when problems arose. Improvements to both hardware and software avoided such difficulties this time around. In addition, a new optical coating allowed the Hopkins Ultraviolet Telescope to observe fainter targets than before. The Wisconsin Ultraviolet Photo-Polarimeter Experiment and the Ultraviolet Imaging Telescope also benefited from upgrades, and a small Australian ultraviolet reflector in the cargo bay added to the harvest of data. Another gain on the Astro 2 flight was the presence of an Extended Duration Orbiter pallet, which allowed the mission to last 16½ days, nearly a week longer than Astro 1 and a new duration record for the shuttle program.



Astro's three ultraviolet telescopes, all on a common mount, peer from the cargo bay of Space Shuttle *Endeavour* during its historic 16-day flight in March. Courtesy NASA.

Lunar Prospector

NASA has selected a new Discovery-class space mission. Lunar Prospector will be launched in June 1997 and fly into a low-altitude orbit around the Moon. The drum-shaped, 126-kilogram spacecraft will study the composition of the lunar crust as well as the strength and structure of the Moon's magnetic and gravitational fields. It will also hunt for minute traces of gases escaping from the surface; one goal is to search for water frozen in shadowed craters near the lunar poles. In an unusual triple sweep by a single company, Lockheed Missiles and Space Company will not only build the satellite and the launcher but also will lead the science team. Lockheed will control Lunar Prospector from its space-science research laboratory, which has been active in solar and magnetospheric physics since the late 1950s. Lockheed's LLV-2 rocket, which will propel the spacecraft into a translunar trajectory from Cape Canaveral, Florida, has not yet flown.

Clementine

The Clementine probe has turned out to be a hardy survivor. In early 1994 Clementine, operated by the Naval Research Laboratory for the Ballistic Missile Defense Organization, orbited and mapped the Moon (*S&T:* August 1994, page 20). It then returned to Earth orbit in preparation for an asteroid flyby but in May 1994 suffered an accidental programming error that left it unable to control its course. When Clementine was flung out of Earth orbit last July 20th, flight controllers thought it was truly "lost and gone forever." Nevertheless, in February the Deep Space Network pointed its giant radio-telescope ears to listen in the direction where Clementine was expected to lie, and they successfully picked up transmissions from the spacecraft. Further attempts to contact the probe were due to be made this spring.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

fraction of its hydrogen atoms that are stripped of their electrons, and hence unable to absorb starlight, must be known. By placing a lower limit on this fraction, recent ultraviolet observations from Earth orbit have provided a key piece to this interstellar puzzle.

An all-sky photometric survey by the orbiting Extreme Ultraviolet Explorer (EUVE) revealed that the giant B-type star Adhara (Epsilon Canis Majoris) shines more than 15 times brighter than any other star at wavelengths near 600 angstroms (*S&T:* December 1994, page 36). Since neutral hydrogen atoms are readily ionized by photons with wavelengths below 912 angstroms, this makes the star at the Great Dog's hind foot largely responsible for the Local Cloud's ionization. Its dominance reflects both its intrinsic brightness and the peculiarly low density of neutral interstellar matter in the direction of Canis Major.

John Vallerga and Barry Welsh (Eureka Scientific, Oakland, CA) used spectra taken by EUVE to estimate that the star has a blackbody temperature between 17,000° and 18,000° Kelvin, nearly three times the Sun's, and that it robs 15 to 19 percent of the Local Cloud's hydrogen atoms of their electrons. Vallerga and Welsh describe their analysis in the May 10th *Astrophysical Journal*.

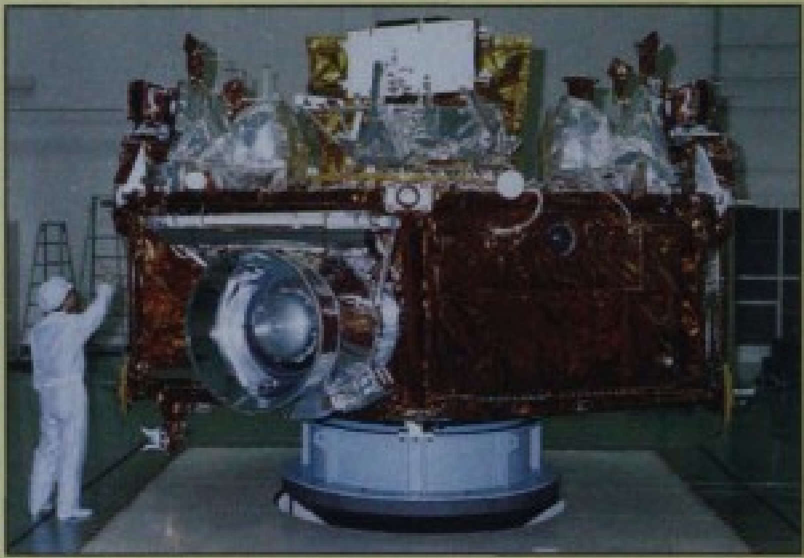
While the researchers have quantified Adhara's ability to ionize the Local Cloud, this alone cannot constrain the cloud's mass nor the ionization state of its principal constituents. Should the Local Cloud prove even more highly charged than the 15 to 19 percent Adhara can apparently provide, another antagonist — the passing shock wave from a recent, nearby supernova or the million-degree bubble surrounding the Local Cloud — must be responsible.

MISSION UPDATE

By Jonathan McDowell

Infrared Telescope in Space

The Infrared Telescope in Space (IRTS) was launched on March 18th aboard Japan's Space Flyer Unit. The 15-centimeter, liquid-helium-cooled telescope exceeded its three-week design life and surveyed more than 10 percent of the sky. A joint Japanese-American effort, the IRTS carries four photometric and spectroscopic instruments that operate at infrared and submillimeter wavelengths. Its targets include galactic molecular clouds, solar-system and interstellar dust, and the cosmic background radiation. The Space Flyer Unit was carried into orbit on the third flight of Japan's H-2 rocket and will be retrieved by the Space Shuttle *Atlantis* at the end of 1995.



The Infrared Telescope in Space (IRTS) peers from one side of Japan's Space Flyer Unit. A joint Japanese-American instrument, the IRTS surveyed solar-system dust, molecular clouds and the cosmic infrared background during its March–April flight. Courtesy H. Okuda and the Institute of Space and Astronautical Science.

International Extreme Ultraviolet Hitchhiker

The International Extreme Ultraviolet Hitchhiker (IEH) is due to make its first flight aboard the Space Shuttle *Endeavour* on mission STS-69 in July. IEH is a joint Italian-American experiment to be carried in *Endeavour*'s cargo bay as a secondary payload. It will make far- and extreme-ultraviolet observations with two telescopes. The Solar Extreme Ultraviolet Hitchhiker will measure the absolute intensity of radiation from the Sun, and the Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR) will obtain spatially resolved spectra at wavelengths from 500 to 1250 angstroms. One of UVSTAR's primary targets is the Io plasma torus, a cloud of ionized gas around Jupiter associated with the planet's volcanically active moon.

Spartan 201

In July *Endeavour* will also carry the Spartan 201 satellite, which will be released into free flight for two days and then recovered by the orbiter's robot arm. Observations from the tiny satellite, which carries an ultraviolet coronagraph supplied by the Smithsonian Astrophysical Observatory, will supplement studies of particles and fields in the region of the Sun's north pole being made from Europe's Ulysses space probe. Spartan 201 first flew in April 1993 and then again last September during Ulysses' south-polar pass.

VLBI Space Observatory Programme

The VLBI Space Observatory Programme (VSOP) spacecraft will be launched in 1996 by Japan's Institute of Space and Astronautical Science (ISAS). The 8-meter radio telescope will be placed in a 1,000-by-22,000-kilometer orbit using ISAS's new M-5 rocket. VSOP will be linked with a network of ground-based radio telescopes using the technique known as very long baseline interferometry (VLBI). The combined system will act like a single radio telescope much larger than the Earth and will map quasars with an unprecedented angular resolution of 90 microarcseconds. VSOP will observe at wavelengths of 1.4, 6, and 18 centimeters. There have been some earlier feasibility tests of space-based radio interferometry using NASA's Tracking and Data Relay Satellite as well as the KRT 10 telescope on the Soviet Union's Salyut 6 space station in 1979, but VSOP will be the first operational space VLBI observatory. A Russian counterpart, Radioastron, is also planned for later this decade.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

NEWS NOTES

No Anomalous Redshifts?

Do some galaxies and quasars display mysterious, "noncosmological" redshifts that have nothing to do with their distances or the expansion of the universe? For decades certain astronomers have argued that they do. The evidence: alleged associations between low- and high-redshift objects. Conventional interpretations say such objects must be at vastly different distances, merely projected on the same line of sight, and therefore unrelated to each other. If they are in fact related, unknown "weird physics" would be required to explain the anomalous redshifts (*S&T*: December 1994, page 32).

Other astronomers have concluded that the associations are just statistical flukes — merely what you would expect to turn up when sifting through large numbers of galaxies randomly scattered. But the dissenters remain skeptical.

Score another point now for the traditionalists. A study of 382 galaxies in 92 compact groups has found no evidence for anything but chance projections in the numbers, sizes, magnitudes, and morphological types of the 45 discordant-redshift galaxies that the groups appear to contain. The discordant galaxies were as small and faint as would be expected if their redshifts truly denoted distance. (A catalog of compact groups was reviewed on page 57 of the July issue.)

The study did turn up one twist, however. High-redshift galaxies are concentrated somewhat more strongly toward the centers of the groups than chance alone would predict. "One of the possible explanations for this discrepancy," writes Claudia Mendes de Oliveira (European Southern Observatory), "is that compact groups can act as gravitational lenses, causing the brightening of background galaxies that would otherwise fall below the magnitude cutoff of the group" (July issue, page 11).

In one group, Mendes de Oliveira was able to find the distances to the discordant pair NGC 4173 and 4175 independently of their redshifts. She used the Tully-Fisher method, which is based on the close relation between a spiral galaxy's absolute magnitude and its rotation velocity. Each of the two galaxies proved to be as far away as its redshift suggests. Her paper is in the March 1st *Monthly Notices* of the Royal Astronomical Society.

MISSION UPDATE

By Jonathan McDowell

Stratospheric Observatory for Infrared Astronomy

NASA hopes to begin work on the Stratospheric Observatory for Infrared Astronomy (SOFIA) next year, to replace the aging Kuiper Airborne Observatory by the turn of the century. SOFIA will carry a 2.5-meter telescope and its associated infrared instrumentation to a stratospheric altitude of 13 kilometers. Courtesy Jerry Plumb, NASA-Ames Research Center.

NASA's proposed 1996 budget, under review by Congress, includes funds to begin construction of SOFIA, the Stratospheric Observatory for Infrared Astronomy. This collaboration with the German space agency, DARA, features a modified Boeing 747 airplane carrying a 2.5-meter telescope. With its high spectral and angular resolution, SOFIA will complement the superior broadband sensitivity of orbiting infrared observatories. It will operate at an altitude of 13 kilometers, far higher than mountaintop observatories and above virtually all the atmosphere's infrared-opaque water vapor. The diffraction-limited telescope will provide the highest-resolution far-infrared images yet — better than 10 arcseconds at a wavelength of 100 microns. The telescope will observe in a wide spectral range from the near infrared to millimeter wavelengths. If approved, SOFIA will start flying around the year 2000. However, continued German participation is not assured if the program fails to get a go-ahead in fiscal 1996.

Granat

Russia's Granat observatory was launched in 1989 and made observations of hard X-ray sources with its French-built Sigma telescope. The satellite ran out of attitude-control propellant last September and is now carrying out an all-sky survey that takes advantage of its uncontrolled spin. Since the orientation of the spacecraft is unknown, making sky maps requires recognizing some previously cataloged sources, and the high scanning speed means that only the very brightest ones can be seen. Granat takes slightly over four days to circle the Earth; its highly eccentric orbit is gradually being circularized by gravitational perturbations from the Sun and Moon.

Clementine

The Naval Research Laboratory reestablished regular communications with its Clementine space probe this spring, almost a year after contact was lost. Launched in January 1994 to test out lightweight sensors, Clementine orbited the Moon from February to May 1994 (July issue, page 32). The spacecraft then returned to an eccentric orbit around the Earth until July, when it entered an orbit around the Sun. However, a programming error led to the unexpected loss of attitude-control propellant and the cancellation of a planned visit to the asteroid Geographos. Unable to point its solar-cell arrays toward the Sun, Clementine soon exhausted its batteries and slipped into an electronic coma. This spring, the probe's more favorable angle to the Sun partially recharged the batteries. NASA's Deep Space Network picked up Clementine's faint signals in February and regained full control on April 10th. What little fuel remained was dumped in an unsuccessful attempt to slow Clementine's departure from Earth. Further engineering tests are planned over the next few months. Clementine's current orbit around the Sun is similar to the Earth's, with a perihelion of 1.02 astronomical units and a period of 387 days.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

smooth out the universe's wrinkles.

John D. Barrow (University of Sussex, England) argues that, during the first 10^{-43} second after the Big Bang, gravity-transmitting particles called gravitons enjoyed close thermal contact with the rest of the primordial soup. In such an environment they would experience an even-handed division of energy, called equipartition, known to operate today in familiar systems like gases and semiconductors. Just as the fastest-moving particles in a room full of air are unlikely to sequester themselves in one unusually warm corner, gravitational thermodynamics would tend to drive the fledgling universe to appear roughly the same in all directions. Ironically, this opposes the contrast-enhancing role gravity has played during the cosmos's subsequent evolution.

Barrow's calculations, presented in the March 15th *Physical Review D*, do predict minuscule temperature differences in the microwave background at the tens-per-million level seen by the Cosmic Background Explorer satellite (*S&T:* October 1994, page 28).

As Alan H. Guth (MIT), one of inflation's early proponents, points out, Barrow's model *assumes* the universe's *homogeneity* (widely separated locations in space starting out the same) and invokes gravitational equipartition to explain its *isotropy* (all directions looking the same from a given point). Thus, while taking a first step around inflation, Barrow's provocative proposal has yet to account fully for the surprising smoothness of the early universe.

MISSION UPDATE

By Jonathan McDowell

Hubble Space Telescope

Planning for the second service call to the Hubble Space Telescope, shuttle mission STS-82, is well under way. In May NASA chose astronauts Mark C. Lee, Steven L. Smith, Gregory J. Harbaugh, and Joseph R. Tanner to be the flight's space walkers. A commander, pilot, and fifth mission specialist will be named soon. STS-82 is now scheduled for February 1997.

The space walkers hope to replace gyroscopes, tape recorders, and a fine-guidance sensor to ensure the telescope's continued good health. They'll also replace Hubble's first-generation spectrographs with two new instruments. The Near Infrared Camera and Multi-Object Spectrometer will take pictures and medium-resolution spectra at wavelengths from 0.8 to 2.5 microns. The Space Telescope Imaging Spectrograph has visible-light and ultraviolet detectors that will be used, along with an array of gratings, to dramatically improve upon Hubble's current spectrographic capabilities.

The Hubble Space Telescope drifts into the distance as Space Shuttle astronauts back away after completing extensive repairs in December 1993. A new team of space walkers is training for Hubble's second service call, due in February 1997. Courtesy NASA.

Submillimeter Wave Astronomy Satellite

The failure of a Pegasus winged booster on June 22nd has generated a serious backlog of small satellites waiting for their turn to fly. NASA's Submillimeter Wave Astronomy Satellite (SWAS) was originally scheduled for launch in June — or September at the latest — because it needed to record Jupiter as a calibration target. But recent tests show that its instruments are sensitive enough to use the fainter planet Saturn as a calibrator, extending SWAS's launch window to the beginning of December. Whether Pegasus will be requalified by then remains unclear. A description of SWAS and its payload appears on page 16 of the November 1994 issue.

SAC B

Argenfina is preparing its first astronomical satellite for launch in October, but it too could face a lengthy delay because of the Pegasus problems. SAC (Satelite de Aplicaciones Cientificas) B will carry three astronomical instruments. Argentina's Hard X-ray Spectrometer will study changes in the spectra of gamma-ray bursts and solar X-ray flares. NASA's Goddard X-ray Experiment will study softer (lower-energy) X-rays from the same sources, while a Pennsylvania State University instrument will map the X-ray sky to study the background radiation emanating from the galaxy and the universe.

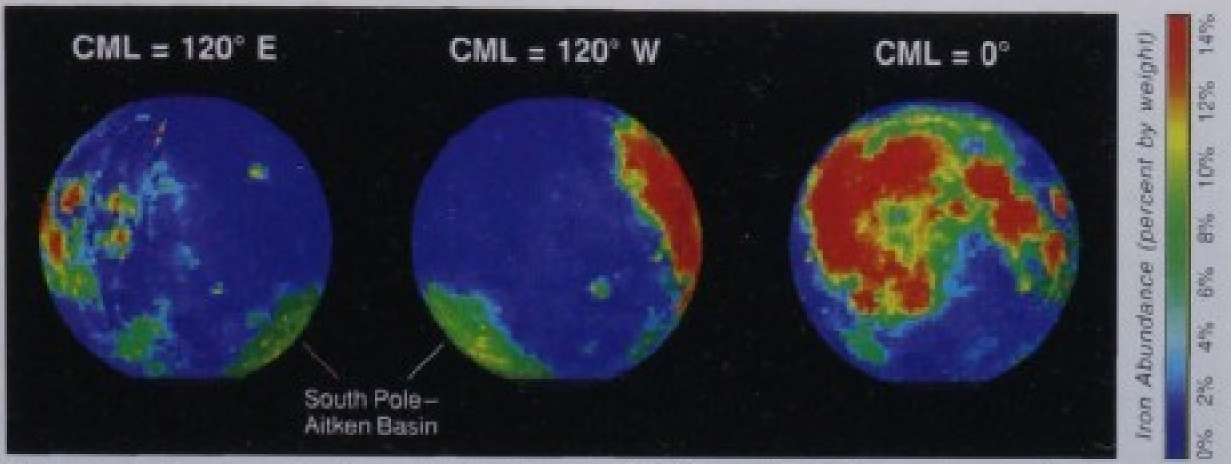
High Energy Transient Experiment

HETE is scheduled to share SAC B's ride to orbit on a Pegasus XL rocket. The goal of its three-year mission is to help identify the mysterious gamma-ray bursters. HETE carries a wide-field monitor to detect X-rays from gamma-ray burst sources, locating them to within 6 arcminutes on the sky. A coaligned camera will search for counterparts at ultraviolet wavelengths. It can detect flashes as faint as 7th magnitude over a 40° field, yielding positions good to a few arcseconds.

Mir

In June 1995 NASA astronaut Norman Thagard broke a 20-year American record for the longest stay in space. He logged 115 days in orbit — mostly aboard Mir — before returning to Earth on July 7th. The previous record of 84 days was set in February 1974 by three Skylab astronauts. But Thagard's endurance record has been eclipsed by more than 30 Russian and Soviet cosmonauts. The world record-holder is Valeriy Polyakov, who spent 437 days in space in 1994–95.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program.



Clementine's examination of the Moon at 7500 and 9500 angstroms in the near-infrared has yielded this map of iron abundance. Red areas on the near side (right) mark iron-enriched mare basalts. But large portions of the far side show little evidence for iron — a clue to the Moon's origin and early evolution. Each globe is labeled with its central-meridian longitude. Courtesy Paul Lucey.

be topped by a floating "scum" of silicate rocks devoid of iron. However, Clementine's own measurements of lunar gravity (July issue, page 33) contradict this notion of a "magma ocean," arguing instead for a spottier covering of molten rock.

One key compositional insight concerns the huge South Pole-Aitken Basin on the far side, an impact so large that it has probably excavated portions of the Moon's upper mantle. According to Lucey and his colleagues, the iron values inside the basin cluster near 10 percent, implying that the Moon's internal composition is unlike that of Earth's mantle (20 to 30 percent iron). Such a mismatch appears to rule out two other theories for the Moon's origin: that it formed along with the Earth, or that it tore away from an Earth spinning too fast to remain in one piece.

While the Clementine data lean toward forming the Moon via collision, a final verdict requires a more definitive gauge of iron content — the kind that will come from a gamma-ray spectrometer aboard the pending Lunar Prospector mission or, ideally, from more samples of the surface itself.

MISSION UPDATE

By Jonathan McDowell

Galileo

The Jupiter-bound Galileo spacecraft passed an important milestone at 5:30 Universal Time on July 13th, when the orbiter and atmospheric probe parted company. After verifying that the probe was in good working order, mission controllers commanded the orbiter to spin up from 3 to 10 revolutions per minute, sever an umbilical cable, and use springs to gently set the probe free. (As expected, this separation maneuver failed to shake open Galileo's main communication antenna, which has been stuck partway out since April 1991.)

The 339-kilogram probe, which has no propulsion system of its own, will remain dormant until just 6 hours before it penetrates the Jovian atmosphere about 6° north of the equator on December 7th. Accelerometers will then trigger the first transmissions of data from the probe's six instruments, which will be relayed to Earth via the orbiter. During its descent the probe will determine the physical and chemical properties of Jupiter's cloudy upper atmosphere. It should reach a pressure level of at least 20 bars before it succumbs to heat or pressure, its battery is exhausted, or the relay link to the orbiter ends.

Galileo was launched from the Space Shuttle in October 1989 and has flown past Venus, Earth (twice), and the asteroids Gaspra and Ida en route to its rendezvous with Jupiter.

Seen here before launch and without its heat shield, the 1.25-meter Galileo atmospheric probe will plow into Jupiter's cloudtops on December 7th. Courtesy NASA-Ames Research Center.

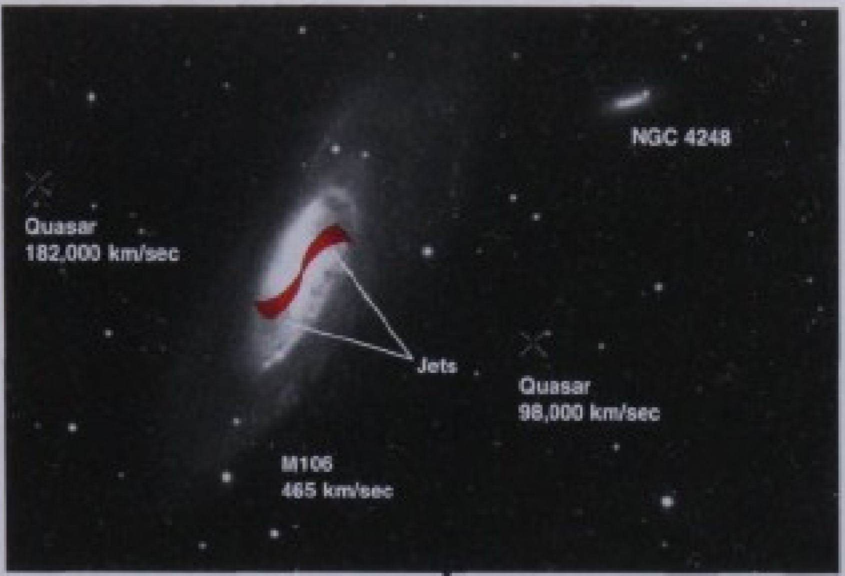
Ulysses

The European Space Agency's Ulysses spacecraft began the final phase of its primary mission in June as it arched more than 70° north of the Sun's equator to begin 110 days of intensive scrutiny of the solar north pole. It reached latitude 80.2 north on July 31st. The only operational problem aboard the probe as it completes its fifth year in space is a wobbling caused by thermal expansion and contraction of its experiment boom. This wobbling means that, when Ulysses is near perihelion, flight controllers need to contact the spacecraft continuously to keep its antenna pointed at Earth. A year ago Ulysses passed beneath the Sun's south pole and discovered that the solar wind blows twice as fast there as it does at the Sun's equator.

X-ray Timing Explorer

As this issue went to press the X-ray Timing Explorer (XTE) was at Cape Canaveral, Florida, awaiting an August 31st launch on a Delta 2 rocket. Developed at NASA's Goddard Space Flight Center, XTE will study rapid variability in celestial X-ray sources for two to five years in a 580-kilometer-high, low-inclination orbit.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (World Wide Web URL: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).



Cosmic coincidence? Crosses mark the locations of two 20th-magnitude quasars on opposite sides of the nucleus of the active galaxy M106. Their redshifts correspond to recession velocities far exceeding that of the galaxy. Martin C. Germano used a 14.5-inch f/5 reflector for this 100-minute exposure on hypered Kodak Technical Pan 2415 film. North is up.

June (I) *Astronomy & Astrophysics.*

Ties between high-redshift quasars and low-redshift galaxies, if proven, would undermine much of 20th-century cosmology. Most astronomers, however, consider it likelier that such arrangements are coincidental, given the numerous quasars and galaxies scattered on the sky. Galaxies also act as gravitational lenses, slightly heightening the visibility of very distant objects behind them. On the other hand, Burbidge notes that the cases where high-redshift quasars and low-redshift galaxies seem associated often involve active galaxies like M106 (seen at left).

MISSION UPDATE

By Jonathan McDowell

Galileo

After six years in space en route to Jupiter, the Galileo orbiter has fired its main engine for the first time. The spacecraft uses a German-built S400 liquid-propellant engine originally developed for geostationary communications satellites; these engines are normally fired only during the first few weeks of a satellite's life. On July 23rd, 10 days after the release of Galileo's atmospheric entry probe (see last month, page 16), ground controllers ordered a 2-second test firing to confirm that the systems were working. Then, on July 27th, the rocket ignited for 5.1 minutes and changed the orbiter's velocity by 220 kilometers per hour — enough to ensure that it will not accompany the probe in a suicidal plunge into Jupiter's atmosphere. Galileo will fly just 1,000 km from the moon Io before another engine burn on December 8th eases the craft into orbit around the giant planet.

The Galileo spacecraft is shown undergoing prelaunch tests before its October 1989 departure for Jupiter. Courtesy NASA-Jet Propulsion Laboratory.

Cassini

The recently released environmental impact statement for the Cassini Saturn orbiter claims that there is less than one chance in a million that onboard failures will lead to accidental reentry of the spacecraft during its August 1999 gravity-assisted flyby of Earth. This danger largely results from the risk that Perseid meteoroids will disable the propulsion system during the encounter. In contrast, the chance that Cassini will be lost during its launch in October 1997 because of a failure in its Titan-Centaur rocket is a comparatively huge 5 percent. NASA believes that even in that case there is only a one in 500 chance that any of the radioactive material in the probe's thermoelectric generators will be released.

In the first few years after launch, Cassini will fly past Venus (twice), Earth, and then Jupiter to pick up speed. Five months after arriving at Saturn in July 2004 for its 4-year-long survey mission, the orbiter will dispatch the European Space Agency's Huygens probe to the surface of the moon Titan.

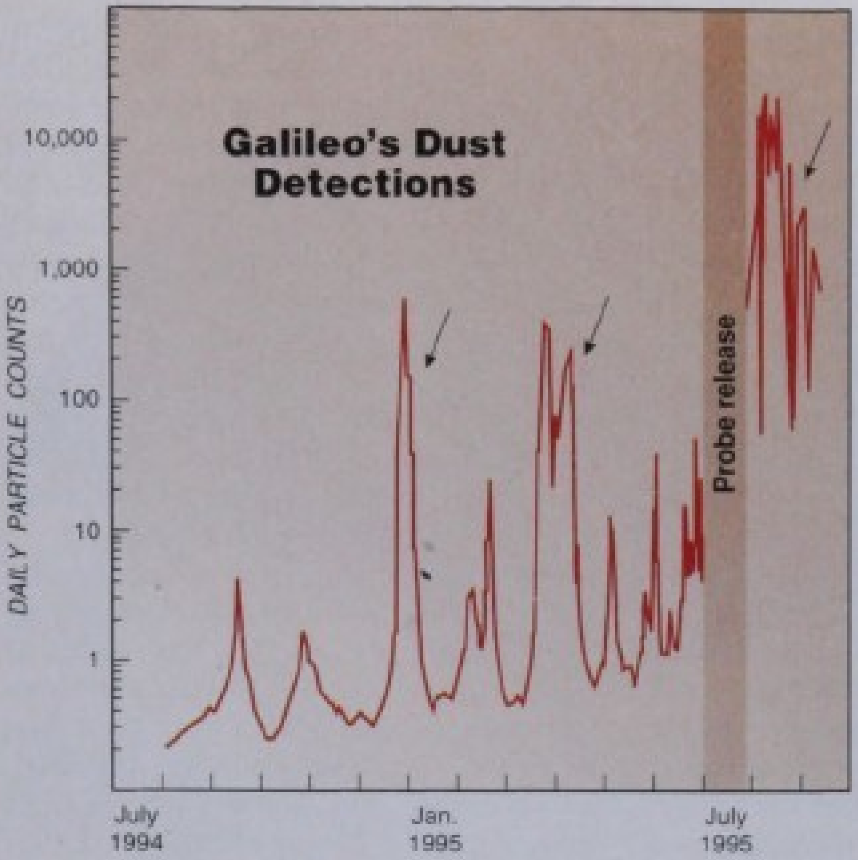
Compton Gamma Ray Observatory

The Compton Observatory began its fifth year in space in April. The Burst and Transient Source Experiment team recently released its third catalog of gamma-ray bursts, which contains data on more than 1,100 events detected through September 1994. Astronomers are eagerly sifting through it for clues to the origin of the mysterious bursts. Compton's other three instruments continue to operate well, though the Energetic Gamma Ray Experiment Telescope is running low on spark-chamber gas and will henceforth operate in a restricted mode.

SURFSAT

As this issue went to press, an unusual student-built satellite was scheduled for launch in September from Vandenberg Air Force Base in California. SURFSAT will carry low-power radio beacons that will simulate a distant planetary probe to test new high-frequency communications technology for NASA's Deep Space Network. SURFSAT also carries two transponders to test the very long baseline interferometry stations that will be used during the Japanese VSOP and Russian Radioastron space-based radio-astronomy missions. The payload consists of two boxes attached to the second stage of a Delta rocket that will be used to loft a Canadian remote-sensing satellite. SURFSAT was developed by students from a dozen colleges, primarily participants in Caltech's Summer Undergraduate Research Fellowship program.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.



A detector on the Galileo orbiter has recorded three long-lasting "storms" of dust particles within the last year (arrows). The spacecraft first noticed an increasing particle count in June 1994, when it was about 250 million kilometers from Jupiter. The vertical band represents the three-week period when Galileo's probe was released and the detector's data could not be relayed to Earth. Courtesy Eberhard Grün and Rainer Riemann.

the Jovian magnetosphere and become true "charged particles," while larger ones are affected less by magnetic forces and never reach escape velocity.

In turn, Douglas P. Hamilton and Joseph A. Burns (Cornell University) countered that the outer section of Jupiter's tenuous ring is a more likely source of microscopic dust, as it offers a better match to the ejection speeds deduced from Ulysses' data.

Comet Shoemaker-Levy 9 can't be ruled out either, Grün says, though coinvestigator Rainer Riemann (MPI) points out that the first — and strongest — detections by Ulysses occurred before the comet broke up.

The particles' high velocities have tipped opinion in favor of Io as the source. But the other two have not been ruled out, and a full explanation will have to wait until Galileo reaches Jupiter.

MISSION UPDATE

By Jonathan McDowell

A Very Busy Launch Schedule

Beginning in early November and for several months thereafter, a flurry of large- and medium-size space-astronomy missions are due to get under way.

First up is the European Space Agency's (ESA's) **Infrared Space Observatory,** one of the most significant missions of the mid-1990s. ISO will be the first major infrared observatory in space since the Infrared Astronomical Satellite (IRAS) flew in 1983. Although ISO's 0.6-meter telescope is no larger than IRAS's, the new spacecraft's detectors are more sensitive and have larger fields of view. Thus astronomers expect ISO to produce significant advances in our understanding of star-forming regions, galaxies, quasars, and the center of the Milky Way. ISO will be launched on an Ariane 4 rocket from French Guiana into an unusual elliptical synchronous orbit that ranges from 1,000 to 70,000 kilometers in altitude.

The Solar and Heliospheric Observatory, SOHO, is about to begin its exploration of the Sun and its effects on the Earth's electromagnetic environment. Courtesy the European Space Agency.

ISO will be followed by NASA's **X-ray Timing Explorer,** set for launch from Cape Canaveral atop a Delta rocket. XTE will study rapid time variations in bright X-ray sources.

Hard on XTE's heels comes the **Solar and Heliospheric Observatory,** a joint ESA-NASA project to study the Sun and the solar wind. After launch on an Atlas rocket, SOHO will be positioned in solar orbit some 1,000,000 km from Earth in the direction of the Sun. At this so-called L_1 Lagrangian point, the gravity of the Sun and Earth almost balance, allowing SOHO to maintain its position with minimal fuel expenditure.

Four more European scientific satellites to be launched in early 1996 constitute the **Cluster** project. This quartet will monitor energetic particles and electric and magnetic fields in the Earth's magnetosphere. The satellites will be placed in highly elliptical orbits during the first test flight of Europe's giant Ariane 5 rocket.

Three small astronomical payloads that were stranded on the ground by problems with the Pegasus XL air-launched rocket should also reach orbit soon. Orbital Sciences Corp. traced its winged booster's June 1995 failure to human error. Assembly workers installed a connecting ring between two stages in the wrong position, preventing the second stage from operating correctly. If all goes well with the planned mid-October Pegasus launch of a U.S. Air Force satellite, NASA will move to dispatch in rapid succession the **Submillimeter Wave Astronomy Satellite** and **High Energy Transient Experiment.** Argentina's first X-ray astronomy satellite, **SAC B,** will ride into space on the same Pegasus as HETE (September issue, page 16).

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (available on the World Wide Web at http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

MISSION UPDATE

By Jonathan McDowell

This month's expanded column looks at the science launches planned for the coming year. For up-to-date information as 1996 marches on, consult this column monthly and visit each mission's World Wide Web home page. Active links to these and other missions can be found on SKY Online at http://www.skypub.com.

Human Space Flight

Following its historic first docking with **Mir** last June and the planned delivery of a special docking module in November, Space Shuttle *Atlantis* is scheduled to link up with Mir a third time in March. Aboard will be astronaut Shannon Lucid, who will begin a long-duration stay aboard the Russian space station. Two more 1996 flights by *Atlantis* will replace Lucid by Jerry Linenger and then Linenger by John Blaha. Meanwhile, crews of two Russian cosmonauts will be stationed on Mir, being replaced on Soyuz flights in the spring and winter. This year should also see the launch of the **Priroda** ("Nature") Earth-observing module to complete the Mir complex.

Space Science

In February the **Tethered Satellite System** will get its second shuttle flight. On its first mission in 1992 the tether snagged partway out. If it reaches its full length of 20 kilometers this time, TSS will usher in a new era in upper-atmospheric studies.

In April the European Space Agency's **Cluster** quartet will be launched on the first Ariane 5 heavy-lift booster (December issue, page 16). The satellites will monitor particles and fields in near-Earth space. The **Fast Auroral Snapshot Explorer** should ride a Pegasus XL rocket into orbit in the summer. FAST was originally scheduled for launch in 1994, but problems with the small, winged booster delayed it.

Astronomy

As 1996 dawns the European Space Agency's **Infrared Space Observatory** (ISO) and NASA's **X-ray Timing Explorer** (XTE) should both be spaceborne.

Japan's **VLBI Space Observatory Programme** (VSOP) will inaugurate the age of practical space-based radio astronomy after the launch of the MUSES B satellite on the first flight of Japan's new M-5 rocket.

Argentina's **SAC B** X-ray astronomy satellite and the U.S. **High Energy Transient Experiment** (HETE) are scheduled to be launched by a single Pegasus XL in February.

The **Submillimeter Wave Astronomy Satellite** (pictured at right) is due for launch later in 1996 on yet another Pegasus XL. SWAS will study emissions from cool gas and dust in the galaxy, as well as the chemistry of molecules in star-forming regions.

Shuttle mission STS-80 in late 1996 will deploy the **SPARTAN 201** free-flying solar observatory on its fourth mission. It will help calibrate the **Solar and Heliospheric Observatory** (SOHO), which was due for launch in late 1995. STS-80 will also carry the **ORFEUS-SPAS** ultraviolet spectrometer on its second flight to study the interstellar medium.

The Submillimeter Wave Astronomy Satellite undergoes a preflight checkout in anticipation of its 1996 launch on a Pegasus XL winged rocket. Courtesy NASA.

If NASA's Mars Pathfinder successfully lands on the red planet next year after its planned late-1996 launch, it will deploy the Sojourner microrover to study Martian rocks and soil. Courtesy the Jet Propulsion Laboratory.

Planetary Exploration

This year is a crucial one for the future of planetary exploration. Assuming its arrival at Jupiter goes as planned in December of 1995, **Galileo** will spend all of 1996 looping past the Galilean moons. (Last October scientists were relieved to find that the orbiter's tape recorder was not broken as feared. An earlier glitch was caused by a weak section of tape that has now been safely wound onto its take-up reel, where it will stay.)

First up among new launches is the **Near Earth Asteroid Rendezvous** (NEAR), to be launched on a Delta rocket in February into solar orbit en route to a rendezvous with minor planet 433 Eros in January 1999.

NASA's **Mars Pathfinder** (MPF) and **Mars Global Surveyor** (MGS) will depart for the red planet in November. Pathfinder will deliver a lander to the Martian surface in July 1997. The lander will deploy a robotic microrover called **Sojourner** (pictured at left) to explore the Ares Vallis landing area. MGS carries backup Mars Observer instruments. After entering Martian orbit in August 1997, it will use aerobraking to lower its altitude and then map the planet from pole to pole with a camera and spectrometer.

Finally Russia's **Mars 96,** an orbiter and two landers, will depart in mid-November on a Proton rocket for arrival at Mars in October 1997.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (World Wide Web URL: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

set a precedent many astronomers find unpalatable. In addition, wide-field imaging and photographic surveys would have to contend with a new artificial satellite outshining the many already in orbit.

For his part, Razavi hopes that the artificial stars will generate interest in space as well as funding for educational activities. Although launch could occur by the end of 1996, the $20 million required to finance the project is still being sought.

Milestones

• The International Astronomical Union's Minor Planet Center has honored George Lovi, *Sky & Telescope*'s former Rambling Through the Skies columnist, by naming a minor planet after him. Lovi died in 1993 (*S&T:* August 1993, page 59). The object now known as **5943 Lovi** was discovered by Edward Bowell at Lowell Observatory in 1984. An inner-belt asteroid on a moderately eccentric orbit, 5943 Lovi is 5 to 10 kilometers across.

• **Pioneer 11,** which left Earth on April 5, 1973, saw its scientific mission come to an end last September 30th. Pioneer 11 visited Jupiter and Saturn, discovering the latter planet's F and G rings in 1979. Now 44 astronomical units (6.6 billion kilometers) distant, the craft will be tracked occasionally for engineering purposes.

• The six Sun-tracking stations of the **Global Oscillation Network Group (GONG)** began working as a unit last October 5th. GONG's mission is to monitor soundwavelike oscillations on the Sun's surface that enable physicists to probe physical conditions in the solar interior.

• **Gérard de Vaucouleurs** died last October in Austin, Texas, at the age of 77. A long-time student of galaxy properties and distances, de Vaucouleurs was perhaps best known for providing evidence for a rapidly expanding, and hence very young, universe. He also created an alternative to Edwin Hubble's galaxy classification system and coauthored the encyclopedic *Reference Catalogue of Bright Galaxies* with his first wife and collaborator, Antoinette. De Vaucouleurs taught at the University of Texas until his retirement in 1988.

MISSION UPDATE

By Jonathan McDowell

Mars Surveyor 1998

NASA has selected the instruments for two robotic missions to Mars scheduled for launch in 1998 and 1999. The Mars Surveyor '98 orbiter will essentially be a weather satellite for the red planet. It will carry a 1-kilogram imaging system containing one camera for capturing wide-angle views and another for scrutinizing surface details as small as 40 meters. The orbiter will look for seasonal and weather-related changes in the planet's atmosphere and on its surface. An infrared radiometer will track the temperature and humidity of the Martian atmosphere.

As the next stage in its exploration of Mars, NASA plans to launch the Mars Surveyor '98 orbiter and lander in 1998 and 1999, respectively. Courtesy Lockheed-Martin Astronautics.

The Mars Surveyor '98 lander will be the first probe to land in the icy Martian polar regions. It will take pictures of the surface as it descends toward the south polar cap. After touchdown, the 250-kilogram lander will deploy a package of stereo cameras and weather sensors, as well as a soil analyzer to study samples dug up by a small robotic arm. NASA managers have also invited the Russian Space Agency to supply an instrument, perhaps an atmospheric dust analyzer or a device to make soundings of subsurface structure.

Midcourse Space Experiment

Scheduled for a March launch into polar orbit aboard a Delta rocket, the Ballistic Missile Defense Organization's Midcourse Space Experiment (MSX) will use a 34-centimeter infrared telescope and an ultraviolet imager to track missiles and satellites and to measure the background radiation from the Earth. Scientists at the Air Force Phillips Laboratory and Johns Hopkins University will also use MSX to make an infrared map of the galactic center with 20-arcsecond resolution and to search for the postulated ultraviolet background from decaying neutrinos. MSX's telescope is unusual in that it is cooled with frozen hydrogen at 8.5° Kelvin, instead of the liquid helium used by previous cryogenic telescopes.

International Ultraviolet Explorer

Last September 30th NASA transferred all science operations for the International Ultraviolet Explorer (IUE) to the European Space Agency (ESA). For more than 17 years, control of the spacecraft was exchanged daily across the Atlantic, with ESA's Vilspa ground station near Madrid in charge for 8 hours and NASA's Goddard Space Flight Center in Maryland in command for the other 16. IUE is in an elliptical, geosynchronous (24-hour) orbit inclined 35° to the equator and drifts back and forth in longitude across the Atlantic. The orbit was recently adjusted so that the spacecraft remains permanently visible from Vilspa. IUE's 45-cm telescope continues to return ultraviolet spectra of comets, stars, quasars, and other objects.

SURFSAT 1

The SURFSAT 1 test satellite (*S&T:* November 1995, page 16) rode into orbit on November 4th. Built largely by participants in Caltech's Summer Undergraduate Research Fellowship (SURF) program, SURFSAT 1 is designed to simulate transmissions from a deep-space probe, allowing NASA to understand the effects of atmospheric distortions on the upgraded Deep Space Network. SURFSAT 1 will also test key communication links for the forthcoming Japanese VSOP radio-astronomy satellite.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

In Brief

• **Bernard M. (Barney) Oliver,** a renowned engineer and astronomy enthusiast, died of heart failure on November 23, 1995. He was 79. Oliver directed research at Hewlett-Packard Co. for decades and is perhaps best known for his role in developing HP's hand-held calculators during the early 1970s. But he was also a devoted student of astronomy and a longtime supporter of the search for extraterrestrial intelligence (SETI). At his death he was a senior scientist and board member at the SETI Institute in Mountain View, California.

• Observations by George Gliba, Hiroshi Koyama, and others reveal that **Nova Cassiopeiae,** discovered by Japan's Minoru Yamamoto last July, brightened further late last year. The nova hovered around 9th magnitude through October and early November, rose to magnitude 8 in late November, and reached visual magnitude 7.2 in an outburst between December 4th and 15th. Equinox 2000 coordinates for the nova are right ascension $1^h\ 05^m\ 05^s$, declination 54° 00′ 40″.

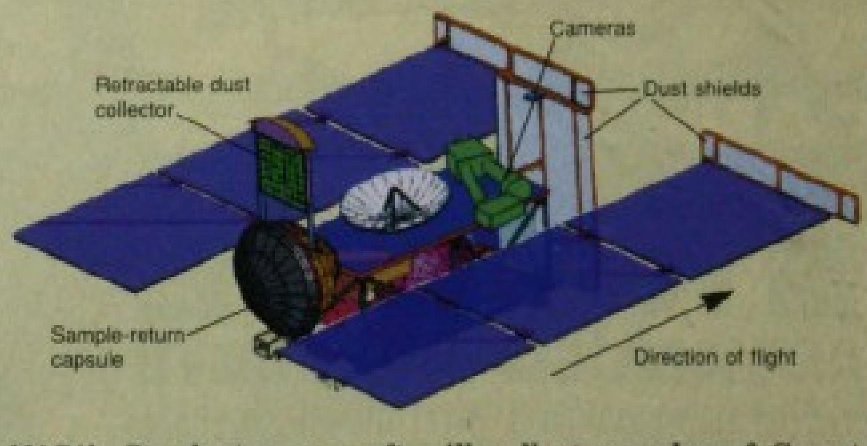
• The **most massive white dwarf** known has been discovered by an international team led by Martin Barstow (University of Leicester, England). As reported in the *Monthly Notices* of the Royal Astronomical Society for December 1, 1995, the object, designated as RE J0317–853, turned up in a search with an ultraviolet detector aboard the Rosat satellite. At 1.35 Suns, the white dwarf's mass lies tantalizingly close to the Chandrasekhar limit (1.4 Suns) past which gravity forces such objects to collapse into far denser neutron stars.

• Last October 30th Harvard physicist Paul Horowitz and his principal sponsor, the Planetary Society, upgraded their equipment for seeking alien radio beacons. The new effort, called **Project BETA** (*B*illion-channel *E*xtra*t*errestrial *A*ssay), uses a surplus 26-meter radio dish and sophisticated electronics to monitor 250 million frequencies at which interstellar communication is presumed to be most likely (*S&T:* February 1988, page 142). From its Harvard, Massachusetts, site Project BETA can cover about 75 percent of the sky. It supersedes Project META, which scanned 8.4 million channels for 10 years without detecting any obvious extraterrestrial transmissions.

MISSION UPDATE By Jonathan McDowell

Stardust

As NASA's fourth Discovery mission, the space agency has selected a plan to collect dust from Periodic Comet Wild 2. The Stardust spacecraft is slated for a February 1999 launch into a heliocentric orbit, returning to Earth for a gravity-assist flyby 23 months later. It will then encounter the comet in December 2003, snapping images while racing past at 6 km per second and coming within 100 km of the nucleus. Stardust will scoop up dust grains from Wild 2's coma, trapping and preserving the tiny particles in a material called silica aerogel. In January 2006 the spacecraft will again swing past Earth, ejecting a capsule bearing the precious cargo of cometary and interplanetary dust for a planned landing in Utah. Stardust's science team, led by Donald Brownlee (University of Washington), chose 81P/Wild 2 because it is a relatively fresh comet with a 6.4-year period. The comet first entered the inner solar system in 1974 after being deflected by the gravity of Jupiter. Its perihelion (closest approach to the Sun) now lies just inside the orbit of Mars.



NASA's Stardust spacecraft will collect samples of Comet Wild 2 and return them to Earth in the year 2006. Courtesy the Jet Propulsion Laboratory.

X-ray Timing Explorer

NASA's X-ray Timing Explorer seemed a reluctant space traveler at the end of last year. The satellite's launch was originally scheduled for the summer of 1995, but problems with another mission's Delta rocket delayed it until the beginning of December. Then followed a long battle with the weather at Cape Canaveral, Florida. Finally a "go" was given on December 18th, only to result in a dramatic on-pad shutdown when the main engine failed to ignite. A liquid-oxygen valve stuck closed, preventing oxidizer from reaching the engine. XTE was finally launched on December 30th. The satellite will track rapidly varying X-ray emissions from black-hole candidates, active galactic nuclei, and other high-energy sources (*S&T:* March 1995, page 16).

Near Earth Asteroid Rendezvous

The Near Earth Asteroid Rendezvous spacecraft arrived at Cape Canaveral on December 6th in preparation for launch in the second half of February. NEAR will become the first probe to rendezvous with an asteroid when it loops around 433 Eros in February 1999 (*S&T:* April 1994, page 16). Built by the Johns Hopkins Applied Physics Laboratory, NEAR is the first of NASA's new Discovery planetary missions (*S&T:* September 1995, page 6). It will use an Earth flyby in January 1998 to alter its orbit for the Eros approach. NEAR should remain in the vicinity of the 40-kilometer-wide asteroid for at least a year, eventually closing to within 35 km of its surface. The Discovery series will continue with Mars Pathfinder (*S&T:* April 1995, page 15), Lunar Prospector (*S&T:* June 1995, page 16), and Stardust.

Konus A

The Russian military satellite Kosmos 2326 was launched on December 20th by a Tsiklon rocket from the Baikonur spaceport in Kazakhstan. The satellite carries a secondary astronomical payload, Konus A, developed by the Ioffe Institute of St. Petersburg. Konus A is a gamma-ray burst detector and spectrometer similar to experiments carried on Soviet Venus probes and the Granat X-ray astronomy satellite during the 1970s and 1980s.

McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes an on-line newsletter on the space program: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html

Dunham (International Occultation Timing Association) and Alan D. Fiala (U.S. Naval Observatory). They have studied solar-limb data derived from eight solar eclipses (both total and annular) between October 1976 and September 1987. As Dunham told *Sky & Telescope*, "Preliminary analysis indicates a variation in the Sun's size possibly synchronized with the period of the sunspot cycle, but more research is needed to be certain." By analyzing timings of Baily's Beads from the edges of the eclipses' tracks, Dunham and Fiala found a 0.1-arcsecond variation in solar radius.

In Brief

• An international search for **supernovae billions of light-years away** has located eleven such beacons, four of which lie at record-setting distances. Saul Perlmutter (Lawrence Berkeley Laboratory) and his colleagues caught the extragalactic explosions with the 4-meter reflector on Chile's Cerro Tololo. As noted in IAU *Circular* 6270, the farthest of the bunch — with a redshift of 0.65 — was caught in Pisces at magnitude 22.7 shortly before reaching peak brightness. These supernovae will augment the database for determining the rate at which the universe's expansion is slowing down (January issue, page 27).

• A high-resolution spectroscopic study has pegged **Omega Centauri** as the most massive globular cluster known. At magnitude 3.6, the sky's brightest globular now appears to have the mass of 5.1 million Suns. This estimate, given by European astronomers in the November (III) 1995 *Astronomy and Astrophysics*, was derived by measuring the line-of-sight speeds of stars within a few arcminutes of the cluster's core. The data were obtained with the Danish 1.5-meter reflector at La Silla, Chile.

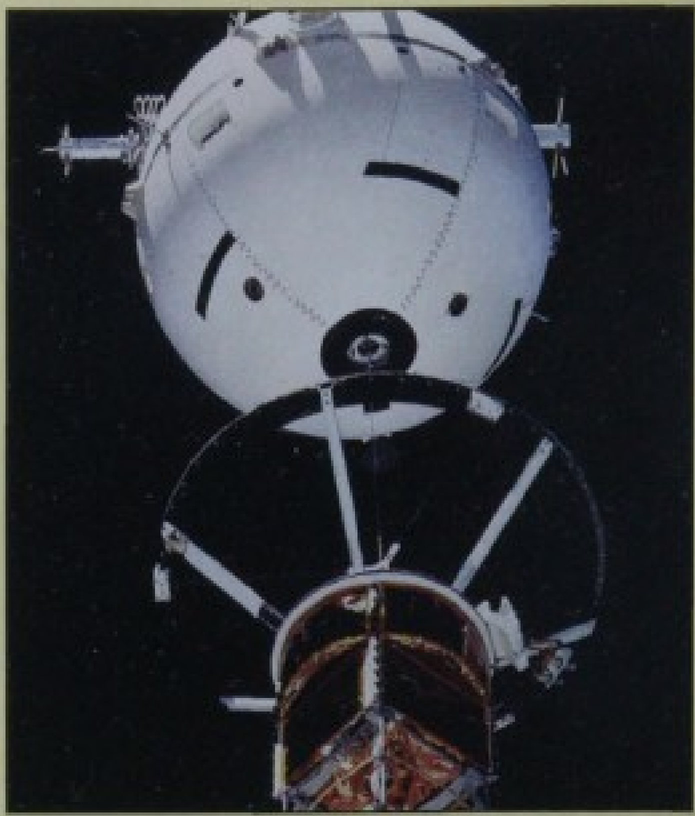
• **Margaret W. Mayall,** head of the American Association of Variable Star Observers from 1949 to 1973, died December 6, 1995, at age 93. In the mid-1950s, when the AAVSO was asked to sever its direct association with Harvard Observatory, she guided the organization's transition to viable independence. An expert on spectral classification, Mayall was involved in the editing and authoring of numerous popular books and articles about astronomy.

MISSION UPDATE

By Jonathan McDowell

Tethered Satellite System

The Tethered Satellite System, scheduled for deployment in February from the Space Shuttle *Columbia*, continues a joint American-Italian project to study the orbital dynamics of a 20-kilometer-long, electrically conducting tether. The Kevlar line takes 6 hours to unreel to its full length. A small satellite on its end is to measure electromagnetic effects during two days of experiments before astronauts rewind everything back into the cargo bay. On the first TSS mission in 1992 the tether snagged on a bolt after unwinding only 260 meters.



The Tethered Satellite System hit a snag during its deployment on a mid-1992 Space Shuttle mission. Astronauts were to give it another try during *Columbia*'s 19th flight, scheduled for February. Courtesy NASA.

Infrared Space Observatory

Following its launch last November, the European Space Agency's ISO spacecraft is completing its in-orbit checkout with flying colors (February issue, page 11). All four instruments have been sending back data; the only significant problem reported so far is that the Long Wavelength Spectrometer's sensitivity may be affected by an unexpectedly large number of cosmic-ray-induced glitches. ISO's detectors are used for 16 hours each day as the spacecraft swings out to 70,000 km from Earth; they must be shut down during each perigee pass through the Van Allen radiation belts.

X-ray Timing Explorer

As reported last month (page 17), the XTE satellite reached orbit on December 30th. By the first week of January its two main instruments had made their first observations of X-ray sources, including a pulsar, the Crab Nebula, and a Seyfert galaxy. The All Sky Monitor, however, was temporarily turned off to analyze problems with two of its three detectors.

Solar and Heliospheric Observatory

The European SOHO satellite trimmed its orbit with several rocket firings on January 5th, when 1.4 million km from Earth, and arced away from the Earth-Sun line. The spacecraft was due to reach its maximum deviation at the beginning of February before falling back toward the L_1 Lagrangian point to enter a "halo" orbit in mid-March. Meanwhile flight controllers worked to check out SOHO's scientific instruments. They took their first helioseismological Doppler image on December 20th. This was followed by their first coronagraphic and extreme ultraviolet images of the Sun.

Pioneer 6

The world's oldest working spacecraft, Pioneer 6, completed 30 years in solar orbit last December. In the late 1960s Pioneers 6 through 9 returned information on the solar wind, and during the Apollo Moon landings they provided hourly reports on the dangers posed to astronauts by solar flares. NASA's Deep Space Network still checks in with Pioneer 6 every few months to verify that it's in good working order.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

Resolving Red Giants

In recent years optical astronomers have routinely resolved the disks of giant stars, thanks to improvements in interferometric imaging (*S&T:* October 1991, page 361; January 1992, page 29). Now Chris A. Haniff (University of Cambridge), Michael Scholz (University of Heidelberg), and Peter G. Tuthill (University of California, Berkeley) have painted a revealing picture of how these stars actually look.

In addition to reviewing other recent imagery, the team tracked the diameters of 10 Mira-type variables over a two-year period. They did so by using an aperture mask to divide the William Herschel Telescope's 4.2-meter mirror into separate zones. They then analyzed the resulting interference patterns with mathematical methods originally developed for radio interferometers such as the Very Large Array.

Unlike main-sequence stars such as the Sun, which are round and sharp-edged, giants are fuzzy. Their edges are gradually dimmed by increasingly pronounced limb darkening. Moreover, the largest, coolest ones, including red supergiants and Mira-type variables, are proving to be lumpy, irregular gasbags that squirm and puff.

As the astronomers note in the September 15, 1995, *Monthly Notices* of the Royal Astronomical Society, many Miras become elongated at times. Take R Cassiopeiae, for example. The enigmatic star has swelled by as much as a third more in one dimension than in another. This ellipticity changes in orientation as well as in degree. Miras also display smaller, more complicated changes in shape and brightness.

The photospheres, or light-emitting surfaces, of the 10 Miras that Haniff's team studied were all at least 1.8 astronomical units in radius — large enough to encompass the orbit of Mars. As it happens, theory shows that Miras this large that have 1 to 1.5 times the Sun's mass cannot pulse in the simplest, fundamental mode. Rather, they engage in *first-overtone* pulsations, wherein the star's inner and outer halves together approach, then recede from, an intermediate zone. Such behavior has been seen in Cepheid variables (*S&T:* October 1994, page 14). At the same time, other astronomers describe evidence that these complex stars do in fact pulse in the fundamental mode.

MISSION UPDATE

By Jonathan McDowell

Hubble Space Telescope

Preparations are intensifying for the February 1997 Space Shuttle mission to service the orbiting Hubble telescope (*S&T:* September 1995, page 16). Highlights of this visit will include installation of two new instruments, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) and the Space Telescope Imaging Spectrograph (STIS). Looking ahead to the third servicing in 1999, NASA has decided to replace Hubble's solar-cell panels again. The flexible blankets installed in December 1993, while expected to last until the year 2002, continue to plague the spacecraft with unwanted vibrations. So in November 1999, if the current schedule holds, astronauts will swap them for rigid panels like those used on some communication satellites. Meanwhile Hubble science operations continue normally, except that one of the satellite's three tape recorders got stuck and had to be turned off. New solid-state recorders will be ferried to Hubble next year along with STIS and NICMOS.

During its December 1993 servicing by shuttle astronauts, the Hubble Space Telescope received the new pair of solar-cell "wings" shown above. These flexible blankets will in turn be replaced by rigid panels during the shuttle visit now planned for 1999. Courtesy NASA.

Near Earth Asteroid Rendezvous

The NEAR space probe was launched on February 17th from Cape Canaveral, Florida. A three-stage Delta rocket sent NEAR out toward the main asteroid belt, where it will fly past minor planet 253 Mathilde in June 1997. It will then swing back in and graze the Earth only 500 kilometers above the surface, using our planet's gravity to put it in an orbit matching that of the near-Earth asteroid 433 Eros. After entering orbit around Eros in February 1999, the box-shaped craft will take pictures, measure magnetic fields, and use an X-ray spectrometer to determine the elemental composition of the asteroid's surface.

Satellite per Astronomia X

Scheduled for launch in late April by an Atlas-Centaur rocket from Cape Canaveral, SAX is Italy's first X-ray astronomy satellite. Its telescope has 30 nested mirrors that can make images with 1-arcminute resolution at energies between 100 and 10,000 electron volts. This covers both the "soft" (low-energy) X-ray range seen by Rosat and the "harder" range observed by ASCA (see below). The satellite also carries detectors to monitor higher-energy X-rays within a 1° field around the target. These will enable astronomers to simultaneously study the full spectrum of X-ray emissions from cosmic sources for the first time.

Advanced Satellite for Cosmology and Astrophysics

Japan's ASCA X-ray astronomy satellite began its fourth year of observations in February. It continues to operate well, but, as expected, the cumulative effect of multiple daily passages through the Van Allen radiation belts has damaged the CCD imagers. Such damage is minimized by using only one of the four chips at a time at the expense of limiting observations to a smaller field of view. Targets for February 1996 included the nearest star system, Alpha Centauri; quasar 3C 279, which recently flared; and supernova remnant SNR 1006, where ASCA recently discovered evidence for cosmic-ray acceleration.

McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (available on the World Wide Web at http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

physics) reports in the January 20th *Astrophysical Journal*, our galaxy contains 490 ± 110 billion Suns' worth of mass within 160,000 light-years of its core.

In Brief

• **Quarks** may not be the indivisible building blocks of nuclear matter after all. Fermilab physicists have analyzed the debris created when protons and antiprotons are forced into high-speed head-on collisions. And, as Frank Wilszek (Institute for Advanced Study) discusses in *Nature* for March 7th, doing so has revealed a subtle excess in the highest-energy debris particles. This excess may be evidence that quarks are built of yet-smaller pieces, just as protons and neutrons are built of quarks, and atomic nuclei, in turn, are built of protons and neutrons. However, several more sedate explanations are also viable: the interactions between quarks may be incompletely understood, or there may be an unknown "vector boson" affecting the shortest-range forces between neutrons and protons (*S&T:* December 1987, page 582).

• **Geminga's parallax** has been measured with the Hubble Space Telescope. As Patrizia A. Caraveo (Institute of Cosmic Physics, Milan, Italy) and her colleagues report in the *Astrophysical Journal Letters* for April 20th, the enigmatic gamma-ray pulsar had already been known to evince a high proper motion. But its newly measured parallax — the first determined for a neutron star at visible wavelengths — has pinned down the object's distance at 510 light-years, give or take 30 percent. This will enable scientists to determine Geminga's absolute luminosity, testing theories for neutron-star emission mechanisms in the process.

• **Ohio State University's "Big Ear"** radio telescope will be shut down by the end of next year. Utilizing a rectangular reflector larger than three football fields, the huge instrument has been used to conduct the longest-running search for extraterrestrial radio transmissions. But the facility rests on land currently slated for residential development and a golf course. The Big Ear's designer, John D. Kraus, notes that its pioneering 1970s sky survey discovered thousands of sources, including many high-redshift galaxies and quasars. A similar survey now under way should be completed before the telescope is decommissioned.

MISSION UPDATE

By Jonathan McDowell

Tethered Satellite System

The second attempt to fly the shuttle-based Tethered Satellite System ended in debacle on February 25th when the 20-kilometer-long tether snapped just before reaching its full length. Nevertheless, the joint NASA-Italian Space Agency experiment achieved its main objective: proving that space tethers can generate electricity. The shoelace-thin cord carried a half ampere of current and a potential of several thousand volts as it sliced through Earth's magnetic field at an altitude of 295 km. The experiment also inadvertently demonstrated the ability to launch a satellite into a higher orbit without using rocket fuel. When the line broke, the satellite and tether recoiled into an orbit with an apogee 100 km higher than the shuttle's. However, the long tether's surface area caused so much atmospheric drag that the satellite reentered the Earth's atmosphere on March 19th.

This video frame shows the 20-km-long cord from the $440 million Tethered Satellite System flying away from the Space Shuttle *Columbia* after snapping unexpectedly in February. Courtesy NASA.

International Ultraviolet Explorer

For the world's oldest operating astronomy satellite, the International Ultraviolet Explorer, the end is finally in sight. IUE will be switched off September 30th after more than 18 years in synchronous orbit. The move follows cuts in the European Space Agency's science budget; NASA funding for the satellite was curtailed last year. IUE's ultraviolet spectrometers provided a generation of astronomers with an unprecedented window on high-temperature stars, mass-exchange binaries, and the interstellar medium.

Galileo

The Galileo spacecraft reached the farthest point (apojove) in its first orbit around Jupiter in mid-March, at a distance of 19 million km from the giant planet. The orbiter fired its rocket engine to raise the future closest approach (perijove) from 185,000 to 670,000 km and to prepare to pass within 1,000 km of the moon Ganymede on June 27th.

Pegasus XL

NASA's Small Explorer program is back on track now that Orbital Sciences Corporation's air-launched Pegasus XL rocket has made a successful flight. Following failures on its first two attempts, the third XL placed a U.S. Air Force ionospheric-research satellite into a polar orbit in March.

Hubble Space Telescope

Astronomer-astronaut Steven A. Hawley, who lifted Hubble out of the shuttle Discovery's cargo bay in April 1990, will join the crew of the second telescope-servicing mission next February. Hawley temporarily left the astronaut corps two months after the Hubble deployment to become an administrator at NASA's Ames Research Center, then returned to Houston in 1992 to help direct flight-crew operations.

Polar

NASA's Global Geospace Science project is well under way following the launch of the Polar plasma laboratory on February 24th. Similar in form and function to its companion Wind spacecraft (*S&T:* February 1995, page 16), Polar was placed in an elongated orbit with an apogee 50,000 km above Earth's north pole. From this vantage it will study charged particles, electromagnetic fields, and the aurora.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

The astronomers will further test this notion with images obtained during last April's total lunar eclipse (June issue, page 10) from the island of La Palma.

In Brief

• Physicists have finally synthesized **metallic hydrogen,** an exotic form of the ubiquitous element that is thought to dominate the interiors of the outer planets. As detailed in *Physical Review Letters* for March 11th, Samuel T. Weir, Arthur C. Mitchell, and William J. Nellis (Lawrence Livermore National Laboratory) achieved the long-sought result by placing liquid hydrogen in a high-pressure gun and momentarily squeezing it to a pressure of 1.4 million atmospheres (1.4 megabars). Its electrical resistance dropped at a lower-than-expected pressure, implying that gas-giant planets harbor even more metallic hydrogen than had been thought.

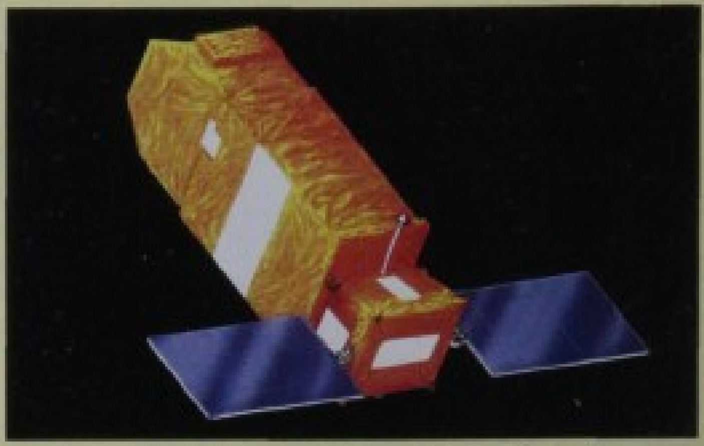
• A second extragalactic source of **very high energy gamma rays** has been discovered with the Whipple Gamma-Ray Observatory. As Michael Catanese (Iowa State University) reported to an audience in Italy, gamma rays with energies above 300 billion electron volts have been detected from Markarian 501, an active galaxy 400 million light-years away in Hercules. Markarian 421, the first source, lies at a similar distance. Gamma rays with such energies pass through orbiting instruments undetected; they can be indirectly observed only when they induce ephemeral flashes in the Earth's atmosphere (*S&T:* September 1995, page 20).

• According to a Paris Observatory group, long-sought **Planet X** could be discerned by precisely timing the pulses from rapidly rotating neutron stars. Ismael Cognard and colleagues note in *Astronomy and Astrophysics* for April (I) 1995 that a massive 10th planet orbiting our Sun might be responsible for unexplained timing residuals in PSR 1937+21, a millisecond pulsar in Vulpecula. José Navarro (National Radio Astronomy Observatory) does warn that small errors in the mass or motion of the already-known planets could mask or mimic the gravitational effects of Planet X. At the same time, he notes, discovering more millisecond pulsars and timing them for a few decades could in principle reveal an unknown massive member of our solar system.

MISSION UPDATE By Jonathan McDowell

Far Ultraviolet Spectroscopic Explorer

After surviving a very close brush with cancellation (*S&T:* December 1994, page 16), the slimmed-down Far Ultraviolet Spectroscopic Explorer is now on track for a late-1998 launch. FUSE will measure the abundance of deuterium (heavy hydrogen) both in the Milky Way and in extragalactic space, testing theories of Big Bang nucleosynthesis. It will also map our galaxy's hot interstellar medium and survey ultraviolet emissions from molecular hydrogen in star-forming regions. The satellite's lone instrument, a far-ultraviolet spectrograph, consists of four coaligned telescopes that direct light onto a set of high-throughput diffraction gratings. The gratings have been assembled by the French space agency, which is collaborating with NASA on the mission. FUSE will be operated from a control center at Johns Hopkins University in Baltimore, Maryland. The spacecraft will be built by Orbital Sciences Corporation and ride to orbit aboard a Delta 7320 rocket.



Astronomers saved the Far Ultraviolet Spectroscopic Explorer (FUSE) from NASA's budget ax by trimming the satellite to the bare essentials. FUSE will probe the interstellar medium and star-forming clouds. Courtesy Scott D. Friedman, Johns Hopkins University.

Cassini/Huygens

Preparations are well under way for the launch of the Cassini mission to Saturn, now scheduled for October 1997. At the Jet Propulsion Laboratory in Pasadena, California, engineers have begun installing science instruments in the orbiter. And Cassini's propulsion module has been test-fired at White Sands, New Mexico. Meanwhile, in Germany, assembly is proceeding on the Huygens probe, which Cassini will drop off at Saturn's moon Titan. The European Space Agency has completed vibration testing of one model of Huygens, subjected another to simulated lightning strikes, and dropped a third from a balloon to test its parachute system.

Cassini/Huygens will be launched on a Titan-Centaur rocket from Cape Canaveral, Florida, and will make two flybys of Venus and one of Earth before heading for the outer solar system. The spacecraft will pass Jupiter on December 30, 2000, and arrive at Saturn in the summer of 2004. Huygens will descend into Titan's atmosphere that December.

Rossi X-ray Timing Explorer

NASA has renamed the X-ray Timing Explorer after Bruno B. Rossi, a pioneering X-ray astronomer at MIT who died in 1993. Launched last December, RXTE is operating well. Shortly after launch its all-sky monitor malfunctioned and had to be shut down, but by late March it was restored to health. The satellite is generating a steady stream of IAU *Circulars* reporting transient and flaring X-ray sources.

Solar and Heliospheric Observatory

The SOHO spacecraft entered a "halo" orbit around the L_1 Lagrangian point on the Sunward side of Earth, where solar and terrestrial gravity balance, on February 14th (not in March as reported in my April column). A month later its regular observing program was interrupted for a few days so the satellite could focus on plumes of gas coming from the Sun's south pole.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

ing the moon's surface crater free requires at least two such eruptions per month. (One recently caught by the Hubble Space Telescope is described on page 10 of the February issue). Planetary geologists hope to catch other spoutings with the Galileo spacecraft, which is now in orbit around Jupiter.

In Brief

• The **most circular orbits** known belong to the pulsar J2317+1439 and its white-dwarf companion. As reported in the April 20th *Astrophysical Journal*, Fernando M. Camilo (Princeton) and his colleagues timed the spin of this neutron star in eastern Pegasus very precisely with the Arecibo radio telescope. They conclude that the eccentricity of its 2½-day orbit is less than 12 parts in 10 million ($e < 1.2 \times 10^{-6}$). Princeton's Joseph H. Taylor attributes the circularity to "very efficient damping in the distant past," when the white dwarf's progenitor was a swollen red giant shedding matter onto the neutron star. Saturn's moon Tethys may follow an equally circular orbit, but current data can limit its eccentricity to only 10 parts per million.

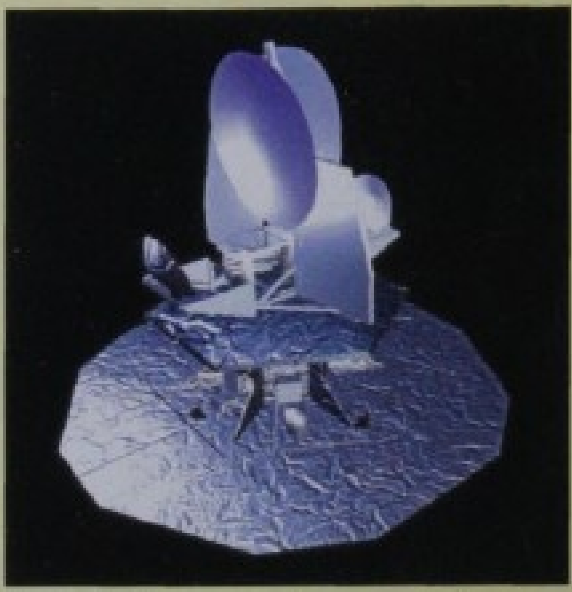
• A collision with Earth may be in the future for **433 Eros,** a 40-kilometer-long, 14-km-wide asteroid whose 1.8-year orbit currently reaches perihelion at a distance of 1.13 astronomical units. Researchers led by Patrick Michel (Côte d'Azur Observatory) modeled Eros's orbital behavior over the next two million years. As the group reports in *Nature* for April 25th, an orbital resonance with Mars has a roughly 40 percent chance of making an Earth-crosser out of Eros sometime in the next million years. Once that happens, the asteroid will be able to hit the Earth. "Such a collision," the researchers write, "is likely in the far future."

• According to David C. Jewitt (University of Hawaii), submillimeter observations of Comet Swift-Tuttle may reveal **Perseid meteors being born.** As he writes in the *Astronomical Journal* for April, the James Clerk Maxwell Telescope captured thermal radiation from large dust particles near the comet's nucleus. The 50 tons of dust released each second during Swift-Tuttle's 1992 perihelion, writes Jewitt, are "destined to populate the Perseid meteor stream" enjoyed by skywatchers each August.

MISSION UPDATE By Jonathan McDowell

Microwave Anisotropy Probe

The Cosmic Background Explorer (COBE) was among NASA's most successful missions. Launched in 1989, it made the first reliable measurements of the spectrum and anisotropy (nonuniformity) of the microwave background radiation believed left over from the Big Bang (*S&T:* January 1993, page 4). In May two new, complementary missions were selected to build on COBE's success. They will both seek smaller-scale anisotropies, the presumed seeds of the large-scale structure we observe in the universe today.



The 595-kilogram Microwave Anisotropy Probe, a joint project of NASA's Goddard Space Flight Center and Princeton University, should begin its 15-month mission in the year 2000. Courtesy NASA.

The Microwave Anisotropy Probe (MAP) will be NASA's next Mid-Size Explorer, or MIDEX. After launch in the year 2000, MAP will become the first spacecraft to orbit at the Sun-Earth L_2 Lagrangian point, 1.5 million kilometers from Earth in the direction opposite the Sun. This unique vantage will enable the spacecraft to point simultaneously away from the Sun, Earth, and Moon and thus avoid their natural and (in the Earth's case) artificial microwave emissions, which would interfere with cosmic signals. MAP will aim to measure differences in the intensity and temperature of the cosmic background in different directions on the sky to an accuracy of 20 millionths of a degree Kelvin. MAP's 1.5-meter microwave dishes will be able to discern fluctuations only ⅕° across, compared with COBE's 7° resolution.

COBRAS/SAMBA

An advisory committee has recommended COBRAS/SAMBA as the European Space Agency's next medium-class science mission. This represents a merger of the proposed Cosmic Background Radiation Anisotropy Satellite (COBRAS) and Satellite for Measurement of Background Anisotropies (SAMBA). After launch in 2004, COBRAS/SAMBA will map the sky at an angular resolution of only 10 arcminutes and detect temperature fluctuations of just 6 millionths of a degree Kelvin, near the limit at which emissions from our own galaxy prevent us from seeing details of the relic fireball. Like MAP, COBRAS/SAMBA will be sent to the L_2 point.

Imager for Magnetopause-to-Aurora Global Exploration

Another newly funded MIDEX program is the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). This NASA satellite will study ultraviolet, radio, and neutral-atom emissions from the aurora borealis and the properties of the polar ionosphere. Due for launch in late 1999, IMAGE will operate in an elongated polar orbit for two years.

BeppoSAX

On April 30th an Atlas-Centaur rocket placed Italy's Satellite per Astronomia a raggi X (SAX) into an equatorial orbit 500 km above Earth. Mission managers then tested the spacecraft's pointing and control systems. In May the satellite was renamed BeppoSAX in honor of Giuseppe "Beppo" Occhialini, a pioneer in high-energy astronomy. BeppoSAX was scheduled to begin observing targets with its main X-ray telescope in June, obtaining simultaneous spectra at energies from 0.1 to more than 200 kiloelectron volts. It will also conduct a survey of the galactic plane.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

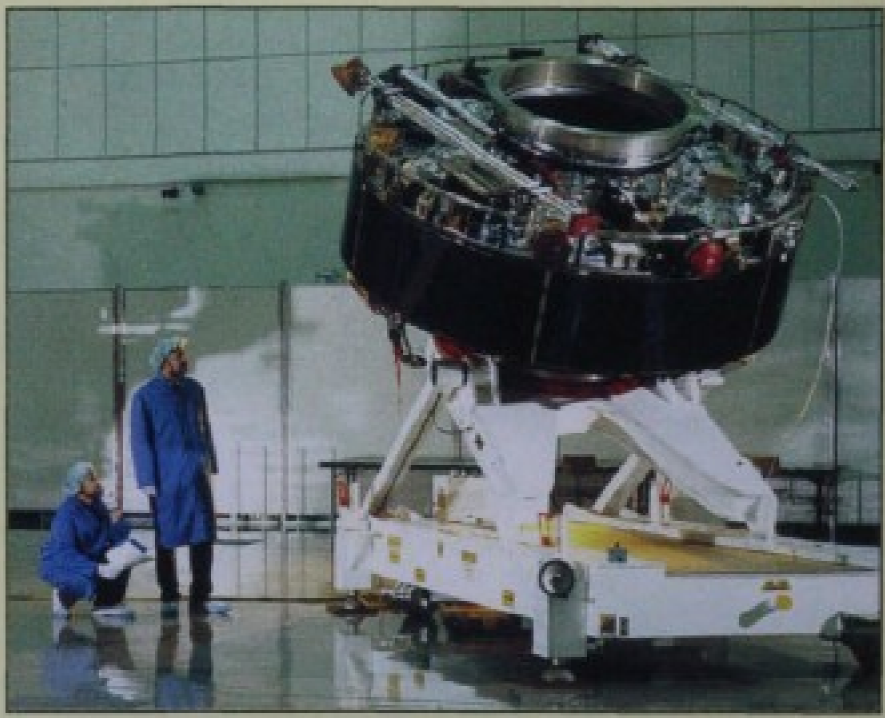
MISSION UPDATE

By Jonathan McDowell

Cluster

On June 4th four identical satellites collectively known as Cluster were lost when the rocket meant to carry them into orbit exploded. The ill-fated launch was the first for Ariane 5, the European Space Agency's next-generation, heavy-lift rocket. Thirty seconds after liftoff Ariane's onboard computer mistakenly ordered the vehicle to turn sharply, causing it to break apart. Automatic systems then destroyed the rocket and its payload some 3.4 kilometers above the launch complex at Kourou, French Guiana. ESA officials suspect flawed computer software and were to present the results of an inquiry in mid-July.

Cluster was part of ESA's Cornerstone 1 science project. Ariane was meant to deliver the payload to an equatorial geostationary transfer orbit to demonstrate the rocket's commercial suitability. The satellites would then have used their own engines to maneuver to entirely different, much higher polar orbits. Cluster was intended to study the Earth's magnetosphere using magnetometers, ion spectrometers, electric-field probes, and particle imagers. On July 3rd, ESA managers decided to build a single replacement satellite to be launched next year.



The first flight of Europe's Ariane 5 rocket on June 4th ended in disaster when the vehicle strayed off course and was destroyed. Lost in the accident were four identical satellites, one of which is shown here, that were intended to explore Earth's magnetosphere. Courtesy ESA.

Tethered Satellite System

NASA's Tethered Satellite System failure review board has reported its findings. The Italian-built satellite was attached to a 20-kilometer American-built cable. On its first flight in 1992 the cable snagged after only two hundred meters of deployment and had to be reeled in. Earlier this year the system got a second flight, during which the electrical properties of a long, conducting space tether were successfully measured. However, the tether snapped just as it approached its full length, and the satellite was flung into a higher orbit from which it has since reentered the Earth's atmosphere (June issue, page 17; July issue, page 109).

The tether remnant and deployer were returned to Earth, where inspection revealed contaminating metal and plastic debris. Some of this debris presumably caused a small hole in the tether insulation. Electrical arcing across the 3,500-volt potential drop between the tether and the deployer resulted, burning through the Kevlar that held the tether together.

Infrared Space Observatory

Astronomers had a brief scare on May 30th when the cryogenically cooled Infrared Space Observatory accidentally spent two minutes looking at the Earth, sending its onboard temperature shooting up to a "sweltering" 10° above absolute zero. The emergency happened near perigee, when the satellite was out of contact with the ground station. Automatic software pointed the telescope away from Earth, and science operations were able to resume two days later when the instruments were restored to their normal temperature below 4° Kelvin. Only a small amount of the liquid helium coolant seems to have been used up during the mishap. In September ESA mission controllers will order ISO to adjust its elliptical orbit slightly so that it remains synchronous with the Earth's rotation.

Galileo

The Galileo orbiter flew past Jupiter's moon Ganymede on June 27th (Universal Time) as it completed its first trip around the giant planet. During this so-called Ganymede 1 encounter, the spacecraft skimmed only 832 km from the moon's surface, 70 times closer than Voyager's nearest approach. The pictures taken by Galileo will be relayed over the next few months and are expected to reveal details of Ganymede's complicated geology. Galileo's second pass by Jupiter itself came 18 hours later, at a distance of 11 Jovian radii. During the week-long encounter period, Galileo examined Jupiter's magnetosphere and auroras, as well as the moons Europa, Callisto, and Io.

Galileo's second orbit of Jupiter is much shorter and will end with the Ganymede 2 encounter on September 6th. At that time the spacecraft will pass even closer to Ganymede and will exploit that body's gravity to lower its orbital inclination.

VLBI Space Observatory Program

The Mu Space Experiment Series B satellite is being prepared for launch from Japan's Kagoshima Island spaceport. Muses B, which is the space segment of the VSOP (VLBI Space Observatory Programme) mission, will carry an 8-meter-diameter radio telescope into a 22,000-km elliptical orbit around the Earth. Muses B will be aboard the first flight of Japan's new M-5 rocket, whose four stages have never flown before, and complications have caused the launch to slip to February 1997. Signals garnered by the satellite will be combined with those from ground-based radio telescopes to produce an unprecedented baseline larger than the Earth.

In addition to his work at the Harvard-Smithsonian Center for Astrophysics, McDowell prepares a weekly electronic newsletter on the space program (World Wide Web URL: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

each find that Tau Boötis A's line-of-sight velocity shifts sinusoidally every 3.3 days. If the variation, some 470 meters per second in amplitude, is caused by an unseen companion, then that object must have at least 3.9 times Jupiter's mass and circle Tau Boötis A from a mere 0.05 astronomical unit — an orbit eight times smaller than Mercury's around the Sun.

• **The Hipparcos mission** has released its first astrometric results on specific stars. As noted in *Astronomy and Astrophysics* for June 10th, the spacecraft has enabled astronomers to quantify the parallaxes of 47 Ursae Majoris, 70 Virginis, and 51 Pegasi. In addition to refining these stars' distances (now 46, 59, and 50 light-years, respectively), Hipparcos's positional measurements place upper limits on the stars' wobbling motions. In turn, this limits the masses of their substellar companions. (The spectroscopic work that revealed those companions places only lower limits on the masses.) With its circular orbit and a mass between 2.5 and 22 Jupiters, write the authors, 47 Ursae Majoris B "satisfies the semantic criterion for classification as a massive planet."

MISSION UPDATE

By Jonathan McDowell

BeppoSAX

Italy's BeppoSAX X-ray astronomy satellite made its first observations in June. It stared at the X-ray binary source and black-hole candidate Cygnus X-1 for three days (see the illustration at far right). In July it looked at the Seyfert galaxy NGC 4151. All the instruments are operating well, and the telescope is producing images with better than 1-arcminute resolution.

Cluster 5

Four scientific satellites called Cluster were lost when their Ariane 5 launch vehicle was lost in June, a potentially devastating blow to European space scientists (September issue, page 18). The European Space Agency (ESA) has decided to combine the Cluster project's structural test model with spare subsystems and launch it as Cluster 5. Under the new program, nicknamed Phoenix by the media, ESA is also considering building the three additional spacecraft that are needed to make four-point measurements — the key feature of the Cluster concept. The options are to build three additional Cluster satellites or three smaller minisatellites that would carry only some of the original Cluster instruments.

This first-light image from the BeppoSAX X-ray satellite *(inset)* shows Cygnus X-1 at energies between 100 and 10,000 electron volts. This view was taken on June 22nd using the satellite's Low-Energy Concentrator Spectrometer. The two spots in the corners are internal calibration sources. Courtesy ESA and the Italian Space Agency.

Gravity Probe B

NASA has decided to continue development of the Gravity Probe B relativity mission. GP-B is designed to carry a telescope and special supercooled gyroscopes to precisely measure, with respect to a star, the satellite's orientation as it orbits the Earth. Einstein's general theory of relativity predicts that the gyroscope-pointing direction will change relative to the star by 0.042 arcsecond over the course of a year because of the Lense-Thirring effect, which describes the dragging of space-time by a moving mass.

Space Infrared Telescope Facility

The Space Infrared Telescope Facility (SIRTF) moved a step closer to reality this summer when NASA awarded Lockheed Martin a contract to build the spacecraft. Ball Aerospace, a veteran of the IRAS project, will build the liquid-helium dewar for the supercold telescope. NASA's Jet Propulsion Laboratory will oversee the project. SIRTF will be launched into solar orbit by a Delta rocket in 2001. Its 0.85-meter beryllium primary mirror will have a mass of only 14 kilograms and will be cooled to 2.8° Kelvin above absolute zero. It will focus infrared light onto a camera, a spectrometer, and an imaging photometer.

X-33

Lockheed Martin received more good news in July when Vice President Albert Gore announced that the aerospace firm had been selected to build the X-33 experimental rocket plane. Although it will not be able to fly into orbit itself, the X-33 will demonstrate technologies needed for a totally reusable launch vehicle. A series of suborbital missions should start in March 1999. The craft will use a lift-generating fuselage and a revolutionary motor design. Its Rocketdyne liquid-hydrogen/liquid-oxygen engine uses a tapering nozzle, called an aerospike, instead of a conventional bell-shaped rocket one. The new engine's internal parts are more conventional, using designs taken from NASA's Saturn rocket program. The X-33 will launch vertically from California's Edwards Air Force Base and land on runways in Utah or Montana. The Boeing 747 Space Shuttle carrier will then return it to Edwards for its next flight.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (World Wide Web URL: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

NEWS NOTES

• **The lowest-mass white dwarf** known has been identified in orbit around the millisecond pulsar J1012+5307 in Ursa Major. The 19th-magnitude white-dwarf companion was "weighed" with spectra taken at the 10-meter Keck I reflector on Mauna Kea. As Marten H. van Kerkwijk (Caltech) and colleagues report in the *Astrophysical Journal Letters* for August 20th, spectra reveal the white dwarf's surface temperature and surface gravity; in turn, these quantities imply a mass of 0.16 Sun. The white dwarf's progenitor presumably shed much of its mass onto its neutron-star companion.

• Another **dwarf galaxy's proper motion** has been refined by astronomers at Yerkes Observatory. Andrea E. Schweitzer and her colleagues scanned photographs of the Ursa Minor dwarf spheroidal galaxy dating back to the 1950s. The diffuse, 10th-magnitude assemblage of stars appears to follow the Large Magellanic Cloud's orbit around the Milky Way at a speed of 209 kilometers per second. Tracking such satellites helps astronomers "weigh" our galaxy's dark-matter halo. These findings were reported at this summer's meeting of the American Astronomical Society.

MISSION UPDATE

By Jonathan McDowell

Mir

In August NASA astronaut Shannon Lucid passed the five-month mark in orbit aboard the Russian space station Mir, significantly exceeding Norman Thagard's 115-day flight last year. Launch of the Space Shuttle *Atlantis* to bring her home and deliver her replacement, John Blaha, was delayed from mid-August to late September because of problems with the solid rocket boosters. More than two dozen Russian cosmonauts have spent more time in space than has Lucid, though she does now hold the cumulative-duration record for a woman, surpassing Yelena Kondakova's 169 days.

Fast Auroral Snapshot Explorer

NASA's Fast Auroral Snapshot Explorer (FAST) finally made it to orbit after a two-year delay caused by problems with the Pegasus XL winged rocket. On August 21st a redesigned Pegasus was dropped from an L-1011 carrier airplane 13 kilometers above the Pacific Ocean. A few seconds later the three-stage rocket ignited to boost FAST into orbit. The satellite uses four sensors to monitor electromagnetic fields and particle acceleration in the aurora on very short time-scales.

Mars Global Surveyor

Mars Global Surveyor (MGS) arrived at Cape Canaveral in August. The box-shaped spacecraft carries spare instruments left over from the ill-fated Mars Observer project. (Observer failed just before reaching the planet in 1993.) MGS is scheduled for launch on November 6th by a Delta rocket; it should reach the red planet next September. MGS will then aerobrake (dip into the Martian atmosphere to slow itself) and lower its orbit from a highly elongated loop to a tight circle only a few hundred kilometers in altitude. MGS will study Mars's geology and climate. A camera will make a detailed surface map and study changing weather patterns, a laser altimeter will measure surface heights, and a spectrometer will analyze the crust's chemical composition.

Mars Pathfinder

A second NASA probe, Mars Pathfinder, also arrived at Cape Canaveral in August. In early December it will ride another Delta rocket on a fast trajectory that will deliver it to Mars next July 4th. Then a lander will separate from the craft and parachute to the surface, where a cluster of giant airbags will cushion its impact. After coming to rest, the lander will deploy cameras and a small weather station and set loose a wheeled robot called Sojourner. This small, 11-kilogram rover will visit nearby rocks and measure their chemical composition. It is *not* equipped to search for evidence of microfossils like those reported in a Martian meteorite in August (October issue, page 18).

Russia's Mir space station sails over the Pacific Ocean in March 1996. A few months later another research module was added to the complex. Courtesy NASA.

Cerise

A French military satellite has been damaged by orbital debris in the first documented case of two known objects colliding in near-Earth space. On July 24th a small piece from an Ariane rocket stage collided with Cerise at nearly 50,000 km per hour, sending the satellite tumbling end over end. The booster was launched in February 1986 and exploded into hundreds of fragments in November of that year, when leftover propellants accidentally ignited. Flight controllers have been able to restabilize Cerise, and it appears that its mission (measuring radio noise in orbit) can continue. Meanwhile the U.S. Space Command's catalog of satellites and debris fragments in Earth orbit recently logged its 24,000th entry.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

spond well to some of the objects observed in HST's detailed views of the Orion Nebula.

In Brief

• What does fighting cavities have in common with planetary nebulae? According to three Belgian scientists, each depends on an unstable giant star in its past. In *Astronomy and Astrophysics* for July 20th, a group led by Nami Mowlavi (Université Libre de Bruxelles) points out that **fluorine** is produced by nuclear fusion during the thermal pulses that intermediate-mass stars undergo as they swell up and become giants.

• The constancy of **Newton's gravitational constant** *(G)* has been reaffirmed by studies of the masses of neutron stars. As Stephen E. Thorsett (Princeton University) explains in *Physical Review Letters* for August 19th, the Chandrasekhar limit depends on the value of *G*. That limit — the largest mass a white dwarf can bear without collapsing to form a neutron star — is about 1.4 Suns. Thorsett tabulated the masses of five neutron-star binaries with ages from 30 million to several billion years. This enabled him to deduce that *G* has changed by at most 0.4 percent per billion years — a limit several times more stringent than those set by other studies (April issue, page 13).

• The **coolest isolated dwarf star** yet known has been discovered in Taurus. J. Davy Kirkpatrick (UCLA) and his colleagues uncovered eight cool, red dwarfs with an infrared camera on the Kitt Peak 1.3-meter reflector. Spectra were then taken with the Palomar 5-meter (200-inch) telescope to classify these objects. In the December 20th *Astrophysical Journal,* the scientists attribute an extremely cool (2000°–2,500° Kelvin) *M*10+ V spectral type to 2MASP J0345432+254023. GD 165B and Gliese 229B (a substellar brown dwarf) are the only starlike bodies known to be cooler and intrinsically dimmer, and each orbits a brighter primary star.

• The **International Ultraviolet Explorer** satellite was shut down as scheduled on September 30th. The observatory's 45-centimeter telescope provided ultraviolet spectra of celestial targets for 18 years, six times its anticipated lifetime. Data acquired by the 670-kilogram device will be reprocessed and archived for continuing scientific use.

MISSION UPDATE

By Jonathan McDowell

DC-XA

The DC-XA ("Clipper Graham") reusable rocket was destroyed in a landing accident on July 31st at the White Sands Missile Range in New Mexico. After eight flights of the DC-X took place under military sponsorship in 1993–1995 (*S&T:* February 1994, page 36), NASA refurbished the rocket and renamed it DC-XA. The cone-shaped craft flew once in May and twice in June. Its fourth and final flight went perfectly until the moment of touchdown, when one of its four landing legs failed to deploy. The rocket toppled over and burst into flames. The DC-X program demonstrated precise computer control of rockets, vertical landing, and rapid reusability.

All four of the DC-XA's landing gear extended properly at the end of this flight in June. But the rocket fell over and burned the following month when it touched down on only three legs. Courtesy NASA.

Galileo

On September 6th the Galileo Jupiter orbiter zipped past Ganymede for the second time, skimming a mere 262 kilometers (163 miles) over the giant moon's surface. That's less than one-third the distance of the pass in late June and closer than the Space Shuttle orbits around Earth. A computer glitch on August 24th had caused a temporary "safing" of spacecraft systems. But Galileo was up and running again well before the flyby, during which it mapped Ganymede's north polar region and probed that moon's gravity field and recently discovered magnetosphere (September issue, page 11). Over the next 24 hours the spacecraft also mapped Io, Amalthea, Europa, and Callisto, but in each case from a distance of hundreds of thousands of kilometers. Galileo made its third close approach to Jupiter itself 18 hours after the Ganymede pass, then headed out toward apojove. Galileo's next encounter, on November 4th, features a 1,200-km flyby of Callisto — one-tenth the approach distance achieved by either Voyager probe.

Advanced Earth Observing Satellite

Japan has launched a large scientific spacecraft to study the ozone layer and the greenhouse effect. The Advanced Earth Observing Satellite (ADEOS) carries Japanese, American, and French instruments including a wind-speed monitor and an ocean-color imager. ADEOS rode an H-2 rocket to orbit from Tanegashima Space Center on August 17th. The satellite's main thrusters failed to operate correctly, but by early September ADEOS had reached its operational orbit using smaller thrusters.

Interbol

Russia's main space-science launch of the year was the Interbol Auroral Probe, which flew into orbit from Plesetsk in late August. The auroral probe and its sibling Interbol Tail Probe, launched last year, are successors to the Prognoz series of solar-terrestrial probes. Each Interbol probe ejected a Czech-built Magion minisatellite. The twin Magions enable scientists to distinguish temporal and spatial variations of Earth's electric and magnetic fields. The tail probe is in a highly elongated orbit within our planet's magnetic wake, while the auroral probe, as its name suggests, remains closer to the Earth in the region where auroral electrons are accelerated.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

MISSION UPDATE

By Jonathan McDowell

This expanded column looks at science launches planned for the coming year, which marks the 40th anniversary of the dawn of the Space Age. For up-to-date launch schedules and other information, consult this column monthly and visit each mission's World Wide Web home page. Active links to these and other missions can be found on SKY Online at http://www.skypub.com.

Human Space Flight

The continuous presence of humans in space, unbroken since 1989, persists into 1997. A succession of American astronauts will join Russian cosmonauts for months-long stays aboard the space station **Mir.** Then in November comes one of 1997's most important launches, when the **FGB Space Tug** rockets into orbit from Kazakhstan. Paid for by NASA but built in Russia, the tug is the core around which the huge **International Space Station** will grow. As the year draws to a close, the Space Station *Endeavour* will rendezvous with the FGB, and its crew will begin the giant station's construction by attaching U.S.-built **Node One** to it.

The upcoming Space Shuttle flight most anticipated by astronomers is that of STS 82, due in February. This is the second service call on the **Hubble Space Telescope,** during which astronauts aboard *Discovery* will replace some worn-out equipment and add two powerful new scientific instruments: an imaging spectrograph and an infrared camera.

Due for launch next October, NASA's Cassini orbiter will deliver Europe's Huygens probe, illustrated here, to Saturn's giant moon Titan in 2004. Courtesy NASA.

Planetary Missions

As described last month (page 24), three robotic probes will reach the red planet in 1997. NASA's **Mars Pathfinder** will land in July and dispatch a small robotic rover, **Sojourner,** to investigate the composition of nearby rocks. **Mars Global Surveyor** will orbit the planet to study its topography and weather. And Russia's **Mars 96** will fire two small penetrators into the planet's surface.

Lunar Prospector will orbit the Moon later this year to search for resources that might support future piloted missions. Illustration courtesy Lockheed Martin.

The main interplanetary launch of the year, due in October, is that of NASA's **Cassini** spacecraft, which will become the first to orbit Saturn when it arrives in 2004. Cassini will also deliver the European Space Agency's **Huygens** probe to Titan, Saturn's largest moon, from which it will transmit information about the atmosphere and surface. October also brings the launch of NASA's **Lunar Prospector.** It will orbit the Moon from pole to pole and make geologic maps. One of the mission's priorities is to search for water ice, thought by some to line the bottoms of permanently shadowed polar craters. Japan will also send a probe to the Moon in 1997. **Lunar A** will release three penetrators designed to bury scientific instruments in the Moon's crust. These devices will measure the flow of heat underneath the surface and record vibrations from moonquakes.

Galileo's explorations in orbit around Jupiter will continue in 1997, beginning with four visits to the icy moon Europa. Galileo will also return to Ganymede and Callisto twice each before completing its primary mission at the end of the year. Meanwhile, in the asteroid belt between Mars and Jupiter, the **Near Earth Asteroid Rendezvous** probe will fly past minor planet 253 Mathilde in June. Then it arcs back for a gravity assist from Earth in early 1998 before pressing on toward a rendezvous with 433 Eros in 1999. And, out beyond Neptune and Pluto, **Voyagers 1 and 2** mark their 20th anniversary in space, and **Pioneer 10** its 25th, as they continue their lonely journeys to the stars.

Astronomy and Space Science

The year begins with two important astronomy launches. Japan's **VLBI Space Observatory Program** (VSOP) will place the first practical radio telescope in space. It will operate in conjunction with ground-based antennas to make radio maps with unprecedented angular resolution. VSOP will be followed by NASA's **Submillimeter Wave Astronomy Satellite.** It will make the first space observations at submillimeter wavelengths, which remain largely unexplored to date. The **Transition Region and Coronal Explorer** (TRACE), due for launch in September, will take ultraviolet and X-ray close-ups of the Sun to see how magnetic fields link the incandescent surface with its 10,000,000° corona. TRACE will work in conjunction with Europe's **Solar and Heliospheric Observatory** (SOHO), launched in 1995. SOHO will be joined at the L_1 Lagrangian point between the Earth and Sun in late 1997 by the **Advanced Composition Explorer.** ACE will measure cosmic rays and will provide early warning of solar flares. It will also measure the composition of the Sun's corona by catching solar-wind particles. Finally, the U.S. Air Force satellite **ARGOS,** to be launched in August, will include a telescope to study rapidly varying X-ray sources.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

abovementioned finds by floating freely in space, rather than in a cluster or binary system.

Yet other brown dwarfs may be orbiting several Sun-like stars whose line-of-sight, or radial, velocities have been tracked with the help of the Doppler formula. Unlike the objects described above, these candidates remain unseen. Their presence is inferred by the reflex motion they induce in the visible stars they orbit (*S&T:* August 1996, page 20). Two such objects, HD 29587B in Perseus and HD 140913B in Corona Borealis, have masses that may be as low as 0.05 Sun, well within the brown-dwarf realm. However, as discoverers Tsevi Mazeh (Tel Aviv University) and David W. Latham and Robert P. Stefanik (Harvard University) stress in the *Astrophysical Journal* for July 20, 1996, dynamically deduced masses are only lower limits, and the candidates may be extremely feeble stars, not brown dwarfs.

In Brief

• On September 5, 1996, the Chilean Senate ratified legislation that spells out **Chile's relationship with the European Southern Observatory.** ESO operates numerous telescopes at its La Silla site and is building a quartet of 8-meter reflectors on Cerro Paranal, a remote mountaintop in the Andean nation's northern desert. Relations between ESO and its host country were shaken in 1994 by a dispute over Paranal's ownership.

• **Big Bear Solar Observatory** will soon change hands from Caltech to the New Jersey Institute of Technology, as will an array of solar radio telescopes in California's Owens Valley. Telescopes have monitored solar activity from their perch in Big Bear Lake for more than a quarter century. But BBSO's longtime director, Harold Zirin, is nearing retirement, and Caltech — a principal user of the Keck and Palomar observatories — is concentrating on nighttime astronomy.

• A new 4-meter reflector will be built near La Serena, Chile, by a consortium of American and Brazilian institutions. According to the U.S. National Optical Astronomy Observatories, a partner in the project, the **Southern Observatory for Astrophysical Research** (SOAR) will incorporate active optics and enable remote observing via the Internet. The telescope should see first light in 2001.

MISSION UPDATE

By Jonathan McDowell

Missions to Mars

NASA's Mars Global Surveyor was launched successfully last November 7th, after a one-day delay caused by bad weather. The spacecraft had some trouble fully extending one of its two solar-cell panels, but flight controllers believe this problem will work itself out. All of the spacecraft's other systems are operating well. MGS will arrive at Mars in September (*S&T:* December 1996, page 24).

Workers at Kennedy Space Center load Mars Global Surveyor into its payload canister in preparation for its successful launch last November 7th. The gray sphere at bottom is part of the Delta II rocket's upper stage. Courtesy NASA.

November's second launch to the red planet ended in disaster. Russia's Mars 96 lifted off on schedule on the 16th, but a problem with the upper stage of its Proton rocket caused the instrument-laden probe to reenter the atmosphere over the South Pacific Ocean.

After two days' delay, Mars Pathfinder was lofted on December 4th. Its landing is planned for July 4th.

SAC-B and HETE

Two astronomy satellites were also lost in November when they failed to separate from their Pegasus rocket's third stage. NASA's High Energy Transient Experiment (HETE) was to have followed up the gamma-ray-burst studies of the Compton Gamma Ray Observatory, using X-ray and ultraviolet detectors to pin down the locations of these mysterious events. Its companion satellite, Argentina's Satelite de Aplicaciones Cientificas-B (SAC-B) would have studied gamma-ray bursts and mapped the sky's energetic X-rays. Although all three stages of the Pegasus XL booster fired perfectly on November 4th, a battery failure left both satellites attached to the rocket. This prevented them from pointing their solar panels toward the Sun, dooming them to power starvation within hours.

Advanced X-ray Astrophysics Facility

The cylindrical optics for NASA's Advanced X-ray Astrophysics Facility (AXAF) have been assembled and were delivered to the Marshall Space Flight Center in late November to begin several months of testing and calibration. A special suite of detectors will measure the mirrors' characteristics, making sure the optics produce sharply focused images. The two focal-plane instruments, the High Resolution Camera (HRC) and the AXAF CCD Imaging Spectrometer (ACIS), are also nearing completion. AXAF is scheduled for launch by the Space Shuttle *Columbia* in late 1998.

Rosetta and Champollion

The United States has pulled out of its commitment to supply the small Champollion lander on Europe's Rosetta comet mission. A second lander, Germany's Roland, may still fly on Rosetta, and Champollion is to be reworked into a separate technology-development mission. Rosetta is slated to be launched in 2003 by a giant Ariane 5 rocket. It should arrive at Comet 46P/Wirtanen in 2011 after one flyby of Mars and two of Earth. Unlike the Comet Halley probes of the 1980s, Rosetta will not zoom past the comet; rather, it will rendezvous with it for a prolonged investigation.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

setts. (Only one star's motions had been tracked before.) Along with the binary's interferometrically determined angular separation (0.13 arcsecond on average), these data enabled the astronomers to establish the cluster's distance. Their estimate of 156±5 light-years dovetails precisely with recent values based on the moving-cluster method.

• The identity of the stellar object in **Cygnus X-3**, one of the sky's brightest X-ray sources, has been firmed up with new infrared spectra. Cygnus X-3, whose stellar component sheds material onto a neutron star, was tracked with the William Herschel Telescope on La Palma and the United Kingdom Infrared Telescope atop Mauna Kea. Writing in *Astronomy and Astrophysics* for October 10, 1996, Marten H. van Kerkwijk (Caltech) and his colleagues identify Cygnus X-3's visible component as a Wolf-Rayet star, the hot, helium-rich core of a massive star that had shed its outer layers.

• **The Hubble parameter**, H_0, has been constrained anew by timing light variations in the twin quasar, Q0957+561 in Ursa Major. Using data from the Apache Point Observatory, a team led by Edwin L. Turner (Princeton) determined that the light in the southern component of the gravitational mirage takes 417 days longer to reach Earth than does light in its northern twin. Along with measurements of the foreground galaxy that bends the quasar's light, this delay implies a Hubble parameter of 63±12 kilometers per second per megaparsec, in line with the latest estimates from the Hubble Space Telescope's observations of Cepheid variables in relatively nearby galaxies.

MISSION UPDATE

By Jonathan McDowell

Mars Pathfinder

NASA now has two probes en route to the red planet (*S&T:* December 1996, page 24). Mars Pathfinder lifted off on a Delta rocket before dawn last December 4th. The second of NASA's "faster, better, cheaper" Discovery spacecraft, it will test new landing technologies, including airbags to cushion its relatively abrupt touchdown. On July 4th Pathfinder will become the first U.S. spacecraft to land on Mars without first going into orbit around the planet. It will then deploy a small rover called Sojourner. Pathfinder's systems are working well except for a malfunctioning Sun sensor, a problem flight controllers believe they can work around. Meanwhile NASA's Mars Global Surveyor, launched on November 7th, remains on target for a September arrival and the start of its tasks in Martian orbit.

Technicians prepare Mars Pathfinder for its successful December launch at the Kennedy Space Center. The lander and rover are enclosed in the cone-shaped entry module at top. Just below that are the disk-shaped cruise stage and the Delta rocket's upper stage. Courtesy NASA.

Mars 96

More details have come to light concerning the failure of the Russian Mars 96 mission last November (February issue, page 19). The Proton rocket's fourth stage successfully placed the spacecraft into a parking orbit around Earth on the 16th, but it then failed to restart and boost the probe to Mars as planned. Subsequently Mars 96 separated from the launcher and fired its own engine, but this was not powerful enough to get it out of Earth orbit. The spacecraft reentered the atmosphere a few hours later; witnesses in northern Chile saw its fiery demise. Parts of Mars 96 may have landed in Chile or Bolivia, and a search is under way for 18 radioactive fuel pellets, each carrying 15 grams of plutonium dioxide. The Proton's upper stage reentered over the South Pacific on the 17th, causing confusion when U.S. officials misidentified it as the spacecraft.

Space Infrared Telescope Facility

The Space Infrared Telescope Facility (SIRTF) has taken a critical step forward. U.S. astronomers have been pushing for the project since the success of the Infrared Astronomical Satellite (IRAS) in 1983. Originally conceived as a shuttle-borne telescope, it soon evolved into a free-flying "Great Observatory" like the Hubble Space Telescope. But, as NASA's budget projections dwindled, SIRTF never got off the drawing board. At last NASA has granted "Phase B" approval to a scaled-back version; this provisional go-ahead should lead to full development beginning next year. The 85-centimeter telescope will be launched into solar orbit in mid-2002.

ORFEUS 2

The German Astro-SPAS (Shuttle Pallet Satellite) has made its third Space Shuttle flight, carrying the Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph (ORFEUS) for the second time. *Columbia*'s November mission was the longest shuttle flight ever, allowing ORFEUS to make observations for a full 14 days. The instrument's 1-meter primary mirror focuses light onto two spectrographs that cover wavelengths from 40 to 125 angstroms. A separate 18-centimeter telescope feeds an experiment that uses Doppler shifts to measure line-of-sight motions of the interstellar medium as small as 1.6 kilometers per second.

McDowell specializes in multiwavelength studies of extragalactic objects at the Harvard-Smithsonian Center for Astrophysics.

cles are commonly known for their ability to move through matter largely unhindered, in the hot, superdense core of the exploding star, they are more easily reabsorbed. But when some tau neutrinos change to their electron-flavored counterparts, energy is returned to the stellar core because the latter kind don't move as far as the former before being reabsorbed.

Finally, the provocative theory posits, the magnetic fields affect where the neutrinos change flavor, producing an asymmetric cascade.

In Brief

• As teams of scientists continue to debate whether ancient microscopic fossils permeate the Martian meteorite ALH 84001, two recent **meteorite auctions** offered a sense of what pieces of the red planet are worth. On December 10th a 7.6-gram slice of the Zagami meteorite, which fell on Nigeria in 1962, fetched $11,000 — close to $1,500 per gram. But the November 20th auction of a 498.5-gram trio of Martian stones yielded a "no sale." (The top bid of $1.1 million fell short of the owner's undisclosed minimum price.) According to Arlan Ettinger, president of Guernsey's auction house, the trio may yet be sold privately.

• Veteran newscaster **Walter Cronkite,** often recalled for his gripping commentary during the Apollo missions, now has a namesake in outer space. Asteroid 6318 has been given the name Cronkite by Eleanor F. Helin (Jet Propulsion Laboratory), the astronomer who discovered it in 1990. The 2- to 3-kilometer object orbits the Sun every four years; its eccentric path crosses the orbit of Mars and comes within about 50 million km of Earth's. At such times asteroid Cronkite brightens to 17th magnitude.

• **Feeding quasar nuclei** the material they need to power their energetic activity may depend critically on the structure of red-giant stars. As Philip J. Armitage and Melvyn B. Davies (Cambridge University) and Wojciech H. Zurek (Los Alamos National Laboratory) write in the *Astrophysical Journal* for October 10, 1996, red giants hold on to their extended outer atmospheres only feebly. As a result, these stars' gases are more easily stripped off when they pass through the accretion disk surrounding a quasar's central black hole.

MISSION UPDATE

By Jonathan McDowell

Stratospheric Observatory for Infrared Astronomy

NASA has given the Universities Space Research Association the go-ahead to acquire a Boeing 747-SP jumbo jet for the Stratospheric Observatory for Infrared Astronomy, or SOFIA. The aircraft will be modified to house a 2.5-meter (100-inch) telescope and should make its first observational flight in 2001. DARA, the German space agency, is providing the telescope. SOFIA will fly at an altitude of 13 kilometers (43,000 feet), above most of the atmosphere's infrared-absorbing water vapor. It replaces the Kuiper Airborne Observatory, which flew between 1975 and 1995 carrying a 0.9-meter (36-inch) telescope (*S&T:* February 1996, page 15).

The Stratospheric Observatory for Infrared Astronomy (SOFIA) will carry a 2.5-meter telescope in a modified 747-SP aircraft beginning in 2001. Artwork courtesy NASA/Ames Research Center.

Advanced X-ray Astrophysics Facility

With the AXAF spacecraft less than a year and a half from launch, testing of its X-ray telescope is now under way at NASA's Marshall Space Flight Center in Huntsville, Alabama. The instrument's four nested, near-cylindrical mirrors are sealed in a large vacuum chamber at the center's X-ray Calibration Facility. Various sources of high-energy radiation shine down a 500-meter-long evacuated tunnel to illuminate the telescope. Specially developed cameras and other detectors are being used to characterize the resulting X-ray images and to make sure that AXAF's optics do not suffer from any unexpected aberrations. Experiments have been running 24 hours a day since before Christmas, and results will be made public soon.

ABRIXAS

To follow up their successful Röntgensatellit (Rosat), German astronomers are developing ABRIXAS; the acronym stands for A Broadband Imaging X-ray All-sky Survey. This spacecraft will view the sky in "hard" (high-energy) X-rays, whereas Rosat's instruments recorded relatively "soft" ones. The three-year-long mission will provide our first comprehensive look at the cosmos at energies around 10 kiloelectron volts (wavelengths near 1 angstrom). ABRIXAS will have seven small X-ray telescopes, each with a 40-arcminute field of view and 30-arcsecond resolution. It thus complements AXAF's narrow-field, very high resolution imaging. ABRIXAS will be launched into orbit from northern Russia on a Cosmos rocket in early 1999.

Pioneer 10

March 2nd marks the 25th anniversary of the launch of Pioneer 10, the first spacecraft to cross the asteroid belt. Pioneer 10 also made the first flyby of Jupiter, in December 1973. Since then it has been heading into interstellar space. On January 1st it was more than 9.8 billion kilometers (66 astronomical units) from the Sun. The probe's nuclear power sources are running down, and flight controllers switched off its charged-particle detectors on December 30th last year. But the Geiger Tube Telescope (a radiation counter) and ultraviolet photometer continue to transmit data about the outer solar system across the 9 light-hours to Earth.

McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

ories (like those involving cold dark matter) that take a long time to build large structures. A few quasars have been detected at redshifts higher than 4.5, when the universe was somewhere around 10 percent of its present age. But it now seems likely that the cosmos had at least two billion years within which to build the rest.

In Brief

• Dynamical evidence for **a supermassive black hole** in NGC 4486B has been found in spectroscopic measurements from the Canada-France-Hawaii Telescope on Mauna Kea. The galaxy, a small elliptical satellite of M87 in the Virgo Cluster, has a double nucleus much like that in the Andromeda Galaxy, which also bears a black hole (January issue, page 13). In a submission to the *Astrophysical Journal Letters,* a team led by John Kormendy (University of Hawaii) infers that a dark, compact object, 400 to 800 million Suns in mass, resides at the 14th-magnitude galaxy's core.

• The infrared appearance of our galaxy has been used to refine the **Sun's distance from the Milky Way's midplane.** In the *Astrophysical Journal* for September 10, 1996, Henry T. Freudenreich (NASA/Goddard Space Flight Center) sets that distance at 51 light-years toward the north galactic pole — agreeing with previous studies for the once-elusive number (*S&T:* March 1996, page 16). Freudenreich utilized data from the Cosmic Background Explorer satellite to map the distribution of red-giant stars, which are expected to best trace the overall shape of a galaxy like the Milky Way.

• **Fomalhaut's age** has been estimated at 200 million years, give or take 50 percent, by applying numerous tests to Gliese 879, the 6th-magnitude *K*-type star that shares Fomalhaut's motion through space. As David Barrado y Navascués (Harvard-Smithsonian Center for Astrophysics) and his colleagues note in the *Astrophysical Journal* for January 20th, Fomalhaut (Alpha Piscis Austrini) appears to be encircled by a disk of dust. Yet the ages of *A*-type stars like Fomalhaut are hard to assess. The result suggests that disks can endure for hundreds of millions of years around hot, young stars — possibly favoring the formation of planets.

MISSION UPDATE

By Jonathan McDowell

VLBI Space Observatory Programme

Japan's VLBI Space Observatory Programme (VSOP) got under way on February 12th when the Muses B satellite lifted off from Kagoshima Space Center atop the first of the nation's powerful M-5 rockets. Once in space the craft was renamed the Highly Advanced Laboratory for Communications and Astronomy, or HALCA. When the acronym is pronounced in Japanese it sounds like *haruka* ("far away"), a nod to the 21,000-kilometer-high apogee of the satellite's very elongated orbit.

HALCA's 8-meter-wide radio antenna will serve as one element of a very long baseline interferometer with a diameter greater than that of Earth. Ground-based antennas on five continents will also participate in the VSOP observations, scheduled to begin in May after the satellite is fully checked out. The telescopes will make high-resolution radio images of sources in galactic star-forming regions and in the centers of other galaxies.

The Highly Advanced Laboratory for Communications and Astronomy (HALCA), an 8-meter radio telescope, heads into space aboard Japan's new M-5 rocket last February 12th. HALCA will observe in unison with Earthbound instruments. Courtesy the Institute of Space and Astronautical Science.

Space Interferometry Mission

NASA is planning ahead for its Origins program, designed in part to search for planets and life elsewhere in our galaxy beginning early next century. A possible Space Interferometry Mission (SIM) now under study would use multiple visible-light telescopes in the same way that VSOP uses multiple radio telescopes to build up a high-resolution image. The precision required for visible-light interferometry is much higher, though, because the wavelength of the radiation is so much smaller. For SIM to work, astronomers would have to know the distance between its light-gathering elements to the nearest hundred-millionth of a millimeter.

As currently conceived, SIM would measure the positions of stars as faint as magnitude 15 with an accuracy of a few microarcseconds, enabling it to detect tiny motions induced in them by the gravitational pull of orbiting planets.

Minisat 01

Minisat 01, the first of Spain's Minisat 0 research satellites, was being readied for launch on a Pegasus winged rocket as this issue went to press in March. The spacecraft carries two astrononomical instruments, an extreme ultraviolet spectrograph (EURD) and a low-energy gamma-ray imager (LEGRI). EURD will attempt to detect diffuse background radiation from the interstellar medium and to search for evidence of decaying massive neutrinos. The Spanish-British LEGRI telescope will make X-ray images at energies from 10,000 to 100,000 electron volts over an 11°-wide field.

The Lockheed L-1011 carrier aircraft that will deploy the rocket will take off from Torrejón Air Force Base near Madrid and head out over the Atlantic Ocean to launch Minisat. This will be the first satellite launch from western Europe and the first flight of Pegasus since the loss of the SAC-B and HETE astronomy satellites last November (February issue, page 19). The rocket will also carry a small payload for Celestis Incorporated containing the cremated remains of 24 people, including 1960's icon Timothy Leary, *Star Trek* creator Gene Roddenberry, and space-colonization proponent Gerard O'Neill.

McDowell studies the physics of quasars and the history of the space program at the Harvard-Smithsonian Center for Astrophysics.

plain in *Nature* for January 30th, the most likely cause for such diametric polarization is a strong magnetic field. Ray's team plans to monitor the T Tauri S outflow as it expands away from the star, perhaps getting the chance to observe other aspects of the star-formation process.

In Brief

• An international team of specialists has found no evidence for a 50-meter-wide **impact crater in Honduras,** despite reports to the contrary following a spectacular bolide last November 22nd (March issue, page 12). According to Jiri Borovicka (Ondřejov Observatory) and María Cristina Pineda de Carías (National Autonomous University of Honduras), that fireball had a peak apparent magnitude of –19 to –21 — roughly a thousand times brighter than the full Moon! The event probably resulted in sizable meteorites near the Honduras-Guatemala border, though none has been recovered yet.

• The U.S. Naval Observatory plans to add a **leap second** to the world's clocks on June 30th at 23 hours 59 minutes 59 seconds Coordinated Universal Time (UTC). Since 1972, leap seconds have been added to the world's atomic clocks when needed to account for the Earth's slowing rotation. According to USNO, the last leap second was added in 1995.

• Further evidence for **intergalactic stars** has been winnowed from the Fornax Galaxy Cluster with the help of the New Technology Telescope in Chile. Tom Theuns (University of Oxford) and Stephen J. Warren (Imperial College of Science, Technology, and Medicine, London) have found what appear to be 10 planetary nebulae (the halos of dying, low-mass stars) between the cluster's galaxies. In the January 21st *Monthly Notices* of the Royal Astronomical Society, the researchers infer that as many as 40 percent of the cluster's trillions of stars lie between, rather than within, its galaxies. This parallels Hubble Space Telescope findings in the Virgo Cluster (May issue, page 18).

• Princeton University's **Robert H. Dicke** died at age 80 on March 4th. A multifaceted physicist who made fundamental contributions to the development of radio astronomy, Dicke was perhaps best known for formulating alternatives to Einstein's general theory of relativity.

MISSION UPDATE

By Jonathan McDowell

Midcourse Space Experiment

The infrared telescope aboard the Midcourse Space Experiment (MSX) has made a detailed map of the galactic plane. Stars and nebulae crowd together so closely in this region that the Infrared Astronomical Satellite was unable to tell them apart during its 1983 all-sky survey. MSX's higher-resolution observations thus provide our first comprehensive census of infrared objects along the plane of the Milky Way. In January, MSX scientists presented spectacular wide-angle views of the galactic center (see the example at right). Unfortunately the satellite's infrared observations have now come to a halt; the telescope's solid-hydrogen coolant ran out on February 26th.

BALLISTIC MISSILE DEFENSE ORGANIZATION

The MSX satellite made this 1°-wide map of the galactic center at infrared wavelengths between 6 and 20 microns. Emissions from stars, warm dust, and cool dust have been colored blue, green, and red, respectively. The brightest spot is the nucleus of the Milky Way.

Mars Global Surveyor

NASA's Mars Global Surveyor is now about halfway to its destination. The spacecraft will enter Martian orbit on September 12th, some two months after the July 4th landing of Pathfinder, also now en route to Mars. Surveyor's camera has passed several tests during its interplanetary cruise, taking pictures of the Pleiades and other targets.

Mir

The Russian space station's 12th year in orbit got off to a shaky start in February when an oxygen generator caught fire in the Kvant ("Quantum") astrophysics module. Although the blaze was extinguished quickly, the cabin filled with smoke and the six Russian, American, and German crew members had to don oxygen masks temporarily. Then, in March, other life-support equipment broke down and a robotic supply ship failed to dock with the station. All these problems forced the crew to breathe oxygen from their reserve supply as they awaited the arrival of another cargo ship in April.

Galileo

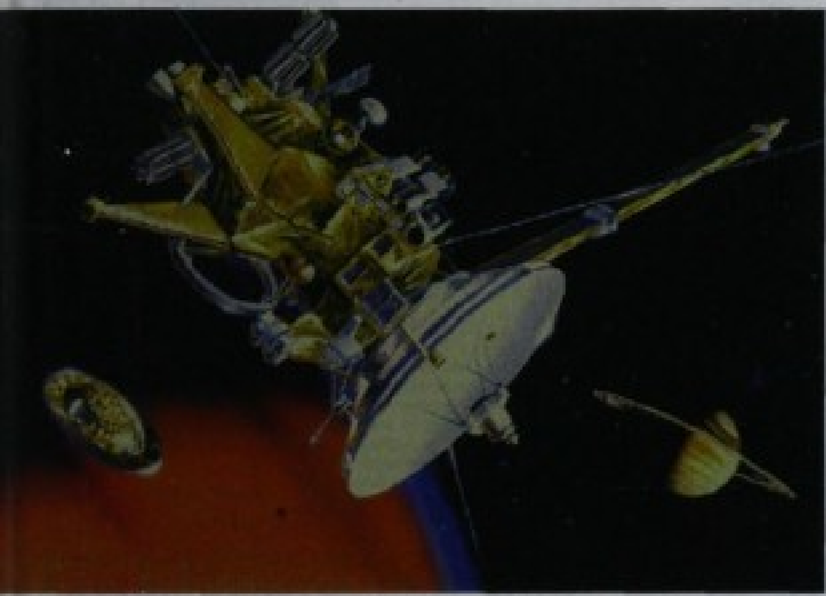
NASA has extended Galileo's tour of the Jupiter system for another two years. After its primary mission ends in December, Galileo will concentrate on exploring icy Europa, with several close flybys planned.

Since last November, when the orbiter flew by Callisto, it has made almost monthly passes near the giant planet's moons. Galileo visited Europa for the first time on December 19th, swung around Jupiter in January, then encountered Europa again in late February. Ganymede was due for successive visits in April and May. After another flyby of Callisto in June, Galileo will head farther out to explore Jupiter's magnetotail before returning to the inner satellite system in September. The extended mission will end in 1999 with a close pass of Io.

An astronomer at the Harvard-Smithsonian Center for Astrophysics, McDowell writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

Cassini

NASA's Cassini orbiter is being readied for its planned October 6th launch toward Saturn. The spacecraft survived a grueling series of "shake and bake" tests in February. Engineers at the Jet Propulsion Laboratory in California subjected the spacecraft to extreme vibrations and temperature swings like those to be encountered during its launch and flight through the solar system. Having withstood the engineers' abuse, Cassini was sent to the Kennedy Space Center in Florida, arriving on April 21st. There it will be joined to the European Space Agency's Huygens probe. Once the combined spacecraft reach Saturn in July 2004, Cassini will go into orbit around the planet and Huygens will be dropped into the dense, smoggy atmosphere of the giant moon Titan.



If all goes as planned, Cassini will dispatch the Huygens probe (left) in November 2004. Huygens will spend 2 to 2½ hours descending through the atmosphere of Titan. Courtesy NASA/JPL.

Meanwhile, February 23rd marked another crucial milestone for the project. Launched that day for the first time was a Titan IV-B rocket, which features new, more powerful solid-fuel boosters than its predecessors. The rocket's second trial will be the launch of Cassini and Huygens.

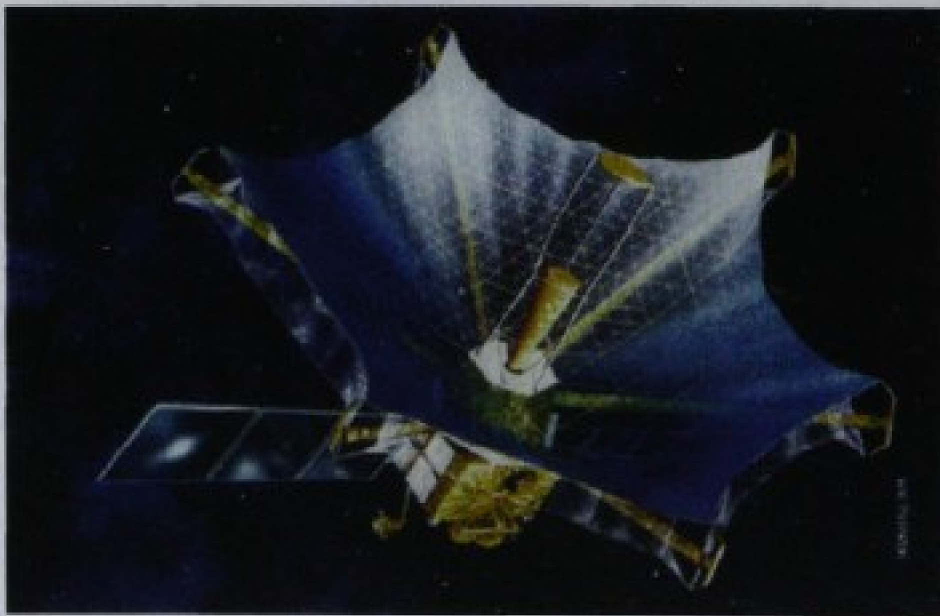
Pioneer

Science operations with the Pioneer space probes have been abandoned after a continuous run of more than 30 years. On March 31st NASA cut support for the occasional tracking of Pioneers 6, 7, and 8, which orbit the Sun between Venus and Mars. Pioneer 6 was the oldest operating spacecraft, launched in December 1965. It and three successors amassed an unmatched record of the solar wind and the interplanetary medium. (Pioneer 9 failed in 1983.) Also shut down were the particle detectors on Pioneer 10, a distant 66 astronomical units — 9.9 billion kilometers — from the Sun. Launched in 1972, Pioneer 10 was the first probe to pass through the asteroid belt and to fly past Jupiter. As Pioneer 10 heads out toward the stars, its transmissions will continue to be used for training tracking-station operators — but no more scientific data will be returned.

HALCA

A Japanese satellite named HALCA (Highly Advanced Laboratory for Communications and Astronomy) made its first radio observations in March with the detection of hydroxyl (OH) maser lines from the galactic nebula W49N. In early April HALCA was teamed with radio antennas on Earth to observe test targets simultaneously using a technique called Very Long Baseline Interferometry (VLBI). These data should resolve radio sources with the resolution of a single dish thousands of kilometers across. Testing was suspended in the weeks thereafter because the satellite was periodically passing through the Earth's shadow, reducing the amount of power available. HALCA is the satellite component of a major international effort called the VLBI Space Observatory Program.

Originally designated MUSES B during its development, Japan's HALCA radio-astronomy satellite has an antenna 8 meters across. Courtesy Institute for Space and Astronautical Science.



BeppoSAX

Launched in 1996, Italy's BeppoSAX observes X-ray sources over a very wide energy range. But the satellite encountered gyroscope problems early this year, which forced a three-week observing hiatus in February. These devices measure and control where the spacecraft is pointing, and those of similar design have been a source of trouble on other missions. Two of BeppoSAX's six gyros have already failed. However, the project has developed software to operate the satellite even if all of them should malfunction. Only a week after coming back online, the satellite made a crucial discovery: it identified the X-ray source counterpart to a gamma-ray burst.

Cluster II

The European Space Agency has approved construction of four Cluster II spacecraft to replace those lost in 1996 when the inaugural flight of Ariane 5 ended catastrophically seconds after launch. The first replacement, called Phoenix, will be fashioned from existing spare parts. Then Daimler-Benz Aerospace in Germany will build three identical satellites from scratch to complete the set. To save money, the Cluster II satellites will be launched in pairs on two Russian-built Soyuz rockets. ESA hopes to carry out both launches in the year 2000.

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BY JONATHAN MCDOWELL

As part of the Mars Pathfinder mission, the Sojourner rover will ramble across the Martian surface and probe the landing site. Courtesy NASA/JPL.

Mars Pathfinder

If all goes well on July 4th, Mars Pathfinder will become the first craft to land on the red planet since the Viking missions of 1976, thus ending a hiatus of more than two decades. This mission also marks the first attempt by NASA to land on Mars without orbiting the planet first. Pathfinder will enter the thin Martian atmosphere at high speed and slow down through a combination of drag, parachutes, and retrorockets. Then, rather than set down gently, it will thump onto the rough and ruddy surface cushioned in air bags and bounce to a stop. A stereo camera and a suite of meteorological sensors are to characterize the landing site, which is located in the mouth of an ancient river channel named Ares Vallis. The spacecraft will then deploy a six-wheeled, 11.5-kilogram rover called Sojourner. It carries a stereo camera of its own, along with an X-ray spectrometer to make crude compositional analyses of the rocks and soil within 10 meters of the touchdown site. Longer excursions may be attempted later in the mission.

Minisat 01

Spain's first astronomical satellite was launched successfully on April 21st. An aircraft carried the Pegasus rocket from Gando Air Base in the Canary Islands out over the Atlantic Ocean and dropped it. The rocket ignited a few seconds later and roared westward into space, giving Minisat 01 an orbital inclination of 151° — the highest ever. (Orbital inclinations are measured relative to due east at the equator, and most satellites are launched eastward to take advantage of Earth's rotation.) Minisat carries an experimental gamma-ray telescope and an extreme ultraviolet spectrograph.

Discovery

Five missions have been selected by NASA for further study as possible Discovery interplanetary missions. The proposed missions, chosen in April, focus on the inner planets, comets, and the solar wind. Two of them are designed to return samples to Earth: Genesis would pick up material directly from the solar wind, while Aladdin would collect pieces of the Martian moons Phobos and Deimos. Vesat would orbit Venus and study its atmosphere, following up the Pioneer Venus mission of 1978. A craft called Messenger would orbit Mercury and map it completely (Mariner 10 flew past the planet three times and made a partial map in the 1970s). Finally, the Contour mission would visit three comets. In October NASA managers will select one or two of these missions for actual development. Existing missions in the Discovery series are NEAR (Near-Earth Asteroid Rendezvous), Mars Pathfinder, Lunar Prospector, and Stardust.

Minisat 01 orbits the Earth "backward" as it studies cosmic gamma rays and ultraviolet emission. Courtesy Instituto Nacional de Tecnica Aeroespacial.

Compton Gamma Ray Observatory

NASA's Compton Gamma Ray Observatory, which has been in orbit for six years, started its second boost to a higher orbit in April. Since the last reboost in December 1993, CGRO had come only 20 kilometers closer to Earth. That is much less than the drop that occurred during its first three years, when heightened solar activity caused Earth's upper atmosphere to bloat and thus increased the amount of drag. This time the orbit is being raised higher than ever before, from 430 to 500 km. Five firings of the main thruster raised the orbital apogee (high point). Further firings in June were scheduled to raise the perigee (low point). One of Compton's instruments, OSSE, recently discovered a concentration of positron emission near the galactic center, a matter-antimatter "fountain" that reaches 15° north of the galactic plane (July issue, page 19).

Flight controllers have raised the orbit of the Compton Gamma Ray Observatory, seen here being deployed by the Space Shuttle. The satellite has been detecting high-energy emission for more than six years. Courtesy NASA.

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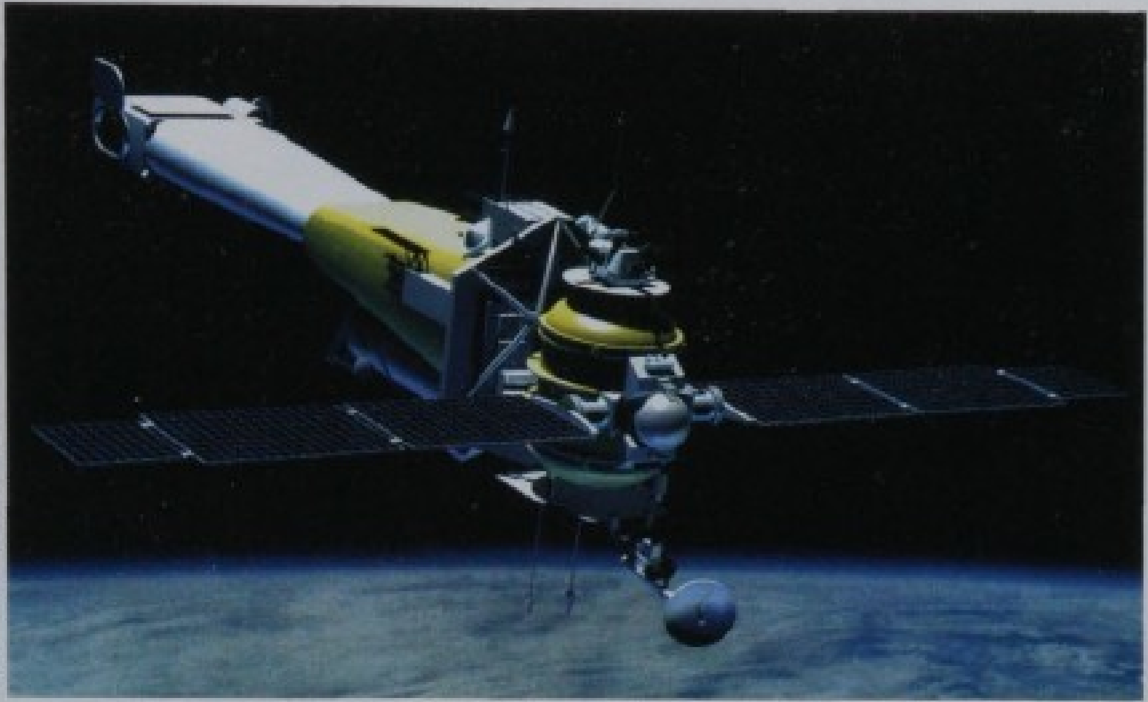
MISSION UPDATE
BY JONATHAN MCDOWELL


DANISH SPACE RESEARCH INSTITUTE

Russia's Spectrum-X-Gamma, scheduled for launch in 1999, will carry a wide assortment of telescopes from many countries for ultraviolet, X-ray, and gamma-ray studies of the cosmos.

Spektr-Röntgen-Gamma

The Russian Space Agency is preparing the first of a new series of Spektr ("Spectrum") astronomical observatories for launch in early 1999. Spektr-Röntgen-Gamma will ride a Proton rocket into an orbit with an apogee of 200,000 kilometers. The massive spacecraft will carry an international array of ultraviolet, X-ray ("röntgen"), and gamma-ray instruments, each fed by their own optics. The Joint European Telescope for X-ray Astronomy (JET-X) has two 4-meter-long reflectors for high-resolution CCD imaging. The Soviet-Danish Röntgen Telescope (SODART) uses two thin-foil reflectors to focus X-rays onto proportional counters and a spectroscopic grating. MART-LIME, an Italian-Russian collaboration, will make imaging and spectroscopic observations with a 6° field of view. Los Alamos National Laboratory's Monitoring X-ray Experiment (MOXE) will watch for outbursts from hundreds of X-ray sources known to flare erratically. Finally, the Tel Aviv Ultraviolet Experiment (TAUVEX) and the Swiss-led Far Ultraviolet Imaging Telescope Array (FUVITA) together have five 20-centimeter telescopes for observations at ultraviolet wavelengths.

Mars Global Surveyor

After a 10-month interplanetary cruise, NASA's Mars Global Surveyor reaches Mars on September 12th. The spacecraft will fire its braking rocket for 25 minutes to drop into a highly elongated path around the red planet. It will then begin the tedious process of lowering its peak altitude from 56,000 kilometers to just 400 km, where it will map the planet from a circular orbit. Surveyor will do so by repeatedly dipping into the Martian upper atmosphere, bleeding off speed with each pass. This procedure, called aerobraking, will be especially tricky because one of the probe's solar-cell panels got stuck 20° short of its fully deployed position. Flight controllers worry that air pressure could cause the panel to fold back up against the body of the spacecraft. To prevent this, the 3½-meter-long panel will be rotated 180° so that its solar cells face into the wind; in this position a small motor will be able to counter the force of the onrushing Martian air. To avoid overheating or otherwise damaging the delicate solar cells, aerobraking will be carried out more gradually and gently than originally planned. High-resolution mapping will begin in March 1998, about two months behind schedule.

Lunar A

The launch of Japan's Lunar A mission, originally scheduled for August 20th, will be delayed until February or March 1999 because of design problems. Once in orbit around the Moon, the spacecraft is to release a trio of penetrators that will free-fall into the lunar regolith at 300 meters per second and reach a depth of roughly 5 meters. But vibration tests conducted in March showed that the release mechanism is not rigid enough, which might have sent the meter-long, 40-kilogram probes into the Moon's surface at the wrong angle, destroying them.

X-ray Multi-Mirror Satellite

The first X-ray telescope for the European Space Agency's X-ray Multi-Mirror (XMM) spacecraft is undergoing testing in Germany. Scheduled for launch by an Ariane 5 rocket in 1999, XMM will carry three telescopes, each with 58 nested, cylindrical mirrors. The trio will produce both images and spectra of cosmic X-ray sources. Although these instruments will have lower angular resolution than those on NASA's X-ray Astrophysics Facility (AXAF), they will have much greater sensitivity, mainly because XMM's highly elongated orbit will facilitate long exposures. A fourth telescope will provide simultaneous observations at visible or ultraviolet wavelengths.

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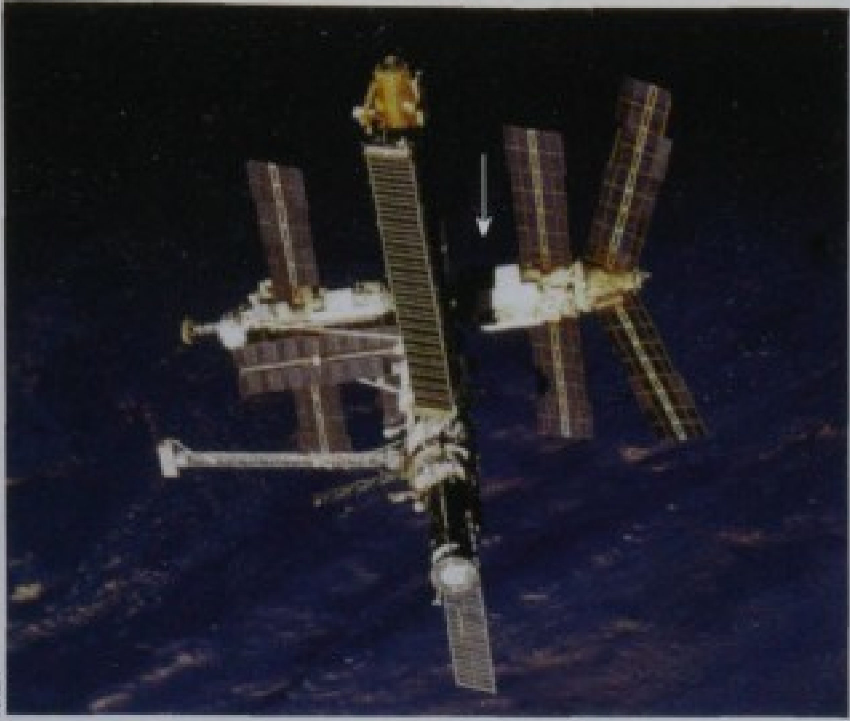
EUROPEAN SPACE AGENCY

The first of three telescope modules for the European Space Agency's X-ray Multi-Mirror (XMM) satellite is now being tested in Germany.

MISSION UPDATE

BY JONATHAN McDOWELL



A collision in June damaged Mir's Spektr module (arrowed) and has made the complex's future uncertain. This preaccident view was taken in September 1996. *Below:* Shuttle commander Charles J. Precourt (left) greets his Mir counterpart, Vasiliy V. Tsibliev in May 1997.

Mir

Forty years have passed since Sputnik 1 rocketed into orbit on October 4, 1957. For all our subsequent successes in space exploration, the task can at times seem as difficult and risky as ever. It's been a particularly tense year aboard the Mir orbital station. On February 23rd commander Vasiliy Tsibliev and five crewmates faced a life-threatening crisis when a lithium perchlorate canister ignited and spewed 2-foot-long flames inside the Kvant astrophysics module. As the complex filled with black smoke, the crew donned gas masks and used fire extinguishers to keep the interior walls from catching fire. The canister, whose contents react to provide breathable oxygen, burned itself out after 15 minutes and the smoke slowly cleared. But stress to the life-support equipment triggered numerous hardware failures in the following weeks.

The Space Shuttle *Atlantis* arrived in May to replace American crewman Jerry Linenger with Michael Foale, then another near-fatal accident occurred on June 25th. Tsibliev was testing a system for manually controlling the docking of a Progress cargo ship. Past dockings have ultilized an automated system, but Russia plans to discontinue its use to save money. Unfortunately, the 8-ton Progress M-34 approached too fast and slightly off course, colliding with the station's Spektr module. As air hissed out of the damaged space station, the crew rushed to seal off the hatch to Spektr after disconnecting electrical supply cables strung through the hatch opening. Another Progress was rushed into orbit in early July. It carried a new hatch that will allow the cables (once reconnected) to pass through, thus restoring much of the electrical power.

FIRST and Planck

In the wake of a major budget crunch, the European Space Agency has announced its intention to merge two flagship projects. Under this plan the Far Infrared and Submillimetre Telescope and a second mission named Planck would share a single spacecraft. FIRST is destined for the L_2 Lagrangian point beyond the Moon. Its telescope and three proposed instruments will study radiation from high-redshift galaxies and the interstellar medium at wavelengths between 85 and 600 microns, filling the spectral gap between ESA's Infrared Space Observatory and ground-based radio telescopes. Planck (formerly COBRAS/SAMBA) is a smaller spacecraft with a cryogenically cooled far-infrared telescope and dish-shaped submillimeter telescope to study irregularities in the cosmic microwave background. The new plan calls for Planck's telescopes to ride alongside FIRST on a shared service module. A final decision is expected next year, with launch to follow around 2005.

Lunar Prospector

NASA is readying the third spacecraft in its Discovery series for a deep-space journey. On September 24th Lunar Prospector will be launched from Florida on a new Lockheed Martin Launch Vehicle 2 rocket. After a five-day trip to the Moon, the spacecraft is to settle into an orbit 110 kilometers high. There is keen interest in Lunar Prospector's neutron spectrometer, which will search for evidence of frozen water in permanently shadowed craters in the polar regions. The spacecraft also carries a gamma-ray spectrometer to map the elemental composition of the terrain below. Completing the payload are an alpha-particle spectrometer to detect radioactive gas escaping from the surface, and a magnetometer to map the Moon's magnetic field. Lunar Prospector won't be the first probe in a polar orbit around the Moon: Lunar Orbiter 4 and Explorer 35 preceded it in the 1960s, but at much higher altitudes.

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Lunar Prospector may determine once and for all whether water ice lies hidden near the Moon's poles. Courtesy Lockheed Martin.

MISSION UPDATE

BY JONATHAN McDOWELL

Infrared Space Observatory

According to the European Space Agency, the Infrared Space Observatory (ISO) completed its nominal 18-month mission in May. However, the liquid helium used to cool the satellite's optics and detectors is lasting much longer than expected. By August ISO had already operated two months beyond its planned lifetime, and it may well survive until next March. To stay cool so long, ISO has avoided looking in a large part of the sky near the Earth. Because ISO has a highly elliptical orbit that precesses very slowly, this "forbidden zone" has hidden the same stars since launch in November 1995. So mission planners had to make the unenviable choice of losing either the galactic center or the Orion region, both of prime interest to infrared astronomy. Orion drew the short straw, but now that constellation is at last emerging from the forbidden zone, and ISO scientists plan to make the most of this unexpected bonus opportunity.

Loaded with more than 2,000 liters of superfluid helium before launch, the Infrared Space Observatory has operated longer than expected. Courtesy European Space Agency.

Voyagers 1 and 2

The twin Voyager space probes recently celebrated 20 years in space. Voyager 2 left Earth on August 20, 1977. Voyager 1 followed on September 5th, using a faster track that overtook its sibling and delivered it to Jupiter in March 1979. Reaching Saturn in 1980, Voyager 1 laid the groundwork for the Cassini mission by swinging past Titan. This redirection forced it out of the ecliptic plane and left the remaining glory to Voyager 2, whose flybys of Uranus in 1986 and Neptune in 1989 had not been part of the official plan at launch. Both of these robotic emissaries continue to operate well. They're now beyond the orbit of Pluto at heliocentric distances of 10.1 and 7.9 billion kilometers, respectively.

Voyager 1 rockets into space on September 5, 1977, aboard a Titan III/ Centaur launch vehicle. Its twin had left Earth 16 days later. Courtesy NASA/JPL.

Notably, these enduring craft were not NASA's first choice. The agency had initially proposed an even more ambitious Grand Tour mission, during which two pairs of spacecraft would visit all five outer planets by exploiting a once-in-150-years alignment. But the tight budgets and uncertain technology of the early 1970s resulted in a pair of smaller craft, which — initially — were to visit only Jupiter and Saturn. They took shape as the Mariner Jupiter-Saturn (MJS) project, oversize versions of spacecraft that had visited Mercury, Venus, and Mars in the 1960s and 1970s, and cousins of the large Viking orbiters. The ambitious design included an articulated platform bearing a battery of cameras and other instruments. They also carried powerful but largely unproven X-band radio transmitters, a critical design decision that made the Uranus and Neptune flybys possible.

STS 85

August's 12-day Space Shuttle mission, STS 85, was devoted largely to tending a free-flying satellite for studies of Earth's atmosphere and testing a robotic arm intended for the International Space Station. But *Discovery* also carried a healthy complement of astronomical payloads. One was the International Extreme Ultraviolet Hitchhiker, a joint NASA-Italian project making its second flight. IEH 2 included the UVSTAR spectrograph, whose main target was the torus of ionized plasma that fills Io's orbit around Jupiter. Another telescope in the package, SEH (Solar EUV Hitchhiker), measured the absolute ultraviolet output of the Sun; it operated in concert with DATA-CHASER, which recorded the solar disk at ultraviolet and soft-X-ray wavelengths.

Elsewhere aboard STS 85 were a Belgian instrument to measure the Sun's total energy output, and a cosmic-dust collector attached to the Japanese robotic arm. The crew also operated the Southwest Ultraviolet Imaging System (SWUIS), a 7-inch Maksutov telescope optimized for ultraviolet studies. It recorded more than 300,000 images of Comet Hale-Bopp during nine viewing sessions.

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MISSION UPDATE

BY JONATHAN McDOWELL

Advanced Composition Explorer

Launched by a Delta rocket on August 25th, the Advanced Composition Explorer (ACE) is NASA's newest sentinel for studying the composition of the solar wind. The spacecraft will take roughly three months to reach the L_1 Lagrangian point, 1½ million kilometers from Earth in the Sunward direction. Here terrestrial and solar gravity, as well as other forces, are in balance, so only occasional rocket bursts are needed to keep ACE in its "halo" orbit around the L_1 point. (The SOHO solar observatory occupies this same region of space.) Built by the Applied Physics Laboratory of Johns Hopkins University, ACE represents the last of NASA's relatively expensive Delta-class Explorer missions. Its nine mass spectrometers and charge analyzers will characterize the elements and isotopes flowing outward from the Sun and arriving from deep space as cosmic rays.

The Advanced Composition Explorer weighed 785 kilograms at launch and has a "wingspan" of 5 meters. Courtesy JHU/APL.

Lewis

The first satellite in NASA's Small Spacecraft Technology Initiative, Lewis was meant to demonstrate a "faster, cheaper" approach to mission design and operation. Unfortunately, three days after liftoff on August 23rd aboard a Lockheed Martin Launch Vehicle (LMLV 1), an imbalance in the craft's attitude-control thrusters sent it into a rapid tumble. With its solar panels pointed away from the Sun, its batteries rapidly discharged and the brand-new spacecraft fell silent. NASA expressed hope that attempts to revive Lewis would be successful, but the spacecraft reentered the atmosphere on September 26th. Beyond its main Earth-observing payload, Lewis had onboard the Ultraviolet Cosmic Background (UCB) experiment, which would have studied diffuse ultraviolet radiation from the interstellar medium and distant galaxies.

Japan

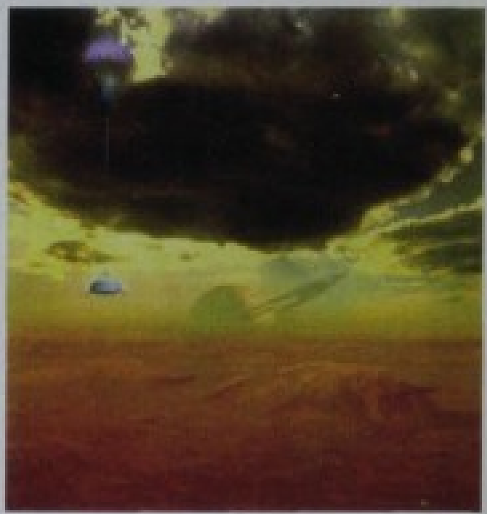
The Japanese space program has been going through rough times lately. A 14 percent cut in long-term funding for the National Space Development Agency (NASDA) has forced both a reduced size and a delay for the HOPE spaceplane, the combination of the Selene lunar orbiter and lander into a single spacecraft, and downsizing of other satellites. Meanwhile, several programs now under way have run into stumbling blocks. First came an 18-month postponement of the ambitious Lunar A mission (September issue, page 26), being developed by the Institute of Space and Astronautical Science. Because of design concerns, that launch is now scheduled for February 1999. In July the large ADEOS Earth-observing satellite failed after only a year in orbit. Worried that the COMETS communication satellite might suffer the same fate because it utilizes so many ADEOS components, NASDA managers have postponed its launch until next February.

Not all the news is gloomy, however. Tests of a robot arm intended for the International Space Station went well during the flight of the Space Shuttle *Discovery* in August (November issue, page 28). A pair of Engineering Test Satellites and the Tropical Rainfall Measuring Mission are still scheduled for November launches. And the ASCA X-ray astronomy satellite continues to work well after four years in orbit.

Unlike its predecessors, which borrowed heavily from American technology, the H II booster is an all-Japanese product that generates 700,000 pounds of thrust at liftoff. Courtesy NASDA.

Cassini-Huygens

In order to exploit favorable planetary alignments and reach Saturn in 2004 as planned, the Cassini-Huygens mission needs to leave Earth between October 6th and November 4th. Over the summer, a threat to the first-available launch date was averted when engineers quickly fixed leaks found in the Titan/Centaur launch rocket. However, at the beginning of September a major blunder forced a delay. The refrigeration unit within the launch vehicle's payload shroud was turned up too high, damaging insulation on the Titan-bound Huygens probe. The spacecraft had to be removed and disassembled to remove any pieces of insulation that might have contaminated its delicate interior. At press time, NASA had rescheduled the departure for the morning of October 13th. Meanwhile, antinuclear activists had demanded that the launch be canceled because Cassini is powered by radioisotope generators, which use heat from the decay of plutonium to provide electricity. The generators are in canisters designed to survive even a catastrophic launch explosion.



If all goes well, in late 2004 an instrumented probe called Huygens will descend through Titan's murky atmosphere and relay its findings to Earth via the Cassini orbiter. Courtesy European Space Agency.

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MISSION UPDATE

BY JONATHAN McDOWELL

Astronomy Satellites

The centerpiece of NASA's 1998 space-astronomy program will be the launch of AXAF, the Advanced X-ray Astrophysics Facility. This revolutionary orbiting telescope will join Hubble and Compton as the third of the agency's Great Observatories. Last year, ground tests of its mirrors confirmed that AXAF should produce much sharper pictures than any previous X-ray mission, with subarcsecond resolution comparable to images obtained in visible light by ground-based telescopes. AXAF also carries gratings that disperse the X-rays into a spectrum; it will be the first mission to study the X-ray universe with both sharp images and high spectral resolution.

The observatory, whose final assembly began in late 1997 in TRW's factory near Los Angeles, will fly into orbit in August 1998 aboard the Space Shuttle *Columbia*. Then astronauts will release AXAF into a circular 300-kilometer-high orbit on the first step of a much longer journey. Unlike Hubble, AXAF will be placed far from the Earth, where it can make long observations without our planet getting in the way. Two solid-fuel rockets are to fire shortly after AXAF is deployed, taking the observatory 60,000 km from Earth. AXAF's own propulsion system then takes over, and after several days the spacecraft will have a perigee of more than 10,000 km and an apogee of 140,000 km. Several weeks must elapse while trapped gases that could contaminate the mirrors leak away into the vacuum. Only then can the aperture door be opened and the commissioning of the observatory begin.

TRW

HUGHES DANBURY OPTICAL SYSTEMS

Above. **After its launch by the Space Shuttle in September 1998, the Advanced X-ray Astrophysics Facility will ascend to a high orbit for its detailed, sensitive observations of cosmic sources. *Left:* AXAF's optics are the largest and most accurately shaped X-ray mirrors ever built. When X-rays glance off one of the four nested surfaces, each a precisely tapered cylinder, they are brought to a focus.**

A smaller astronomy observatory will fly in October on a Delta rocket. The Far Ultraviolet Spectroscopic Explorer (FUSE) carries a 64-cm telescope that covers the 900- to 1200-angstrom ultraviolet range. The telescope will direct light onto a very high resolution spectrograph to allow astronomers to study the precise composition and temperature of stars and gas clouds, as well as use Doppler shifts to measure line-of-sight velocities accurately.

NASA's Small Explorer program continues to suffer delays, with infrared and submillimeter observatories originally scheduled for 1998 slipping to 1999. However, the TRACE (Transition Region and Coronal Explorer) X-ray solar observatory is scheduled to take off in March aboard a winged Pegasus rocket.

Solar-System Exploration

January sees the first planetary encounter of the year — and the target is Earth! The Near Earth Asteroid Rendezvous (NEAR) spacecraft returns home briefly for a gravity assist after its two-year trip to the asteroid belt. The flyby will redirect NEAR toward its final destination, minor planet 433 Eros, with an arrival in early 1999. Galileo, still in orbit around Jupiter, will be making approaches to the Jovian moons Io and Europa throughout the year, while Lunar Prospector is expected to be in orbit around the Moon.

In April, the Saturnbound Cassini probe makes its first planetary flyby on a convoluted seven-year journey to the ringed planet. Cassini will gain speed without using precious

JET PROPULSION LABORATORY

The Cassini spacecraft fires its engine to brake into orbit around Saturn in July 2004. Four months later it will release the European Space Agency's Huygens probe for a plunge into the dense atmosphere of the giant moon Titan.

rocket fuel by slipping past our neighbor planet Venus, taking that opportunity to test its cameras and other instruments. It will make another pass of Venus in 1999 before heading back to Earth and then to the outer solar system.

July sees the inaugural launch in NASA's New Millennium program, which focuses mainly on tests of advanced technologies rather than scientific goals. The first probe, Deep Space 1, will fly on a new, lighter version of the Delta rocket using only three strap-on solid-fuel boosters and a smaller third stage. DS 1's key experiment is its propulsion system: it will be the first probe to utilize solar-electric propulsion, or "ion drive," as its main engine. Other tests include a lightweight combined camera and spectrometer, and the use of solar concentrators instead of traditional solar-cell panels to provide electricity. In 1999 DS 1 will fly past minor planet McAuliffe (named for teacher Christa McAuliffe, who died aboard Space Shuttle *Challenger*) on its way to visit Mars and Comet West-Kohoutek-Ikemura in the year 2000.

In December, the Mars Surveyor 1998 lander will escape Earth's gravity aboard a Delta rocket. It and a companion orbiter, to reach the red planet in 1999, will be described in this column in the months to come. Then, at year's end, the Mars Global Surveyor should be nearing its final orbit — after almost a year of aerobraking — and preparing to make the most detailed maps of the Martian surface ever.

JET PROPULSION LABORATORY

Mars Global Surveyor (MGS) is repeatedly dipping into the red planet's upper atmosphere so that air friction will lower its orbit. Problems with one solar-cell "wing" in October caused some concern (see page 32).

Space Technology

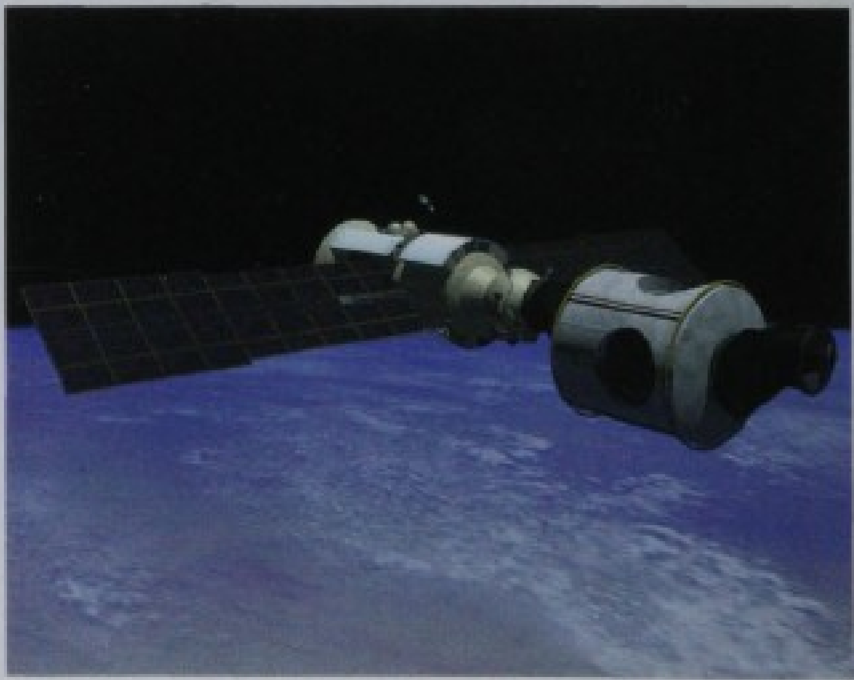
The coming year will see the beginning of transition between the Mir orbital complex and the new International Space Station (ISS). Provided no more serious failures occur, Russian astronauts will maintain their presence on Mir throughout the year, but the American presence is coming to an end. David Wolf will be replaced by Andrew Thomas in January, but when Thomas returns to Earth in June he is not currently expected to be replaced; Americans and Russians will next fly together in 1999 on the first ISS crew. The station's assembly begins in June with the launch of the Functional Cargo Block, a Russian-built module. Several Space Shuttle missions will bring up other components to join it, culminating at year's end with the Service Module, a copy of Mir's core unit. There have been numerous problems with the financing of the Service Module, whose schedule problems caused a six-month delay in the whole ISS program. NASA is having an Interim Control Module built stateside, which could be launched instead if needed. The only 1998 Shuttle missions not devoted to Mir or ISS are the Neurolab science mission and the AXAF launch.

Other events of note in 1998 include the first launch of the Zenit-3SL rocket by Sea Launch. A joint venture between Boeing, Ukraine, and Russia, this commercial rocket is designed to lift off from a mobile launch pad floating in the ocean. The idea is similar to the San Marco launch platform off the Kenyan coast, used by the Italians since the 1960s. But that platform always stayed in one place and could be used to launch only very small satellites. Among other new launch vehicles to be tested are Orbital Science's X-34, an air-launched rocket similar in concept to its smaller Pegasus that introduces a liquid-fueled engine developed by NASA, and the Boeing Delta 3, with a new liquid-hydrogen upper stage. Provided nothing goes wrong on its second test flight, Europe's mighty Ariane 5 should begin regular launches.

ORBITAL SCIENCES CORP.

The X-34 spaceplane is slated to make its debut in 1998. This robotic, single-engine rocket will drop from a wide-body jet, accelerate to eight times the speed of sound and a peak altitude of 80 kilometers (50 miles), then make an automated touchdown on a conventional runway. NASA planners hope that the X-34's successors will dramatically lower the cost of transporting cargo and people to and from Earth orbit.

Jonathan McDowell, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*



NASA

The International Space Station (ISS) will begin to take shape in the latter half of 1998. First up will be Russia's Functional Cargo Block (at left), which will then be joined by NASA's Node One (at right). Over the next few years a giant research complex will be assembled around this modest core.

MISSION UPDATE

BY JONATHAN McDOWELL

Mars Pathfinder

On November 4th project managers at the Jet Propulsion Laboratory announced that the Sagan Memorial Station on Mars had fallen silent and was presumed dead. The last full transmission from Mars Pathfinder's base station came in on September 27th; thereafter only faint, brief signals on October 2nd and 7th broke the silence from Ares Vallis. Commands will continue to be sent to the lander at least once per month in the hope of regaining contact. But apparently the internal battery that helped keep the station warm has given out, as predicted. If so, repeated exposure to the cold Martian night have likely have caused the lander's electronics to fail, probably permanently. Since the rover Sojourner communicates to Earth via the lander, it too is out of touch. Still, Mars Pathfinder lasted much longer than its modest one-month objective; it also validated the airbag landing method for rocky sites, determined the composition of rocks and the properties of dust in its vicinity, and strengthened the idea that liquid water was common on the Martian surface in the past.

JPL/NASA

The rover Sojourner awaits instructions for approaching the large rock "Chimp" to its right. The rock's elemental composition was obtained a week later, just before Mars Pathfinder fell silent on September 27th.

Lunar Prospector

NASA hopes there will be no further delays to preclude the January 5th launch of Lunar Prospector, the next mission in its Discovery series. The probe's departure has already been postponed twice because its new Athena 2 rocket had not been fully tested. This will be the first launch from the Spaceport Florida Authority, a new commercial site at Cape Canaveral with a single converted Trident missile launch pad. Lunar Prospector will survey the Moon from orbit and hunt for water at the lunar poles. Its data will complement the global mapping done in 1994 by the Department of Defense's Clementine spacecraft. Meanwhile, a second Clementine mission, which would have explored several near-Earth asteroids, recently fell victim to President Clinton's line-item veto.

BeppoSAX

After spending two months in safe mode following multiple gyroscope failures, the Italian BeppoSAX X-ray observatory was revived in August to test new attitude-control software that requires only a single working gyro. Normal science observations resumed on August 14th, and by early September approval was given to resume observing "targets of opportunity" on short notice. This quick-response capability is particularly important for tracking gamma-ray bursts. However, as of mid-November, no new bursts had been observed since BeppoSAX's return to service. One was nearly seen on October 29th, when the spacecraft's gamma-ray burst monitor spotted an event in Gemini. But the source was located 20° outside the view of its wide-field X-ray camera.

Explorer 1

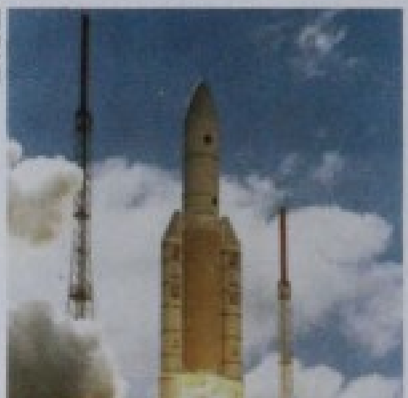
NASA, Caltech, and the Jet Propulsion Laboratory all plan 40th-anniversary celebrations to commemorate the first U.S. satellite, Explorer 1. Rushed to completion in response to the Soviet Union's Sputnik successes, the 5-kilogram payload was launched into a 360-by-2,570-kilometer orbit by a Jupiter C rocket on January 31, 1958 (February 1st Universal Time). Explorer's charged-particle detector discovered trapped radiation around Earth that became known as the Van Allen belts.

JPL/NASA

The jubilant trio of JPL director William Pickering (left), physicist James Van Allen, and rocketeer Wernher von Braun hold a model of Explorer 1 and its integrated Sargeant rocket stage after the satellite's 1958 launch.

Ariane 5

Officials at the European Space Agency breathed a collective sigh of relief when the second Ariane 5 heavy-lift rocket placed two dummy satellites in orbit at the end of October. (The first Ariane exploded seconds after launch in June 1996, destroying four Cluster satellites.) While largely successful, this second trial was marred by a sensor problem that triggered a premature shutdown and left the satellites in an orbit thousands of kilometers lower than expected. Like the Space Shuttle, Ariane 5 has a main engine fueled by liquid hydrogen and two huge solid-propellant strap-on boosters. This "stack" is then topped with a conventional upper stage and a payload. Ariane 5 was originally designed to carry the Hermes spaceplane, but European governments have since lost interest in piloted space flight and most Ariane 5 flights will now loft heavy communications satellites into orbit. Future European astronomical satellites will also rely on Ariane 5, the first of which will be the X-ray Multi-Mirror (XMM) observatory in late 1999.



ESA/CNES

An Ariane 5 booster roars from its launch pad on October 30, 1997.

JONATHAN McDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Technicians at TRW in Redondo Beach, California, assemble the AXAF spacecraft. Courtesy AXAF Science Center.

Advanced X-ray Astrophysics Facility

Launch of the Advanced X-ray Astrophysics Facility (AXAF), one of NASA's "Great Observatories," may be delayed slightly because its electrical integration and testing are behind schedule. Although the observatory itself is almost completely assembled and its performance was checked out extensively in calibrations last year, more tests are needed to ensure that the satellite will carry out commands correctly. Builder TRW had contracted to deliver AXAF by June 1st, in preparation for its launch aboard the Space Shuttle *Columbia* at the end of August. But delivery may now be a little later than planned. NASA has not determined what effect this will have on the launch date, but the project's astronomers are still optimistic that they will be seeing data from AXAF by the end of the year.

SPARTAN 201

The fourth flight of this Shuttle Pointed Autonomous Research Tool for Astronomy on mission STS 87 was a dramatic failure. The free-flying spacecraft carries an ultraviolet coronal spectrometer and a white-light coronagraph to study the outer atmosphere of the Sun. On last November's flight it was to help recalibrate the instruments on the Solar and Heliospheric Observatory (SOHO), which has been in space since 1995. However, SOHO suffered a systems failure on the day *Columbia* headed into orbit and was inoperable for a couple of days, delaying the joint experiment. With that issue resolved, SPARTAN was deployed on November 21st. But as NASA scientists waited for the spacecraft to perform its orientation maneuver, nothing happened. An attempt to recapture SPARTAN with the shuttle's robot arm also failed and, worse, left the spacecraft tumbling. Three days later spacewalking astronauts grabbed SPARTAN with their gloved hands, and it was returned to Earth undamaged. An investigation showed that the satellite was working perfectly but that a crucial command to switch it on never reached the craft. As this issue went to press NASA had not yet determined if the astronauts were responsible.

The SPARTAN 201 solar-observing spacecraft appears at the end of Space Shuttle *Columbia's* robot arm. Its coronagraphic telescope is 2.3 meters long. Courtesy NASA/JSC.

Small Explorers

NASA officials have approved two new Small Explorer missions for development. The High Energy Solar Spectroscopic Imager (HESSI) combines simultaneous imaging and spectroscopy of both gamma rays and X-rays. It will monitor the energy release in solar flares on time scales down to 10 milliseconds, and its telescope will localize the emission to within a few arcseconds. GALEX, the Galaxy Evolution Explorer, will use a 50-centimeter telescope to carry out the first detailed all-sky survey at ultraviolet wavelengths and a deep search for distant galaxies. The satellite's cameras and spectrographs will measure redshifts, dust extinction, and ultraviolet luminosity in 100,000 galaxies closer than redshift $z = 2$. It should also determine whether the rate of star formation changes rapidly in galaxies and the kinds of stars that form at various times in their evolution.

Discovery Missions

NASA has also selected two more planetary missions in the Discovery program. Genesis (formerly Suess-Urey) will spend two years collecting particles from the solar wind at the L_1 Lagrangian point on the Earth-Sun line; it will then return the samples in a sealed capsule to the Utah desert. The goal is to determine the original chemical and isotopic composition of the solar nebula. The second mission, Contour (Comet Nucleus Tour) is an ambitious project to visit comets 2P/Encke in 2003, 73P/Schwassmann-Wachmann 3 in 2006, and 6P/d'Arrest in 2008. Contour will fly close to the nuclei of these well-known periodic comets, recording spectra and analyzing dust coming from them. These new Discovery missions complement one already selected, Stardust, which will return dust from Comet 81P/Wild 2 to Earth in 2004. NASA's new emphasis on its Origins scientific theme comes out clearly in these recent selections. The emphasis on cometary exploration marks a big comeback from the agency's refusal to launch a Halley's Comet probe in the 1980s.

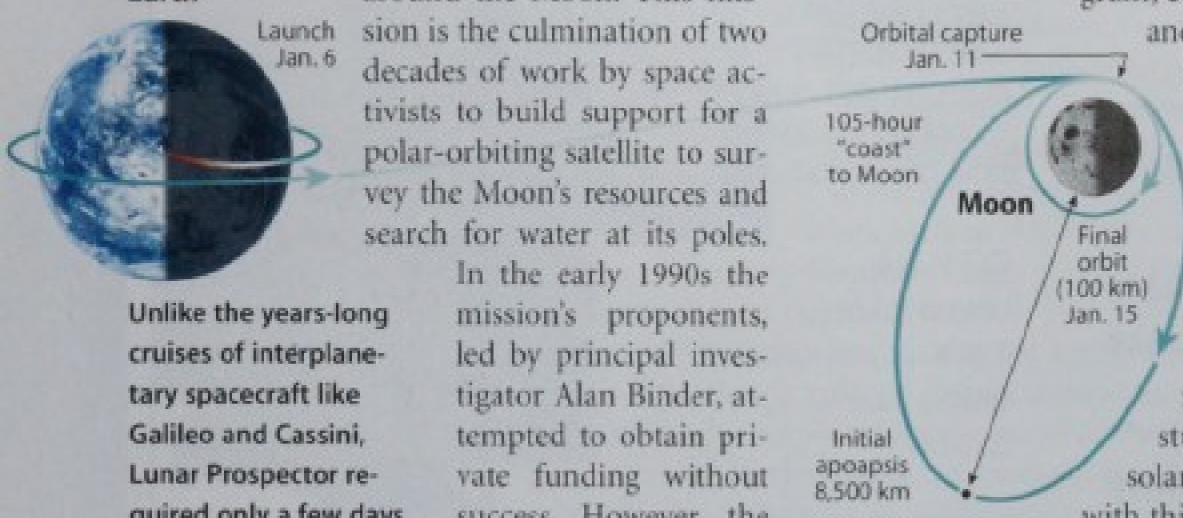
Jonathan McDowell *is an astronomer at the Harvard-Smithsonian Center for Astrophysics who specializes in extragalactic objects. He writes a weekly electronic newsletter on the space program (http://heawww.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Lunar Prospector

Following its spectacular nighttime launch on January 6th, NASA's Lunar Prospector is now collecting data in orbit around the Moon. This mission is the culmination of two decades of work by space activists to build support for a polar-orbiting satellite to survey the Moon's resources and search for water at its poles.



Unlike the years-long cruises of interplanetary spacecraft like Galileo and Cassini, Lunar Prospector required only a few days to reach its objective.

In the early 1990s the mission's proponents, led by principal investigator Alan Binder, attempted to obtain private funding without success. However, the lunar-orbiter concept gained popularity with NASA's revised emphasis on small, cheap missions, and in 1995 Prospector was selected as part of the Discovery program (*S&T:* September 1995, page 6).

Prospector's launch was delayed by six months, but finally the first flight of Lockheed Martin's Athena 2 rocket placed the spacecraft in a temporary parking orbit after lifting off from a commercial pad at Cape Canaveral. Firing a final, solid-fuel stage then put the probe on a four-day coast to the Moon. On January 11th Prospector's own engines placed it in elliptical orbit around the poles. Repeated firings over the next few days were used to maneuver the spacecraft into a low orbit just 100 kilometers above the lunar landscape. The satellite, also built by Lockheed Martin, carries instruments to measure alpha particles, neutrons, electrons, and gamma rays emanating from the surface; others will map the magnetic field and gravity of the Moon. Its spinning cylindrical body, reminiscent of the communications satellites of the early 1980s, is simpler and cheaper than the three-axis stabilization system used on most modern spacecraft.

LOCKHEED MARTIN

The scientific findings of NASA's Lunar Prospector, seen here prior to its January launch, will complement the data gathered in 1993 by Clementine — a Department of Defense mission.

Equator-S

A new space-science satellite was launched last December 2nd to round out the International Solar-Terrestrial Physics program, complementing results from the SOHO, Polar, Geotail, and Wind satellites already in orbit. The Max Planck Institute for Extraterrestrial Physics in Germany developed the small Equator-S satellite to study Earth's equatorial magnetosphere, replacing a more ambitious mission canceled by NASA in the 1980s. Equator-S carries instruments to understand the effects of the Sun on the space environment near Earth, particularly the "plasma sheet" in the geomagnetic tail and the magnetosphere's outer boundary (the magnetopause). The Max Planck science team will study how the solar wind interacts with this protective "bubble" around the Earth, which is considered similar to the plasma boundaries in many astrophysical objects. Equator-S was launched piggyback with a communications satellite into geostationary transfer orbit by an Ariane 4 rocket, then it fired a small motor to double its apogee height to 67,000 km.

MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS

Equator-S carries seven scientific instruments in a spinning, 230-kilogram package measuring 2.3 meters in diameter.

Ulysses

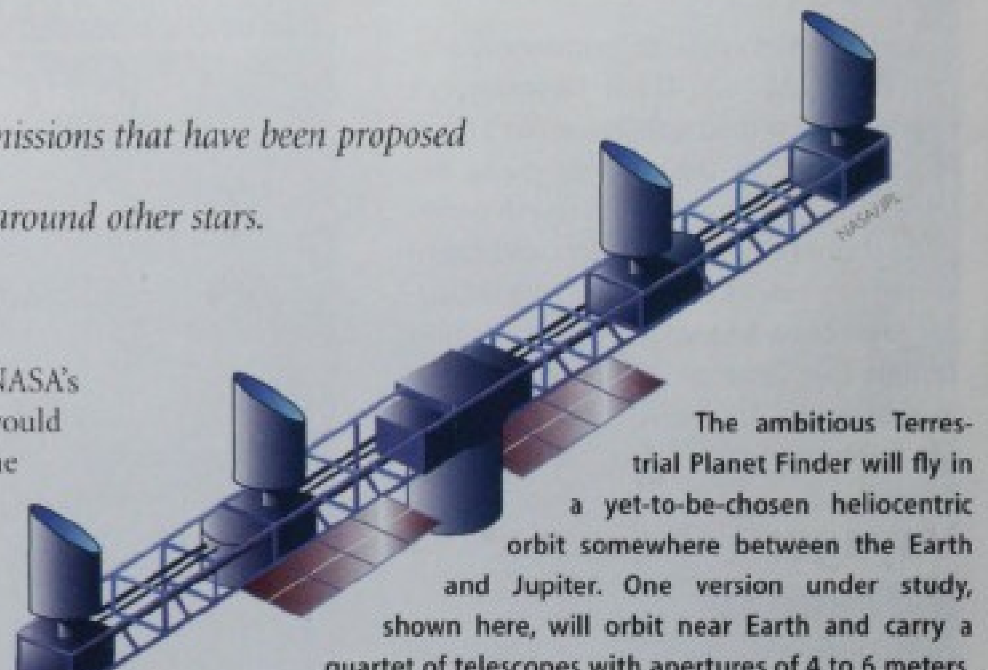
The European Space Agency's Ulysses, launched in 1990, is the first and only spacecraft to have traveled over the Sun's polar regions. Since completing its north-polar pass in 1995 (*S&T:* March 1996, page 24), Ulysses has been arcing back down toward the ecliptic plane. It reaches aphelion at 5.4 astronomical units, near the orbit of Jupiter, in late April. ESA communicates with Ulysses via NASA's Deep Space Network, and science data is still streaming in. In January Ulysses began an experiment called MIDAS (Multi-Project Investigation During the Alignment of Spacecraft), conducted jointly with the Advanced Composition Explorer (ACE) launched in 1997. The pair are studying high-speed clouds of plasma released into space from the Sun's atmosphere, called coronal mass ejections (CMEs), as well as variations in plasma believed to be of interstellar origin. ACE is stationed at the Lagrangian point on the Sunward side of Earth, while Ulysses reached opposition, aligned with the Earth-Sun line, on February 26th. With Ulysses so much farther away, an impressive baseline can be obtained to study the evolution of CMEs and other solar-system-wide events.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

This month's column highlights a quartet of astronomy missions that have been proposed as part of NASA's Origins program to search for planets around other stars.



The ambitious Terrestrial Planet Finder will fly in a yet-to-be-chosen heliocentric orbit somewhere between the Earth and Jupiter. One version under study, shown here, will orbit near Earth and carry a quartet of telescopes with apertures of 4 to 6 meters.

Deep Space 3

To be launched around the year 2001, DS 3 is part of NASA's New Millennium technology-development series and would consist of three satellites launched into orbit around the Sun. The satellites would stay in an equilateral triangle a few hundred meters on a side, with their relative distances measured accurately by lasers and maintained by small thrusters. Two would use flat, 12-centimeter-wide mirrors to reflect starlight to the third spacecraft, called a combiner. The combiner would use adjustable optics to keep the length of the two incoming light beams constant to within a few nanometers (tens of angstroms). Combining the beams in an optical interferometer would then yield images with a resolution of a milliarcsecond or less. Such capability could resolve a truck's headlights from the distance of the Moon. However, it's important to realize that DS 3 and other proposed planet hunters will have only a very small field of view — so none of them will replace Hubble's ability to return spectacular images of nebulae and galaxies.

Space Interferometry Mission

The Jet Propulsion Laboratory is also developing the Space Interferometry Mission, which unlike Deep Space 3 will be a single satellite. Its 10-meter-wide interferometer will afford a resolution of 10 milliarcseconds over a 0.3-arcsecond field of view. The individual "siderostat" telescopes will be movable to keep the light path stable to about 10 angstroms. SIM's main task is to search for wobbles in the positions of stars, thereby indicating the presence of planets around them. It will also be able to measure parallaxes of bright stars out to 80,000 light-years (25 kiloparsecs), at last putting the galactic distance scale on a firm footing. Finally, its high-resolution images of the nearest active galactic nuclei should provide convincing evidence for (or against) the presence of massive black holes in those objects.

NASA's Space Interferometry Mission may reach orbit as early as 2005. Prototypes of its high-precision truss were tested aboard the Space Shuttle mission STS 85 last August. Courtesy NASA/JPL.

Terrestrial Planet Finder

The most ambitious mission now being considered by NASA, the Terrestrial Planet Finder would be a spaceborne infrared interferometer powerful enough to obtain infrared spectra of terrestrial-sized planets around other stars. These spectra would be good enough to resolve absorption features in the planets' atmospheres, thus identifying candidates for habitable worlds. TPF could become a reality by the end of the next decade, but the technology required to cancel out a primary star's light completely enough to allow this kind of observation is still some way off. Its proposed successor, Planet Imager, would actually resolve surface features on extrasolar planets by having several TPF-class interferometers flying in a 6,000-km-wide formation and observing in concert. Although an exciting challenge, for now Planet Imager remains a gleam in the NASA administrator's eye.

Next Generation Space Telescope

Currently envisioned for launch around 2008, the NGST would be a general-purpose large (6- to 8-meter) space observatory that in some ways would replace the Hubble Space Telescope. However, NGST will observe primarily at infrared wavelengths, as its primary task is to study high-redshift galaxies and protogalaxies. It would be launched by an Atlas-class launch vehicle, probably to an orbit beyond the Moon, and be much less massive than HST despite its larger aperture. The mirror itself may unfold in space, since none of the current launch vehicles have payload fairings large enough to carry it up whole. A Sun shield will then deploy to keep the mirror cool. In addition to its cosmological studies, NGST would observe star-forming regions and survey asteroids in the Kuiper Belt. The new telescope may be preceded by three demonstration missions around 2001 to 2003: an inflatable Sun-shield test, a study of the effects of weightlessness on large mirrors, and possibly a test of an unfolding mirror.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, works on science planning for the forthcoming AXAF mission. He writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Advanced X-ray Astrophysics Facility

NASA has selected the crew that will deploy its AXAF X-ray observatory. Space Shuttle mission STS 93 will be commanded by Eileen Collins, the first woman in charge of a space-flight crew. Together with rookie pilot Jeff Ashby, she will fly NASA's oldest shuttle, *Columbia,* into orbit. Then French mission specialist Michel Tognini and NASA's Cady Coleman will join veteran Steven Hawley (who also deployed the Hubble Space Telescope in 1990) in placing AXAF in space.

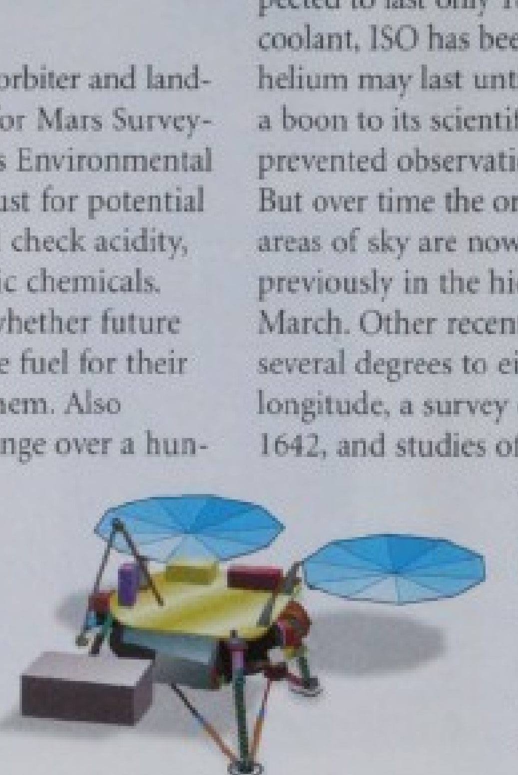
In contrast to other shuttle-launched telescopes like HST and Compton, AXAF's release won't use the Canadian robot arm. Instead, AXAF will be stored backward in the payload bay, with its telescope aperture connected to a solid-fuel rocket booster, mounted in a pivoting circular belt. Once *Columbia*'s crew opens the bay doors, the contraption will swivel upward with AXAF's rear instrument compartment pointing well out of the bay. Then the belt will swing open as springs and small explosive charges push AXAF and its booster clear of the shuttle. Collins and Ashby must then back off well clear of the satellite, as an automatic timer counts down to ignite the large firework that will propel AXAF to high orbit. Launch of STS 93 is now planned for early December.

Air Force pilot Eileen M. Collins *(left)* will head the mission to launch the Advanced X-ray Astrophysics Facility, NASA's next Great Observatory. Assembly of AXAF was completed in March with the installation of its solar panels. In February scientists tested the flow of data between instruments, the spacecraft, and the AXAF control center.

Mars Surveyor 2001

With preparations for the Mars Surveyor 1998 orbiter and lander well under way, detailed planning has begun for Mars Surveyor 2001 missions. Its lander will carry the Mars Environmental Compatibility Assessment to analyze surface dust for potential hazards to human explorers. Specifically, it will check acidity, electrical conductivity, and the presence of toxic chemicals. The In Situ Propellant Production will assess whether future explorers might use atmospheric gases to create fuel for their return from Mars instead of bringing it with them. Also aboard will be an advanced rover that could range over a hundred kilometers from the landing site.

Following the NASA administrator's recent intervention to reverse an order to shut down advanced planning for human planetary exploration, the selection of the Mars 2001 experiments represents a clear victory for those in NASA wishing to lay the groundwork for an eventual voyage by astronauts to the red planet.



It will be early 2002 before the Mars Surveyor 2001 lander and rover (in the box at left) touch down on the red planet.

X-ray Multi-Mirror Mission

The European Space Agency's next mission, XMM, will be launched a year after AXAF. In February ESA publicly unveiled its largest-ever astronomical spacecraft, which is undergoing tests at the ESTEC space center in the Netherlands. The satellite has three mirror modules, each with 58 nested X-ray mirrors, providing more light-gathering capacity than AXAF at the expense of less sharply focused images. Two of the mirror modules have grating spectrometers behind them for high-resolution spectroscopy, and all three have CCD cameras. A separate optical monitor telescope will provide simultaneous measurements of the visible brightness of targets. The German-built satellite consists of a service module, the mirror modules, a long telescope tube, and the instrument compartment. It will be launched by an Ariane 5 rocket into a highly elliptical orbit toward the end of 1999.

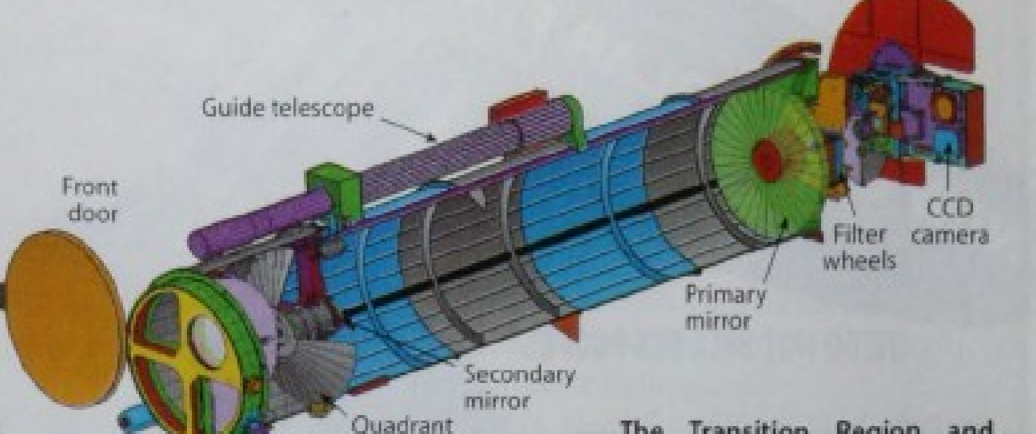
Infrared Space Observatory

The Infrared Space Observatory, a European Space Agency astronomy mission, is nearing the end of its life. Originally expected to last only 18 months before exhausting its liquid-helium coolant, ISO has been in orbit for more than two years, and the helium may last until May 1998. The extended lifetime has been a boon to its scientific studies. When ISO was launched, its orbit prevented observations of some particularly interesting targets. But over time the orbit has precessed enough that the remaining areas of sky are now visible. The star-forming regions in Orion, previously in the hidden zone, could be viewed beginning in March. Other recent ISO observations include a long scan of several degrees to either side of the ecliptic plane at 90° ecliptic longitude, a survey of interstellar dust near the cloud Lynds 1642, and studies of the Small Magellanic Cloud and the Triangulum spiral galaxy.

JONATHAN MCDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL



The Transition Region and Coronal Explorer has different coatings on the four quadrants of its primary mirror to permit observations of the Sun at specific ultraviolet wavelengths. Courtesy NASA-Goddard Space Flight Center.

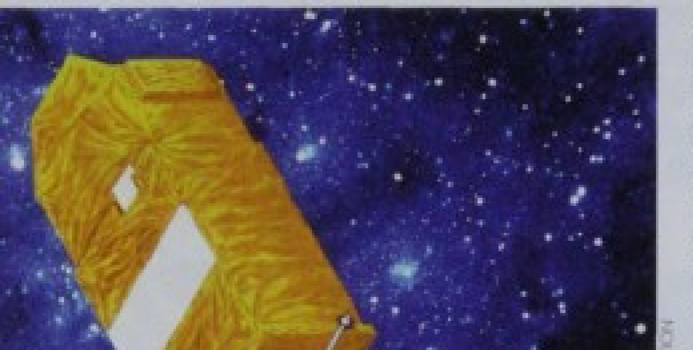
Transition Region and Coronal Explorer

NASA's third Small Explorer satellite reached orbit on April 2nd and attained first light on April 20th. TRACE will carry out high-resolution imaging of the Sun at several diagnostic ultraviolet wavelengths. Its 30-centimeter Cassegrain telescope is unusual in that each quadrant of the primary mirror has a different coating. Three quadrants have coatings matched to three distinct extreme-ultraviolet emission lines from iron ions in the solar corona. The fourth quadrant collects a broad range of longer ultraviolet and visual wavelengths; filters select several hydrogen, carbon, and iron emission lines from this broader spectral swath. Scientists will choose the desired sector of the primary mirror by using a shutter at the Sunward end of the tube. TRACE has an 8.5-arcminute field of view and should yield arcsecond-resolution images of a significant fraction of the solar disk.

The satellite, launched by a Pegasus rocket from Vandenberg Air Force Base, will follow an orbit above the day-night terminator, so that TRACE can look at the Sun all the time without Earth getting in the way. If our planet were a perfect sphere, an orbit around it would normally stay fixed relative to the stars and thus shift relative to the Sun during Earth's yearly trek. TRACE's orbital height and inclination, combined with the gravitational effects of the Earth's flattened poles, cause its orbit to shift by exactly the amount needed to compensate for Earth's orbital motion, keeping TRACE in its so-called Sun-synchronous path.

Far Ultraviolet and Spectroscopic Explorer

NASA announced this spring that launch of the FUSE satellite on a Delta rocket has been delayed from October until at least next February. Although the Far Ultraviolet and Spectroscopic Explorer is running only a couple of weeks behind schedule, the Delta pads at Cape Canaveral are so fully booked with commercial and Mars-probe launches that no schedule slot was available for several months. FUSE is another ultraviolet observatory using mirror segments with different coatings, but it has a rather different design and a very different program of planned observations. Its four mirror segments are physically separate, off-axis components that reflect light onto very-high-resolution spectrographic gratings. FUSE will extend Hubble studies of stars and the interstellar medium to the 900- to 1200-angstrom ultraviolet band, where many more spectral lines can be observed. An important cosmological measurement planned for FUSE is to find out how much deuterium ("heavy" hydrogen) exists in different cosmic sources, in order to pin down conditions present shortly after the Big Bang. FUSE will be operated by a team at Johns Hopkins University.



The FUSE spacecraft must now wait until at least next February before its ultraviolet studies can commence.

Space Infrared Telescope Facility

NASA Administrator Daniel Goldin has approved the start of design and development work on SIRTF, the fourth and final Great Observatory. (The other three are the Hubble Space Telescope, Compton Gamma Ray Observatory, and Advanced X-ray Astrophysics Facility.) Historically, NASA projects first go through many years of paper studies (termed Phase A and Phase B) before receiving this key go-ahead for final development and construction (Phases C and D). Originally planned as a multibillion-dollar, shuttle-launched mission in a low-altitude orbit, SIRTF has evolved into a Delta-class payload that will orbit the Sun. SIRTF's 85-cm-diameter infrared telescope will build upon the stunning successes of its predecessors, the IRAS mission (1983) and the just-completed Infrared Space Observatory mission (see below). Launch is scheduled for December 2001.

Infrared Space Observatory

As anticipated (June issue, page 24), the Infrared Space Observatory ran out of liquid helium on April 8th. Observations were halted when the telescope's detectors rose above 4° Kelvin. The final image was of the galaxy NGC 1808, the last of more than 26,000 observations made over 28 months of operation (compared to the planned 18 months). Project managers at the European Space Agency then began a month of engineering tests on the satellite, during which ISO acquired some near-infrared spectra of stars using detectors that do not require cryogenic temperatures. In any case, ISO's story is far from over, with many of the observations still to be analyzed and published. Calibration and analysis of the data is only now reaching maturity, and completion of the science archive will take several years.

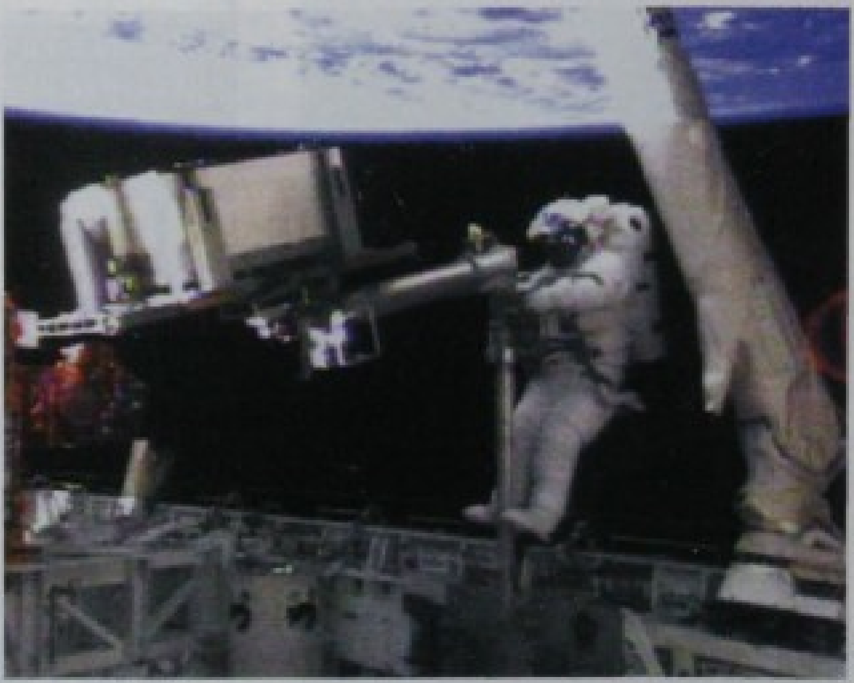
JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL

Hubble Space Telescope

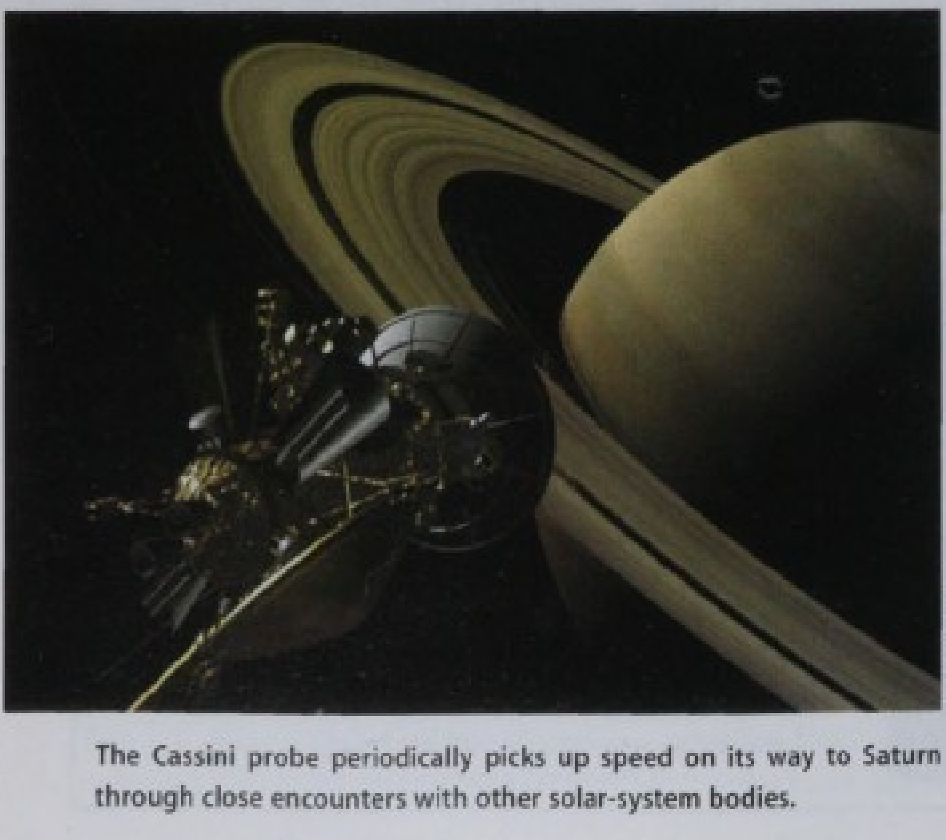
Following a decision to operate the Hubble Space Telescope through the end of the next decade, NASA has given approval for a new Wide Field Camera (WFC3) to be added to Hubble in 2002. The next Hubble-related Space Shuttle flight is the Hubble Orbital Systems Test (HOST) in October, flying with U.S. senator and pioneering astronaut John Glenn and Spartan 201 (see below). It will test a replacement computer and a new cooling system for the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). In 1999 the Servicing Mission 3 flight will install the Advanced Camera for Surveys (ACS), which is really three cameras providing imaging from mid-ultraviolet wavelengths all the way to the near-infrared. ACS will replace the European Space Agency's (ESA) Faint Object Camera, the last of Hubble's original instruments.

In 2002 Servicing Mission 4 will carry WFC3 and the Cosmic Origins Spectrograph (COS) to the observatory. WFC3 will provide the first wide-field, near-ultraviolet imaging, down to 2000 angstroms. The COS is derived from the spectrograph on the Far Ultraviolet Spectroscopic Explorer (FUSE), though it will not reach FUSE's far-ultraviolet wavelengths. It also reuses the structural parts of Hubble's old Goddard High-Resolution Spectrograph, which was returned from space in 1993. COS will be able to take spectra of much fainter targets than the Space Telescope Imaging Spectrograph (STIS) now operating on Hubble. The orbiting observatory's current plans call for operating eight additional years using STIS, WFC3, NICMOS, ACS, and COS without further shuttle visits until Hubble returns to Earth in 2010.


The solar observatory Spartan 201 will make its fifth flight on the Space Shuttle in October.

Cassini

The Cassini probe to Saturn made its first gravity-assist flyby on April 26th, when it passed 284 kilometers above the surface of Venus. Two short rocket burns to trim the probe's course were canceled as unnecessary. Most of Cassini's science instruments were not switched on during the flyby, to save on the cost of operation and data analysis. However, a radio antenna did conduct a search for emissions from possible Venusian lightning, and calibration tests of the spacecraft's radar used Venus as a target. In March ESA's Huygens lander attached to the main probe was successfully checked out. Cassini will return to Venus next year and will reach Saturn in 2004.


The Cassini probe periodically picks up speed on its way to Saturn through close encounters with other solar-system bodies.

Spartan 201

NASA has approved a plan to refly the Spartan 201 solar satellite on an October Space Shuttle mission. On its fourth flight last November, Spartan failed to switch on after being deployed. An inquiry determined that astronaut Kalpana Chawla forgot to send the computer command that would have activated the spacecraft. An attempt to recapture Spartan with the robotic arm sent the satellite into a tumble. Although astronauts recovered it a few days later, no observations were made with the satellite's two instruments. On the forthcoming STS 95 flight, Spartan will make observations to help calibrate the Solar and Heliospheric Observatory (SOHO) satellite.

Deep Space 1

Launch of the Deep Space 1 mission has been delayed from July until October, using a Delta launch slot recently freed up by the delay of the FUSE mission (July issue, page 28). The slip for Deep Space 1 was forced by the redesign of solar-array electronics and the elimination of artificial-intelligence software from the mission's control system in favor of older-style programs. The new launch date rules out a planned Mars flyby and comet visit. Deep Space 1 is the first of NASA's New Millennium missions, which are intended mainly to test new technology rather than do science. New asteroid and comet targets for DS 1 will be named this summer.

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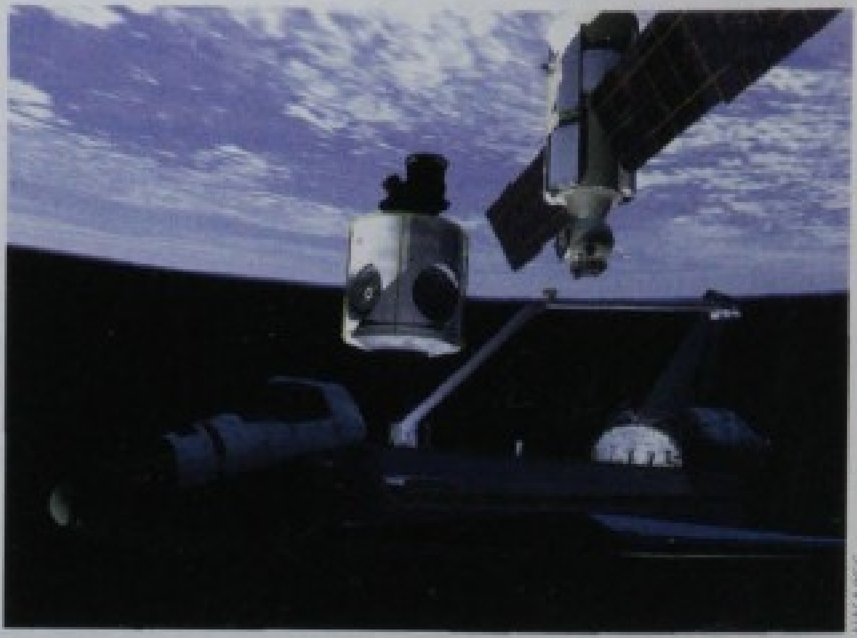
BY JONATHAN McDOWELL

Space Telescope Science Institute

On June 8th, NASA Administrator Daniel S. Goldin announced that the Space Telescope Science Institute has been chosen to manage science operations for the forthcoming Next Generation Space Telescope (NGST). Located at Johns Hopkins University in Baltimore, the institute opened in 1983 to support astronomers using the Hubble Space Telescope. The new assignment means the institute will continue to function after HST's mission ends in 2010. Unlike Hubble, the NGST will observe primarily at infrared wavelengths. Design studies are under way, with a projected launch in 2007.



NASA/KSC

Above: **The Space Shuttle *Endeavour* prepares to join the Unity docking node in its payload bay with the Russian-built Zarya module. This first step in the assembly of the International Space Station may occur late this year.** ***Left:*** **Astronauts Robert Cabana, Nancy Currie, and Richard Struckow (from left) examine Unity as it awaits launch.**

International Space Station

Already behind schedule, the space station faces another delay this fall. In May the launch of the first module, named Zarya ("dawn"), was postponed from the summer to November. Also known as the Functional Cargo Block, Zarya is a Russian-built tug with a cluster of docking ports. It is similar in shape and mass to Mir's add-on modules, like the Spektr laboratory damaged in last year's collision. In December a Space Shuttle flight is slated to rendezvous with Zarya and connect Boeing's Unity docking node to it. Unity has six connection ports, and by 2003 it will link Zarya with the U.S. laboratory module, an airlock module, a solar-panel truss, another docking node, and a "cupola" viewing dome. These components form only the central section of the final space station. In April 1999 the Russian Service Module will dock at Zarya's free end, and shortly thereafter a Soyuz ship will deliver the station's first crew. However, the Service Module is behind schedule, as the Russian government has failed to deliver the money for workers' wages. Although Zarya and Unity are both ready to fly, many observers expect the first launch to slip yet again, into the early part of next year.

NASA/KSC

Röntgensatellit

Germany's Rosat X-ray observatory has completed eight years in orbit. On April 25th Rosat reverted to "safe" (standby) mode when it overheated after too much exposure to sunlight. A few days later, when the spacecraft was commanded to resume operations, its star camera failed to work. There is a second unit on Rosat's Wide Field Camera telescope, and although the WFC itself was damaged years ago when accidentally pointed at the Sun, its star camera may be pressed into service to support the primary X-ray telescope. Meanwhile, assuming that the observatory will soon be restored to operation, astronomers are readying their proposals for the 1999 observing season.

MAX PLANCK INSTITUTE

Four nested sets of mirrors, each a combined paraboloid-hyperboloid, form the heart of Rosat's optical system. The largest mirror set is 84 centimeters across.

Galileo

The Galileo orbiter successfully completed another flyby of Jupiter's icy moon Europa on May 31st, the fourth so far in the spacecraft's extended mission. Galileo passed 2,500 km above Europa's equatorial region, then flew within 600,000 km (8 Jupiter radii) of the planet's cloudtops. On June 1st, during its outbound leg, the spacecraft looked back at the volcanoes of Io before beginning a new two-month orbit. Only three days earlier, however, Galileo lapsed into a safe mode because of a software error, and controllers scrambled to transmit new commands for acquiring the Io observations. These modifications permitted full use of the gyroscopes that turn Galileo to point at various targets like Io and Jupiter as it skims in close to the giant planet. Similar troubles arose in December 1997, when magnetospheric radiation damaged a computer chip and caused the gyros to start acting up. The new command software sidesteps the problem. Galileo's three previous extended-mission flybys of Europa took place in December, February, and March. Four more are planned through next February.

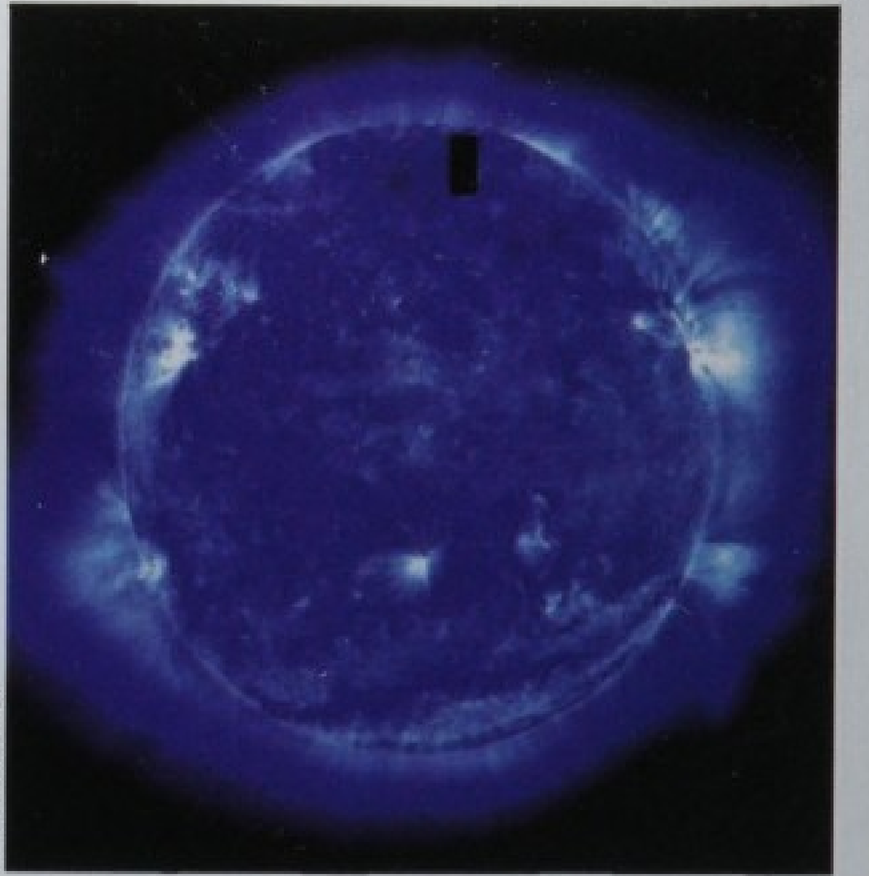
JONATHAN McDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Solar and Heliospheric Observatory

SOHO, a joint European-U.S. mission, was lost on June 25th during a routine orientation maneuver (September issue, page 20). The spacecraft repeatedly entered an emergency safe mode before going entirely silent. In July an inquiry board tentatively concluded that the craft's operators had caused the failure by sending the wrong commands and switching off a working gyroscope. Despondent solar physicists held out little hope that the mission could be saved. However, on July 23rd radar antennas detected the spacecraft slowly tumbling, and radio contact was soon reestablished. By early August the observatory, though still operating in spurts as the solar panels turned to face the Sun, began to return to life. Project engineers must now recharge SOHO's batteries, thaw its hydrazine fuel, and determine whether the delicate scientific instruments were damaged during the prolonged power outage. SOHO was launched in late 1995 and serves as astronomers' main facility for studying the Sun from space.



SOHO-EIT CONSORTIUM

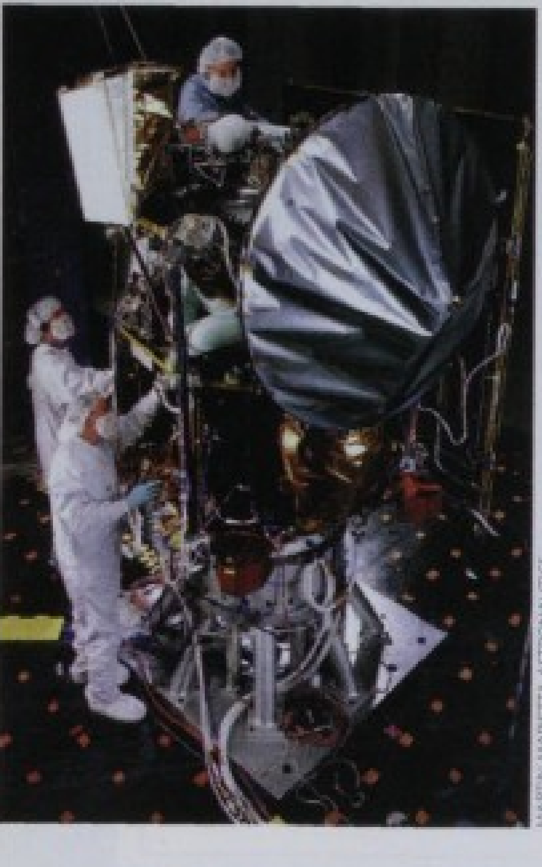
SOHO's last hurrah? This image was taken on June 24th — the day before contact with the spacecraft ended. Acquired at the extreme-ultraviolet wavelength of 304 angstroms, it shows gases in the Sun's lower corona at a temperature of about 80,000° Kelvin.

Advanced X-ray Astrophysics Facility

On June 25th the five-member crew of Space Shuttle mission STS 93 visited the AXAF Science Center in Cambridge, Massachusetts, which will serve as the mission's research hub once the spacecraft is launched aboard *Columbia* in late January. Commander Eileen Collins noted that this will be the heaviest shuttle launch mass to date (112,500 kilograms) and that AXAF's deployment is planned for the first day in orbit, when crew members are still adjusting to microgravity. Pilot Jeffrey Ashby, a Navy Gulf War veteran, will be on his first mission. Flight engineer Steven Hawley is the most experienced crew member (four prior flights) and the only astronomer aboard. Catherine ("Cady") Coleman will be in charge of deploying AXAF and its Integrated Upper Stage booster. She will be backed up by Michel Tognini, a French astronaut who visited Mir in 1992. Tognini could also be called upon for an emergency spacewalk if needed. Once in operation AXAF will send its data through the Deep Space Network to the control center, which is run by the nearby Harvard-Smithsonian Center for Astrophysics and Massachusetts Institute of Technology, before being distributed to researchers.

Mars Surveyor

A communication antenna on the Mars Polar Lander was damaged during a test on June 30th when it banged into the spacecraft's solar panels, which were folded up at the time — not extended as they would be in flight. The antenna is undergoing repairs and should be reinstalled in time for the lander's January launch as part of the Mars Surveyor 1998 mission. Meanwhile, plans for future spacecraft in the series are being scaled back because of budget and development problems. The Jet Propulsion Laboratory had hoped to build on the success of Sojourner by flying a larger rover on the Mars Surveyor 2001 mission, but that has been postponed until 2003. The 2001 flight will now carry fewer experiments as well, though a smaller rover, Sojourner's backup, may be added to the payload. Money problems also threaten the ambitious plans for a sample-return mission, which would leave Earth in 2005 and return from Mars in 2008.



MARTIN MARIETTA ASTRONAUTICS

Technicians attend to the Mars Surveyor 1998 orbiter, which is scheduled to rocket into space on December 10th. Its companion lander should be launched 18 days later.

Nozomi (Planet B)

A Japanese M-V rocket took off from Kagoshima Space Center on July 3rd (Universal Time) carrying a small, instrumented spacecraft destined for Mars. Before reaching its destination, however, Nozomi ("Hope") must complete some preparatory maneuvers. A high-apogee orbit will carry the craft close by the Moon twice to build up speed. Then a rocket burn during its final perigee pass in December will shoot the craft into solar orbit. Nozomi's long interplanetary cruise will end in October 1999 when the craft reaches Mars. From its elliptical orbit, Nozomi is to study the planet's atmosphere, charged particles, and magnetic field. Its payload consists of experiments from Japan, the U.S., Germany, Canada, and Sweden.

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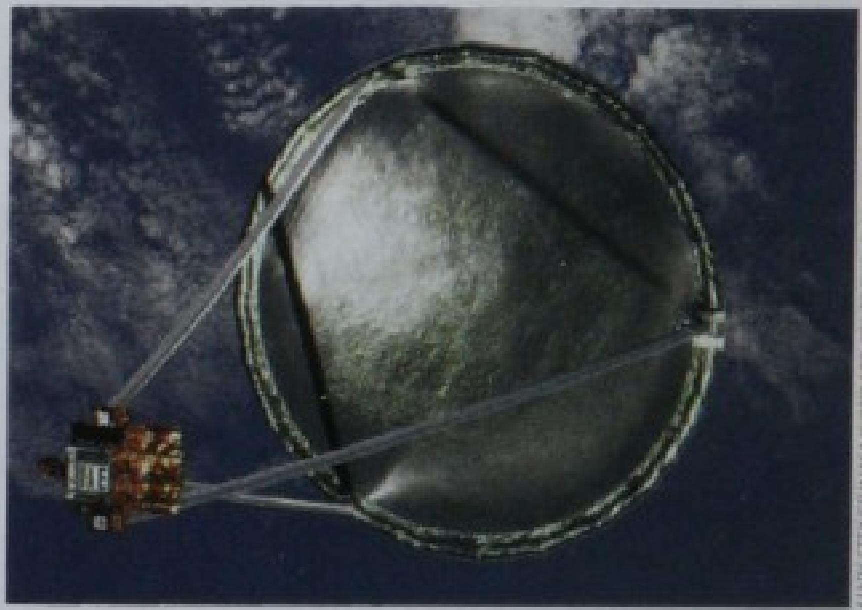
BY JONATHAN McDOWELL

In May (page 26) Mission Update covered missions planned for NASA's Origins program. Here are some proposals in the space agency's complementary Structure and Exploration of the Universe (SEU) program.

Advanced Radio Interferometry between Space and Earth

The proposed ARISE project would build upon the experiments conducted recently by Japan's HALCA radio-astronomy satellite (*S&T:* September 1997, page 16). In like manner, ARISE would be arrayed with ground-based radio telescopes to create an interferometer, but it would be able to detect sources 50 to 100 times fainter than its precursor. Proposed for launch in 2005, ARISE would use an inflatable, 25-meter-wide antenna like the one tested on the Spartan 207 satellite in 1996. Placing the spacecraft in a 40,000-kilometer-apogee orbit would allow mapping on 10-microarcsecond scales, corresponding to objects only a few light-years across at cosmological distances.



MARK STEINER (NASA/GODDARD SPACE FLIGHT CENTER)

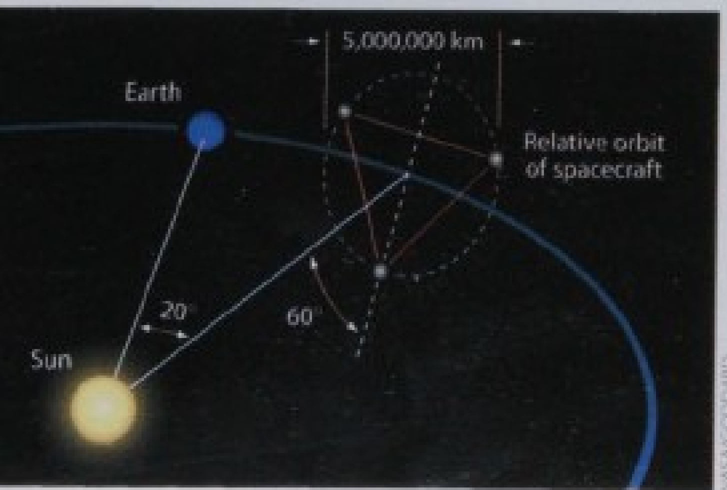
NASA's success with this 14-meter-wide inflatable mirror during a 1996 Space Shuttle flight has paved the way for ARISE, an ambitious radio-interferometer concept.

Constellation X

Constellation X is envisioned as a set of six X-ray telescopes in high-altitude orbits working together as a single observatory. The observatory would study X-ray sources with more sensitivity than will be possible with either NASA's Advanced X-ray Astrophysics Facility or Europe's X-ray Multi-Mirror mission. Each member of the sextet would utilize a telescoping tube, stowed during launch and extended once in space, to provide the long focal length needed for two detector modules. The Spectroscopy X-ray Telescope will resolve spatial detail down to about 15 arcseconds and identify the spectral features of many phenomena; the Hard X-ray Telescope will offer a spatial resolution of 1 arcminute in the energy range of 10,000 to 40,000 electron volts.

Laser Interferometer Space Antenna

LISA would be the first space mission to search for gravitational radiation, tiny ripples in space-time that are predicted by Einstein's general theory of relativity but to date have eluded detection. LISA would consist of three satellites in orbit around the Sun. They would form the corners of a huge triangle about 5,000,000 km on a side, their exact separations determined to within the size of an atom by a laser interferometer. Free of the shaking and seismic effects experienced by instruments on Earth, LISA should be able to detect radiation from neutron stars, white dwarfs, and massive black holes.



NASA/GODDARD

The triad of widely separated detectors in NASA's proposed Laser Interferometer Space Antenna (LISA) would create an enormous gravity-wave detector in space.

Gamma-ray Large Area Space Telescope

As a successor to NASA's Compton Gamma Ray Observatory, GLAST is intended to study gamma-ray emissions from active galactic nuclei and the galactic plane. It will also attempt to identify the unknown sources discovered by Compton's EGRET telescope. Thanks to recent instrumentation advances in particle-accelerator detectors, GLAST should be able to record gamma rays with energies from 10 million to more than 100 billion electron volts (10 MeV to 100 GeV) and to locate bright sources to within a few arcminutes. Its single telescope will use metal foils to convert gamma rays into electron-positron pairs, which will then be trapped by particle detectors and calorimeters. NASA's timetable calls for GLAST to be lofted into a low-altitude orbit sometime in the next decade.

Orbiting Wide-angle Light Collectors

The OWL project has been designed to observe the highest-energy gamma rays and cosmic rays, those with almost a trillion times the rest energy of a proton (10^{20} eV). A few of these high-energy particles have been detected from the ground, yet theorists are hard pressed to explain how they are created. In an attempt to find out, a pair of OWL satellites will look down instead of up, spotting light flashes caused when these high-energy particles smash into Earth's atmosphere. The resulting "air showers" of lower-energy secondary particles and photons radiate a megawatt of light for a few microseconds. Operating as a stereo camera in orbit, OWL will see a much larger part of the atmosphere than any ground-based array and is expected to observe 100 particle events each year.

JONATHAN McDOWELL *writes a weekly electronic newsletter on space programs (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE
BY JONATHAN McDOWELL

Launch Failures

The space industry was recently hit with a streak of four launch failures during a month-long interval. The dismal roll call began on August 12th with a spectacular, billion-dollar fireworks display over Cape Canaveral. A Lockheed Martin Titan IV-A suffered a momentary power failure 40 seconds after liftoff, causing its guidance computer to reset itself and command the huge rocket to tip over. The vehicle disintegrated, and a large military-intelligence satellite was lost. Next came the debut of Boeing's Delta III rocket on August 26th. It also fell victim to a guidance failure, this time caused by poor modeling of the rocket's dynamic response. The control system was unable to damp out an oscillation and ran out of fuel, dumping a communications satellite into the Atlantic Ocean. At the end of August North Korea claimed to have launched its first satellite. The United States could not find the payload in orbit, however. It now seems likely that the satellite, which reportedly was broadcasting the revolutionary songs of Kim Il Sung, came to rest on the Pacific seabed. During the fourth failure, on September 9th, a payload of 12 telephone-relay satellites was propelled at high speed into the Siberian tundra when a Zenit rocket launched from Kazakhstan shut down too early. Although none of these four vehicles are slated to carry future astronomical satellites, the indirect effects of finding new launch slots for high-priority commercial payloads may cause some delay for pending science missions.

The ill-fated flight of a Titan IV-A rocket and its classified payload on August 12th lasted just 40 seconds.

Mars Surveyor 1998

NASA's Mars Climate Orbiter (MCO) arrived at Cape Canaveral on September 11th in preparation for its launch on December 10th. A three-stage Delta II rocket, fortified with four strap-on, solid-fuel boosters, will place the 3,100-kilogram spacecraft into orbit around the Sun. After that, the first critical maneuver for MCO will be to deploy its solar panels — its precursor, Mars Global Surveyor, had problems with this task. Then on December 25th MCO's main engine will redirect the trajectory toward Mars (the initial path will be a deliberate "miss" so that the Delta rocket stage can't contaminate the Martian surface). The launch of MCO's companion, Mars Polar Lander (MPL), will follow on January 4th with a similar sequence of events. MCO is to reach the red planet in September 1999, with MPL arriving three months later.

The Mars Climate Orbiter will study the red planet's surface and atmosphere with a high-resolution color camera and an infrared radiometer.

Advanced X-ray Astrophysics Facility

Soon to be renamed by NASA, the forthcoming AXAF satellite completed its main prelaunch tests in August and was shipped to Florida from TRW's California factory in late September. During vacuum testing earlier this year, a door on the CCD Imaging Spectrometer camera failed to open. Engineers made some quick hardware modifications and improved operating procedures, and the door passed a retest with flying colors and preserved a January 21st launch date aboard the Space Shuttle *Columbia*. Meanwhile, the five-member crew continued to train for the mission (October issue, page 28). After this shuttle orbiter flew in May, its Spacelab module and long-duration equipment were removed to make room for the X-ray telescope. In October NASA begins stacking the shuttle's Solid Rocket Boosters in the huge Vehicle Assembly Building, and on December 4th *Columbia* will be hoisted up and bolted to the boosters and external tank, before being rolled out to the launch pad a week later. AXAF will be connected to its Inertial Upper Stage booster and then loaded into *Columbia* on the launch pad.

Solar and Heliospheric Observatory

The slow recovery of the SOHO satellite continued early this fall. Having reestablished contact with the spacecraft after a month's silence (October issue, page 28), on August 13th ground controllers began a slow, careful thawing of the craft's frozen hydrazine fuel. They then warmed the rest of the propulsion system. The thrusters returned to life on September 16th, pointing the craft back at the Sun and allowing the instruments to warm up. The next step will be to begin turning on the scientific instruments, whose electronic health remains unknown. The spacecraft's uncontrolled tumble alternately heated and cooled the science module, and some detectors may have been damaged.

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BY JONATHAN McDOWELL

The space calendar for 1999 looks eerily like the one for 1998, with the troubled International Space Station and a number of astronomy missions suffering delays over the past few months. The coming year also features a renewed assault on Mars, with no fewer than four missions active around our neighbor planet.

Mars "Attacked"

As 1999 begins, Mars Global Surveyor has resumed its once-per-orbit dipping into the red planet's atmosphere, a process (termed aerobraking) that lowers the spacecraft's altitude without using fuel. By March the craft's orbit should be circular and about 400 kilometers high. This path will run almost directly from pole to pole and be *Sun synchronized,* such that the landscape below can be mapped at the same local time on each successive orbit. Only then will the MGS craft — which reached Mars on September 12, 1997 — be able to begin its intended mapping mission.

The space year will be inaugurated on January 3rd by the departure of Mars Polar Lander (MPL) from Cape Canaveral, Florida. Following hard on the heels of the Mars Climate Orbiter, launched the previous month, MPL should arrive at the planet's south-polar ice cap next December. As it approaches Mars, the MPL craft will release a pair of Deep Space 2 penetrators. These 2-kilogram probes will bury themselves in the ground to conduct surface studies. Unlike the Mars Pathfinder mission, MPL has no airbags — it relies instead on a retrorocket system at touchdown like the one used by the Viking landers in 1976.

In September, the Mars Climate Orbiter (MCO) joins Global Surveyor in orbit around the red planet. MCO will use aerobraking as well as rockets to reduce its speed and circularize its path. The final orbit, also Sun synchronous, will be achieved in early December, in time to be used as a radio relay for the lander at the south pole. The Mars Climate Orbiter's main mission is to study Martian weather.

The Japanese spacecraft Nozomi (formerly Planet B) acquired this image of the Moon during a close swing-by last September 24th. In October the spacecraft reaches Mars to study the interaction of the planet's magnetic field with the solar wind. Courtesy Tadashi Mukai (Kobe University).

Meanwhile, Japan's Nozomi probe, launched last July, reaches Mars in October 1999. The probe will fire its engine to enter an elliptical orbit with a closest approach of 150 km. No aerobraking is planned, so Nozomi will spend most of its time much further from the planet than NASA's orbiters. The focus of Nozomi's international payload of instruments is how the solar wind and interplanetary gas affect the fringes of the Martian atmosphere. The planet's weak magnetic field offers much less protection against solar-wind encroachment than ours does, nor does it form trapped belts of charged particles or auroras.

Other Interplanetary Probes

In January the Near Earth Asteroid Rendezvous spacecraft completes its three-year journey to minor planet 433 Eros and takes up a close orbit around it. Another asteroid mission, Deep Space 1, was launched in October 1998 and should fly past minor planet 1992 KD in July if its experimental ion drive is successful. In February, NASA's Stardust space probe will be sent into orbit around the Sun. Stardust will fly past Comet 81P/Wild 2 in 2004 and return to Earth with a sample of comet dust two years later.

Japan's sole scientific launch of the year will be Lunar A, now set for August or September. Japan has flown spacecraft past the Moon before, but Lunar A will be its first to achieve orbit there. The 520-kg probe carries a set of "penetrator" rockets, which will be fired at the lunar surface to punch instrumentation deep into the dusty regolith.

In August the Saturn-bound Cassini/Huygens probe swings past Earth at a distance of 1,000 km to pick up speed before

If all goes well, at least nine missions will be flown to Mars between 1996 and the end of the first decade of the 21st century.

heading off to the outer solar system. Finally, in October the Galileo spacecraft will complete its four-year exploration of the Jovian satellite system with a close pass of the volcanic moon Io.

Astronomy and Planetary-Science Highlights in 1999		
Date	**Location**	**Event**
January	Cape Canaveral, Florida	Launch of Mars Polar Lander
January	433 Eros	Near Earth Asteroid Rendezvous at Eros
January	Vandenberg AFB, California	Launch of Submillimeter Wave Astronomy Satellite
February	Cape Canaveral	Stardust launched toward Comet Wild 2
February	Kapustin Yar, Russia	Launch of ABRIXAS X-ray satellite
March	Cape Canaveral	Launch of AXAF X-ray observatory
June	Venus	Cassini makes second Venus flyby
June	Earth orbit	AXAF begins regular observing
August	Earth	Cassini makes Earth flyby
August	Kourou, Guyana	Launch of X-ray Multi-Mirror telescope
September	Lunar orbit	Lunar A fires penetrators at Moon's surface
September	Mars orbit	Mars Climate Orbiter enters orbit
October	Mars orbit	Nozomi reaches Mars
October	Io	Galileo makes Io flyby
October	Wallops Island, Virginia	Launch of High Energy Transient Experiment 2
December	Earth orbit	Shuttle *Columbia* services Hubble Space Telescope
December	Martian south pole	Mars Polar Lander touchdown

Note: If 40 years of space flight have taught us anything, it's that space flight is unpredictable. Thus the dates in this table are tentative. More information about almost all the listed missions is available on the World Wide Web. Links to the appropriate sites are available at http://www.skypub.com/.

Astronomical Satellites

Six Earth-orbiting astronomy missions are scheduled for launch in 1999. The Submillimeter Wave Astronomy Satellite (SWAS) was placed in storage several years ago when its Pegasus launch vehicle ran into problems. In mid-1998 NASA managers gave the go-ahead to reactivate the program, and the SWAS team began racing to meet a December launch slot. However, that now seems likely to slip into January, following more problems with Pegasus. SWAS is to study long-wavelength emissions from interstellar molecules in our galaxy.

Germany's ABRIXAS X-ray satellite will be lofted by a Russian-built Kosmos 3M rocket from a launch base near Volgograd in February. An acronym for "*A Broadband Imaging X-ray All-sky Survey*," ABRIXAS will make the first high-resolution studies in "hard" (very high energy) X-rays, thus complementing the "soft" X-ray survey done by its predecessor, Röntgensatellit (Rosat). This marks the first astronomy mission developed by the integrated institutions of the former East and West Germanies.

The Far Ultraviolet Spectroscopic Explorer (FUSE) will take over Pad 17A at Cape Canaveral as soon as the smoke clears from Mars Climate Orbiter's departure and ride its Delta rocket into orbit in February. The Wide Field Infrared Explorer (WIRE) is the next astronomy mission in the Pegasus queue. Like SWAS, it is part of NASA's Small Explorer program. Once it reaches orbit in March, WIRE will study the sky at mid-infrared wavelengths.

The Advanced X-ray Astrophysics Facility (AXAF) should finally reach orbit this spring and begin its study of a wide variety of X-ray-emitting objects. Courtesy NASA.

The biggest astronomy mission of the year will be the Advanced X-ray Astrophysics Facility, now scheduled to ride the Space Shuttle *Columbia* sometime in the early spring. AXAF's launch was delayed twice because ground testing took longer than expected. Once the spacecraft is safely in orbit, engineers at the AXAF control center will spend a couple of months checking and calibrating the observatory's systems. If all goes well, its long-awaited studies of the high-energy cosmos will begin during the summer. For the first two months of observations, AXAF will mostly stare at bright stars to check the focus of its images, and at the Cassiopeia A supernova remnant and the Coma cluster of galaxies, both of which have been well studied by other satellites. Two additional months of observations will be made by scientists directly involved with the AXAF program before the telescope is put into the service of astronomers worldwide (for example, I'll be using it to look at the nearby galaxy Messier 33).

In 1996 the High-Energy Transient Experiment was placed in orbit, but this X-ray satellite was unable to separate from its rocket stage. A replacement, HETE 2, has been built at MIT from spare parts and is due to fly in October. The design of the experiment, which is intended to locate gamma-ray bursts, has been improved following the recent successes in this field with BeppoSAX and other satellites; an extrasoft X-ray imager has joined the payload.

Other flights initially scheduled for 1999 have been postponed. The European Space Agency's X-ray Multi-Mirrror (XMM) mission has slipped a few months, while the Spektrum-X-Gamma observatory remains an underfunded casualty of Russia's economic problems and will not be ready for at least two years. Nevertheless, barring accidents it looks as if 1999 will be a busy year that clears the backlog of astronomy satellites waiting for their ride to space.

Jonathan McDowell, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Röntgensatellit (Rosat)

The German X-ray observatory known as Rosat has completed its eight-year scientific mission. Launched on June 1, 1990, Rosat carries an X-ray telescope equipped with two German detectors called position-sensitive proportional counters (PSPCs), a high-resolution imager (HRI) supplied by U.S. scientists, and a British-built wide-field camera (WFC) for recording objects at extreme-ultraviolet wavelengths. Last April 28th Rosat's main star tracker failed, and scientific observations slowed to a trickle while engineers learned to use the WFC's star camera for guiding instead. On September 20th Rosat was accidentally aimed too near the Sun, which severely damaged the HRI imager. By October 23rd, when an attempt to observe Cygnus X-1 failed, it became clear that the camera was no longer usable. Observations with one of the PSPCs ended during an earlier accidental Sun pointing, and the gas supply on the other ran out several years later. So scientists at the Max Planck Institute for Extraterrestrial Physics (MPE) were forced to declare the scientific program over. Some end-of-life tests included checking the HRI's ultraviolet calibration and its door mechanism, along with observations using the remaining PSPC gas. Rosat stands as the longest X-ray imaging mission ever flown, and it leaves behind a rich scientific archive (*S&T:* August 1995, page 35).

MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS

A Rosat composite image of M31, the Andromeda Galaxy, showing bright X-ray sources in its core (center) and spiral arms. Spoke-and-wheel artifacts are due to the imaging system.

Triana

U.S. vice president Albert Gore proposed Triana in 1997 as a craft to be stationed at the gravitationally stable L_1 Lagrangian point along the Earth-Sun line and relay live images of our planet's sunlit hemisphere. Although the Triana concept was not taken seriously by many initially, it is now part of NASA's Earth Probe series of remote-sensing missions and its payload has been selected. Francisco Valero (Scripps Institution) will lead development of Triana's instruments, which will include a color camera and a radiometer to measure Earth's global radiation budget. Meanwhile, NASA's Goddard Space Flight Center is building the spacecraft itself. Triana will be launched in December 2000 from the Space Shuttle, using an upper stage to reach the L_1 Lagrangian point.

The Triana spacecraft is intended to bring real-time images of Earth to computer users worldwide. Apollo 17 image courtesy NASA.

JUDITH PILLINGER / OPEN UNIVERSITY

The Mars Express mission will carry an instrumented lander named Beagle 2, seen here as a full-size engineering model.

Mars Express

NASA's robotic emissaries to the red planet will have some company early next century, as the European Space Agency recently approved funding for its Mars Express project. To be launched in June 2003 on a Russian Soyuz rocket with a Fregat upper stage, Mars Express will reach its destination six months later. The orbiter is intended to accomplish many of the scientific objectives of the failed Mars 96 mission. It carries a stereo color imager, an infrared mapping spectrometer, a radar altimeter, and atmospheric analyzers. Also aboard will be Beagle 2, a small, British-developed lander whose sensor package will search the surface for evidence of life. Beagle 2 will have a panoramic camera, a miniature laboratory for gas and soil analyses, and a robot-arm "mole" that will get soil samples from under rocks by using a small drill developed by a dentist! The lander will have a mass of only 60 kilograms.

Deep Space 1

The advanced-technology probe Deep Space 1 rocketed into solar orbit on a Boeing Delta rocket in October. Built to test various hardware and software innovations, DS 1 is the first spacecraft to use a beam of electrically accelerated xenon ions as its main propulsion system. The craft is expected to use this "ion drive" to modify its orbit around the Sun for a flyby of the high-inclination Mars-crossing minor planet 1992 KD next July. However, during its first trial, the drive switched itself off after only 4½ minutes. Engineers at JPL have since restarted the balky drive but have yet to solve unrelated problems with a star tracker. DS 1 is the first craft in NASA's New Millennium series; Deep Space 2 involves small surface penetrators that are to be launched aboard the Mars Polar Lander in early January.

Jonathan McDowell is an astronomer at the Harvard-Smithsonian Center for Astrophysics. He writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

BY JONATHAN McDOWELL

Galileo's Excellent Adventures

Encounter	Flyby Date (UT)	Flyby Distance (km)
Io[1]	1995 Dec. 7	897
Ganymede	1996 June 27	835
Ganymede	Sept. 6	261
Callisto	Nov. 4	1,136
Europa	Dec. 19	692
Europa[2]	1997 Jan. 20	27,419
Europa	Feb. 20	586
Ganymede	Apr. 5	3,102
Ganymede	May 7	1,603
Callisto	June 25	418
Callisto	Sept. 17	535
Europa	Nov. 6	2,043
Europa	Dec. 16	201
Europa	1998 Feb. 10	3,557
Europa	Mar. 29	1,644
Europa	May 31	2,514
Europa[3]	July 21	1,834
Europa[4]	Sept. 26	3,582
Europa[5]	Nov. 22	2,271
Europa	1999 Feb. 1	1,495
Callisto	May 5	1,311
Callisto	June 30	1,050
Callisto	Aug. 14	2,288
Callisto	Sept. 16	1,053
Io	Oct. 11	500
Io	Nov. 26	300

[1] No data; tape-recorder malfunction.
[2] No data taken; Jupiter in solar conjunction.
[3,5] Limited data gathered due to safe mode.
[4] Limited data gathered due to gyro problem.

Galileo

The Galileo orbiter, which was launched in 1989 and reached Jupiter in December 1995, is entering the final year of its mission around the giant planet. During 1998 it made six flybys of Europa (see the table). But on two of these, including November's, almost all data was lost when the onboard computer unexpectedly threw the vehicle into a safe (standby) mode. Gyroscope problems marred a third. Galileo's recent results include evidence of variable magnetic fields on Callisto and Europa, suggesting that both may have subsurface oceans, and finding that some of Io's volcanic eruptions reach temperatures of 1,400° K. In 1999 Galileo will make one last visit to Europa, fly past Callisto four times, then make two long-anticipated close flybys of Io.

SPARTAN 201

This version of the Shuttle Pointed Autonomous Research Tool for Astronomy made its fifth flight last November on the STS 95 mission. Although overshadowed by the presence of 77-year-old crew member John Glenn, SPARTAN's reflight was important for NASA. On its previous mission, procedural errors resulted in the observatory not being switched on before it was released in space. This time everything went well, as Stephen Robinson used *Discovery*'s robot arm to deploy the autonomous payload and recapture it safely after two days of observations. Data from the ultraviolet coronal spectrometer and white-light coronagraph will help calibrate the Solar and Heliospheric Observatory, which resumed operations in October after tumbling out of control earlier in 1998 (*S&T:* October 1998, page 28). SPARTAN 201 is equipped to study the heating of the solar corona and the acceleration of the solar wind.

HST Orbital Systems Test

Also aboard *Discovery* was a package that tested a new computer for the Hubble Space Telescope, a cooling system for its NICMOS infrared camera, and a replacement solid-state data recorder. Unexpected radiation upsets in HST's electronics and the premature depletion of NICMOS's liquid-nitrogen coolant prompted this test flight of the new hardware, which will be installed in the observatory next December. (The coolant in NICMOS ran out in November 1998, ending its observations at long-infrared wavelengths.) During HOST's operation, the cryogenic cooler for NICMOS eventually bottomed out at 73° Kelvin, and the data recorder reportedly was unaffected by charged particles encountered along the shuttle's 460-kilometer-high orbit.

Submillimeter Wave Astronomy Satellite

SWAS is a Small Explorer mission and part of NASA's Origins program. The satellite has a telescope 60 centimeters in aperture to collect energy at wavelengths of 0.55 to 0.61 millimeter (corresponding to frequencies of 550 to 490 gigahertz, respectively). This submillimeter band is rich in spectral lines from molecular clouds, and SWAS will be used to study the clouds' cooling rates and sites of star formation. To reach orbit, SWAS and its Pegasus XL rocket were first carried by a converted L-1011 airliner to an altitude of 12 km over the Pacific Ocean near the central California coast. The aircraft dropped Pegasus, which ignited its rocket motor 5 seconds later just after local sunset (3:57 Universal Time on December 6th). The spacecraft is now operating as planned in a circular, 660-km-high orbit with an inclination of 70°.

VOLKER TOLLS AND NASA/GODDARD SPACE FLIGHT CENTER

Technicians install an aerodynamic fairing around the SWAS spacecraft two weeks before its December launch aboard a Pegasus XL rocket.

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NASA/JSC

The SPARTAN 201 payload hovers in free flight after its release by the Space Shuttle's robotic arm in November 1998.

MISSION UPDATE

BY JONATHAN McDOWELL

Solar and Heliospheric Observatory

After returning from the brink of disaster last summer, the European Space Agency's SOHO resumed its observations of the Sun just in time to coordinate with the SPARTAN 201 flight last October. However, on December 21st SOHO's last attitude-controlling gyroscope failed, and solar physicists were left once again without data from their outpost at the Earth-Sun Lagrangian point. This time SOHO remained under ground control while in safe mode, and it is being pointed at the Sun (to keep the solar panels fully illuminated) using fuel-squandering thruster firings. Mission scientists had already been developing software that would allow SOHO to make observations without gyros — but it had not been uploaded before the surprise failure in December, nor had it by early February.

Last December 21st, about 4½ hours before a critical gyroscope failure, the SOHO observatory recorded this false-color view of the Sun in the light of ionized helium (304 angstroms). Courtesy NASA.

Submillimeter Wave Astronomy Satellite

Launched in early December as part of the Small Explorer program, SWAS completed its initial calibrations in only a couple of weeks. Tests of its various observing modes included a method in which the whole spacecraft is "nodded" a few degrees back and forth about once a minute to provide background data. (In the more conventional "chopping" mode, only the secondary mirror is toggled.) By New Year's Day, SWAS was well into its scientific observing program and performing exceptionally well. Principal investigator Gary J. Melnick (Center for Astrophysics) reports "water, water everywhere," with strong detections of H_2O lines in all molecular-cloud targets, including a strong outflow from the BN/KL object in the Orion molecular cloud. SWAS has also mapped the Orion complex using infrared emissions from neutral carbon and ^{13}CO molecules. So far, the young molecular clouds observed by SWAS don't show any emission from molecular oxygen. Melnick hopes future observations will reveal its presence in older clouds, thus providing a direct test of models of interstellar chemical evolution.

Wide Field Infrared Explorer

Another Small Explorer is scheduled for launch in late February. WIRE utilizes the same basic design as SWAS and carries a 0.3-meter telescope that will be cooled by solid hydrogen to 7.5° Kelvin. It will survey large areas of sky at 12- and 25-micron wavelengths for distant, infrared-bright galaxies in the throes of vigorous star formation. The main WIRE survey is expected to pick up from 30,000 to 70,000 galaxies at a typical redshift of around 0.5. Interesting candidates will be studied spectroscopically at some future date by the forthcoming Space Infrared Telescope Facility (SIRTF). WIRE will also be used to search for protostars in nearby molecular clouds, small asteroids, and the debris trails of comets. Small missions like this one, with modest resolution (0.5 arcminute in WIRE's case) and wide fields of view (0.5°), are a crucial complement to more capable observatories such as SIRTF and the Hubble Space Telescope, whose narrow fields of view preclude survey work.

Nozomi

Japan's Planet B space probe, renamed Nozomi ("Hope") after launch, ran into engine trouble in December that will cause it to reach Mars four years late. The craft had already been in orbit around Earth for six months in an elliptical track that extended beyond the Moon. A lunar flyby on September 24th had redirected Nozomi into an even larger loop out to more than 1.7 million kilometers. On December 18th a second lunar pass flung the spacecraft inward, and it skimmed 1,000 km above Earth's cloudtops just two days later. At that moment the probe fired its main engine to target it for Mars, but the engine's performance was well below expectations. A large make-up firing the following day preserved the Mars encounter but not the planned rendezvous date in October. To conserve what fuel remains, Japanese space officials decided to delay the craft's arrival until December 2003. Nozomi is to enter orbit when it finally gets to Mars, from which it will photogragh the planet and study the charged particles and electromagnetic fields in its vicinity. Japan's two previous interplanetary craft, Sakigake and Suisei, studied Comet Halley in the mid-1980s.

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The Wide Field Infrared Explorer is prepared for its February 26th launch aboard a Pegasus XL rocket. WIRE is similar in design to the Submillimeter Wave Astronomy Satellite. Courtesy David Shupe (IPAC/Caltech).

MISSION UPDATE

BY JONATHAN McDOWELL

Stardust

Stardust will encounter Comet Wild 2 and collect micron-size samples of dust about three months after the comet's perihelion passage. The key to Stardust's stash-and-dash collection technique is an ultralight material called *aerogel*, displayed here by project investigator Peter Tsou. A thousand times less dense than glass, the aerogel will capture and hold cometary particles striking it at 6 km per second.

Launched on February 7th, Stardust will be the first mission to return samples to Earth from beyond the Moon. The spacecraft is now in a solar orbit, and a flyby of Earth on January 15, 2001, will slingshot Stardust through the inner asteroid belt in late 2002. At that time its ultralow-density *aerogel* collectors will trap tiny particles of interplanetary and perhaps interstellar dust. Then, on New Year's Day in 2004, Stardust is to pass only 100 km from the nucleus of Comet 81P/Wild 2 at a speed of 6 km per second, and once again the aerogel collectors will trap material for study. Two years later the probe returns to the vicinity of Earth, its sample-laden capsule screaming into the atmosphere at 12 kilometers per second toward a landing in Utah.

Chandra X-ray Observatory

The CXO is being prepared for a July 9th launch from Kennedy Space Center after overcoming several setbacks over the past year that caused the launch date to slip from January to April to midsummer. Early this year, with only weeks to go before Chandra was to leave the factory of TRW, its manufacturer, engineers decided to replace some suspect electronics. The observatory was flown to Florida on February 4th, but NASA managers decided to push Chandra's launch aboard STS 93 back in the queue.

The well-protected Chandra X-ray Observatory arrives at NASA's Kennedy Space Center.

Mars Global Surveyor

In orbit around the red planet since September 1997, Mars Global Surveyor finally completed the aerobraking phase of its mission in February — with a bit of drama. Flight controllers had to make a crucial rocket firing to end aerobraking and raise the low point of the orbit to a safe height. Just over a day before the burn, however, a broken water main flooded Lockheed Martin's mission control center in Denver, Colorado, putting it out of action. Fortunately, the Denver facility came back on line in time to execute the crucial commands. The spacecraft assumed its final orbit about March 1st, at which time detailed mapping and other experiments commenced.

Internet users can get a real-time update of Mars Global Surveyor's location over the red planet at http://mpfwww.arc.nasa.gov/mgs/realtime/mgsrt.html.

Lunar Prospector

Somewhat overlooked amid all the current missions to Mars is Lunar Prospector, which has been circling the Moon since January 1998. In December controllers lowered the spacecraft's orbital altitude from 100 to 40 km, and they dropped it again on January 29th such that at its closest Lunar Prospector was skimming only 15 km above the cratered surface. Irregularities in lunar gravity soon made the orbit more circular, and as of mid-February it varied in altitude from 20 to 40 km — far lower than a satellite would be able to orbit Earth. Prospector's new flight path will let scientists map the gravity field of the Moon in much better detail.

Solar and Heliospheric Observatory

SOHO is once again back in operation. After last summer's crisis, when the spacecraft was lost for more than a month, trouble hit again in December when the last gyroscope failed. But after some late nights by software developers the observatory resumed taking data on February 2nd, controlling its orientation using backup systems.

Znamya 2.5

When the Progress-M 40 cargo ship undocked from Mir on February 4th, it was supposed to unfurl the Znamya 2.5 space-mirror experiment. Cosmonauts on Mir would then use a remote-control joystick to point the 25-meter-diameter Mylar sail and reflect sunlight onto darkened areas of Earth. But a procedural mistake by ground controllers caused the spinning sail to become snagged and torn on an antenna during the deployment attempt, and the spacecraft was dumped in the Pacific Ocean the following day. The Znamya experiment, ostensibly intended as a prototype for systems to illuminate Arctic cities, drew criticism from astronomers concerned about the potential for light pollution (February issue, page 19).

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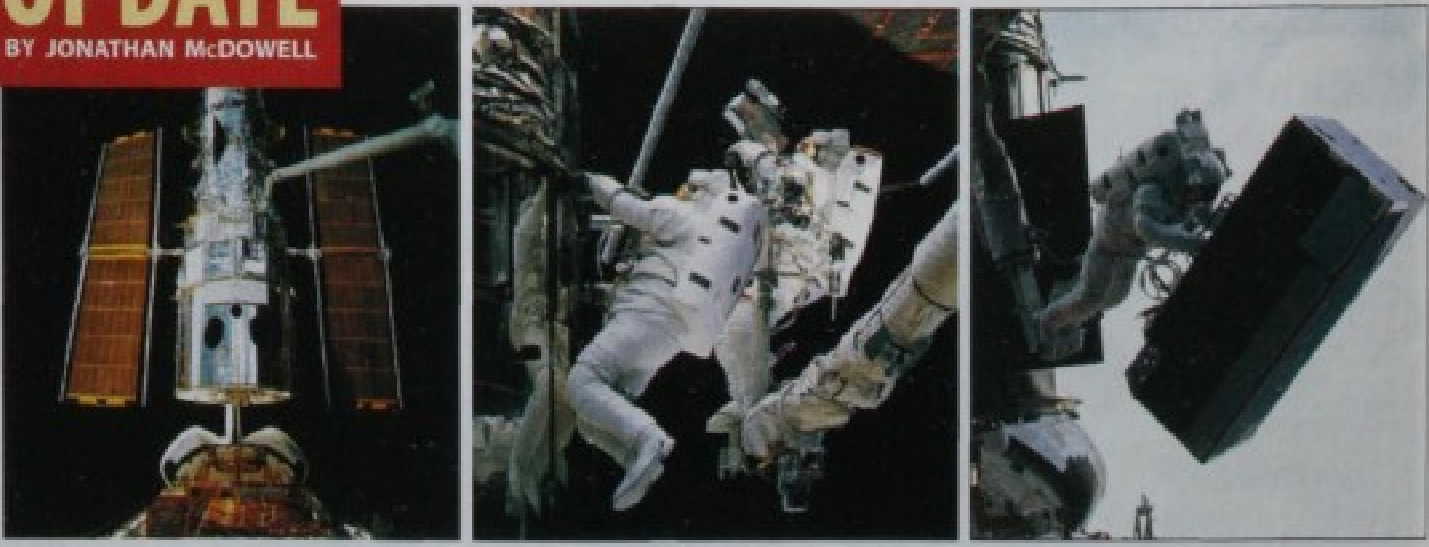
MISSION UPDATE

BY JONATHAN McDOWELL



NASA / JSC

Left: The Space Shuttle made its previous Hubble Space Telescope house call in February 1997. *Center:* Astronauts Steven Smith (left) and Mark Lee approached Hubble to begin work. *Right:* Smith grappled the Goddard High Resolution Spectrograph after removing it from the telescope.

HST Servicing Mission

The Hubble Space Telescope is just one gyroscope failure away from shutting down, and NASA managers are worried that it will not keep working until Space Shuttle astronauts make a scheduled "house call" for repairs next year. So in October *Discovery* will conduct an extra servicing mission. The spacewalking repair crew will consist of astronauts Steven Smith (who flew on the second HST servicing mission in 1997), John Grunsfeld, Michael Foale, and Swiss astronomer Claude Nicollier (who was on the first servicing mission in 1993). They will replace all six gyroscopes and install some equipment originally planned for next year's flight, like a new computer and data recorder that were tested last year (March issue, page 30). A replacement camera, a cooling system for the infrared camera now on board, and new solar-cell panels must wait until the previously scheduled visit, which now will probably slip until late 2000. HST's gyroscopes are based on a design that has been used since the 1970s with mixed success; the ones that failed recently fell well short of their expected lifetime. The replacement units should last longer once in orbit.

SMC/TE, KIRTLAND AIR FORCE BASE

Weighing about 2½ tons, the Air Force's Advanced Research Global Observation Satellite carries an X-ray telescope among its many experiments.

Advanced Research Global Observation Satellite

After years of delays, the U.S. Air Force launched its ARGOS scientific research satellite on February 23rd. It now occupies an 845-kilometer-high polar orbit. The main payload is an electric-propulsion system, but also aboard are atmospheric experiments and an X-ray astronomy detector provided by the Naval Research Laboratory. This Unconventional Stellar Aspect (USA) experiment consists of a large array of traditional X-ray proportional counters, with an "effective area" of 2,000 square centimeters. USA's detectors originally flew in 1985 on the shuttle-borne SPARTAN 1 spacecraft and were refurbished after their return to Earth. Like the Rossi X-ray Timing Explorer, USA will study the variability of bright X-ray sources in our galaxy. Rossi looks at many targets for relatively short periods, while USA will make very long observations — up to a month — of a few sources. The ARGOS launch also placed two small satellites in orbit: Sunsat, built by students of Stellenbosch University in South Africa, and Ørsted, a Danish payload that will map Earth's magnetic field for the first time since NASA's 1979 Magsat mission.

Astro E

Japan's next X-ray astronomy satellite, called Astro E for now, will be launched in February 2000. It employs thin-foil X-ray telescopes similar to those of its predecessor, ASCA (Astro D), to yield a spatial resolution of about 1 arcminute. The five ASTRO E imaging telescopes will have a longer focal length of about 4.5 meters, thanks to an optical bench that extends after launch. Astro E has four X-ray CCD imagers similar to the ones pioneered by ASCA and used on Chandra, as well as a hard X-ray detector. However, its flagship instrument is the XRS, the first X-ray solid-state microcalorimeter, which can obtain X-ray spectra at much higher energy resolution than can CCDs. The liquid-helium-cooled calorimeter works by measuring temperature rises of about 0.001° Kelvin in the detector caused by absorbing single X-ray photons. The XRS was built by NASA's Goddard Space Flight Center in collaboration with Japan's Institute of Space and Astronautical Science.

STEPHEN S. HOLT, NASA / GSFC

Japanese and American technicians examine XRS, the spectrometer that will be installed aboard the Astro E spacecraft.

Wide Field Infrared Explorer

Everything was "go" on the night of March 4th, when the Wide Field Infrared Explorer headed into Sun-synchronous orbit aboard its Pegasus XL rocket. But soon thereafter the telescope's cover was prematurely ejected before the satellite could be stabilized. Strong earthlight bathed the telescope and caused some of its solid-hydrogen coolant to boil off, causing WIRE to spin faster and faster. The tumble was too fast for onboard systems to counteract, and days later the remaining cryogen and battery power both ran out. The mission had been meant to last four months (April issue, page 28). WIRE's 30-cm infrared telescope was designed to catalog faint galaxies and quasars. With the much larger Space Infrared Telescope Facility planned for launch in 2002, a replacement for WIRE is unlikely to be funded.

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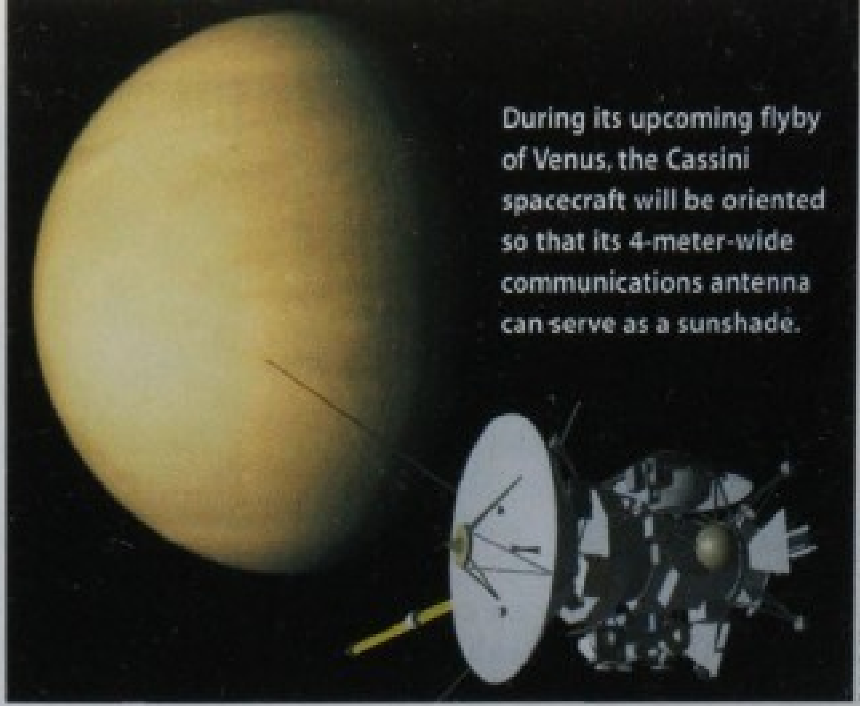
BY JONATHAN McDOWELL



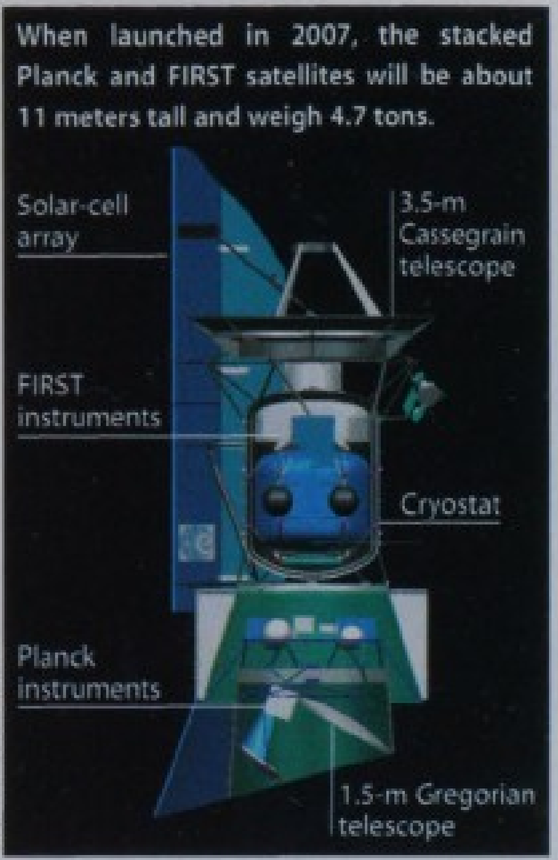
During its upcoming flyby of Venus, the Cassini spacecraft will be oriented so that its 4-meter-wide communications antenna can serve as a sunshade.

DAVID SEAL AND NASA/JPL

Planck and FIRST

After surviving several budget hurdles, the space observatories known as Planck and the Far Infrared and Submillimeter Telescope (FIRST) have been approved for development by the European Space Agency. Astronomers are relieved that this mission, which combines both spacecraft into a single payload, now seems on track for a launch in 2007 aboard an Ariane 5 rocket. Planck will survey subtle irregularities in the cosmic background radiation left over from the Big Bang and thus provide a definitive test of galaxy-formation theories. Its 1.5-meter-aperture telescope should map these fluctuations down to scales of 10 arcminutes. The detectors, to be built by a French- and Italian-led consortium of 40 institutions, will cover the microwave spectrum from 0.3 to 10 millimeters in wavelength and identify temperature deviations of just two parts per million. Meanwhile, FIRST is the successor to ESA's highly successful Infrared Space Observatory. With a primary mirror 3.5 meters across, FIRST will be the largest infrared telescope yet flown in space. It will carry enough liquid helium to cool its instruments for 4½ years, and it will observe at wavelengths from 80 to 670 microns. Planck and FIRST will occupy the L_2 Lagrangian point, 1½ million kilometers from Earth in the anti-Sunward direction.

When launched in 2007, the stacked Planck and FIRST satellites will be about 11 meters tall and weigh 4.7 tons.



EUROPEAN SPACE AGENCY

Cassini

The Saturn-bound Cassini spacecraft makes its second flyby of Venus on June 24th. Launched from Earth on October 15, 1997, Cassini first swept past Venus in April 1998 at a distance of 284 km and used a gravity assist to give its orbit an aphelion of 1.6 astronomical units (240 million km). June's flyby, a pass just 598 km from the Venusian cloudtops, will stretch Cassini's orbit out to 2.6 a.u. from the Sun and into the asteroid belt. The new trajectory will be temporary, though, since a close pass by Earth this August will redirect Cassini toward a Jupiter flyby in late 2000 and its eventual arrival at Saturn 4 years later. Eight of the 12 instruments aboard Cassini — including its visible and infrared imagers — will take data as Venus zips by.

Mars Express

In March the European Space Agency signed a contract with Matra Marconi Space, which will design and build Mars Express for launch in June 2003. Conceived as a replacement for the failed Mars 96 mission, which carried several European-built instruments, Mars Express will be launched by a Russian Soyuz booster and a Fregat upper stage. The spacecraft uses technology developed for the Rosetta comet mission to be flown the previous year. Mars Express's orbiter will map the Martian landscape, search for subsurface water with radar, and act as a communications relay for its lander and for other Mars missions. Dubbed Beagle 2, the lander will carry experiments to study Martian surface chemistry and to search for life (February issue, page 30).

Sea Launch

From its floating pad in the Pacific Ocean, Boeing's Sea Launch enterprise carried out its first mission on March 28th and placed a dummy satellite in a geostationary transfer orbit. The *Sea Launch Odyssey*, a converted oil rig, and its companion ship and control center, *Sea Launch Commander*, are based in Long Beach, California. Prior to March's test the two vessels sailed to a point on the equator at 154° west longitude, near Kiritmati (formerly Christmas Island). Such equatorial sites are optimum for launching communications satellites destined for geostationary orbits. Sea Launch's Zenit 3SL rocket was built by Ukrainian and Russian contractors. The first two stages also comprise the Zenit 2 rocket, which lost 12 satellites in its first commercial flight last year. That spectacular and costly failure made a test launch of the Zenit 3SL necessary.

The 60-meter-tall Zenit 3SL towers above its oceangoing platform, *Sea Launch Odyssey*, and the rocket's control ship, *Sea Launch Commander*. The rocket is stowed horizontally during its transport to the launch site on the equator in the Pacific Ocean.

BOEING DEFENSE AND SPACE GROUP

JONATHAN McDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

A Broadband Imaging X-ray All-sky Survey

On April 28th Germany's ABRIXAS satellite enjoyed a perfect launch on a Russian Kosmos 3M rocket — but soon ran into trouble. The satellite separated from the rocket's second stage in a 600-kilometer-high orbit, and a tracking station picked up its signals. Initial euphoria evaporated when the satellite's battery system failed and the vehicle fell silent except for weak signals received whenever sunlight shone on the solar-cell panels. Controllers are hoping the satellite can be revived in late June, when the panels will be illuminated for long periods. But if the battery system cannot be connected, the mission will be lost. ABRIXAS would have cataloged sources emitting "hard" X-rays from 0.5 to 10 keV (kiloelectron volts), using a focusing telescope with a spatial resolution of about 30 arcseconds. The last mission to survey the sky in this energy range was the High Energy Astronomy Observatory 1 in 1977. HEAO 1 had no telescope, resulting in very rough positions for a small number of sources. As a footnote, the ABRIXAS launch from State Test Range 4 at Kapustin Yar, near Volgograd, was the first orbital mission from this site since 1987. Kapustin Yar was used for the first Russian V-2 launches in 1947, and it is the equivalent of the White Sands and Wallops Island sites in the United States.

Mars Global Surveyor

Now in its operational polar orbit around the red planet, NASA's Mars Global Surveyor has begun its primary mission to study the ruddy surface at high resolution. In mid-April mapping was interrupted when MGS's dish-shaped communication antenna became stuck. Troubleshooting showed that something is blocking the motion of the dish whenever it turns beyond a certain angle. If it can't be freed before February 2000, MGS will have to interrupt mapping and pivot toward Earth in order to transmit its data. Until then the Earth-Mars geometry will keep the antenna's motion within the usable range of angles, and the study of the planet continues for the time being.

View from Sun August 1, 1999

MGS's Mapping Orbit

Semimajor axis:	3,775 km (377 to 454 km altitude)
Inclination:	92.866°
Eccentricity:	0.007
Period:	118 minutes
Periapsis:	–90.0° latitude
Descending node:	near 2 p.m. local time
Ground track:	repeats every 88 orbits

USGS / NASA / JPL

Champollion

The tortuous history of the Champollion comet lander took another twist this spring when it narrowly escaped cancellation. Originally slated to fly to Comet 46P/Wirtanen with Europe's Rosetta probe, it was transferred to NASA's New Millennium program in 1997 as the Deep Space 4 project (since renamed Space Technology 4). The project grew in ambition, involving an orbiter and a lander that would return a sample of a comet's nucleus to Earth. However, in late March officials at NASA Headquarters threatened to cancel the mission unless it was held to its $158 million budget and revamped to maintain the intended emphasis on technology development. A quick redesign preserved the mission by combining everything into a single spacecraft and by abandoning the return of a sample. Champollion will be launched in April 2003 and, propelled by a solar-electric engine like the one on Deep Space 1, will rendezvous with Comet 9P/Tempel 1 in April 2006. The spacecraft will reconnoiter the comet for a few months, search for a safe landing area, then anchor itself to the nucleus for a long-duration stay. Champollion will then drill to a depth of perhaps 1.4 meters and analyze the extracted material.

PAUL WEISSMAN, NASA / JPL

Although Champollion was originally designed to bring a piece of cometary nucleus to Earth, recent cost cutting has eliminated the mission's sample-return capability.

Galileo

Having completed its 20th orbit of Jupiter, Galileo has begun a series of flybys to lower its perijove, the closest point of the orbit to Jupiter. After flying past Europa in February (March issue, page 30), the spacecraft made its deepest and longest orbit since first looping around Jupiter in 1995, reaching an apojove of 11,000,000 km on March 18th. This kept the spacecraft out of trouble during solar conjunction, when communication with Earth becomes difficult. Galileo skirted only 1,322 km from the surface of Callisto on May 5th. During several flybys last year the onboard computer reset itself, triggering an electronic "safe" mode and the loss of scientific data. The same glitch happened during May's flyby, but new software bypassed the problem and allowed the probe to continue taking data without interruption.

The brush with Callisto altered Galileo's orbit, dropping apojove back down to only 8,000,000 km and lowering perijove to 593,000 km. After staying a safe distance from Jupiter's deadly inner radiation belt for 3½ years, the spacecraft will dip ever deeper on the next few orbits. By September its perijove will be just 400,000 km — roughly the Moon's distance from Earth — to position it for close Io passes on October 10th and November 26th. If Galileo survives the Jovian radiation belts, it faces another danger: the budget ax. The mission officially ends in December, but the Galileo team hopes to operate the spacecraft until the Cassini flyby of Jupiter in December 2000, since simultaneous measurements by Cassini and Galileo would allow cross-calibration of their instruments and give a stereo view of Jupiter.

Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).

MISSION UPDATE

BY JONATHAN McDOWELL

Good-bye, Mir? Russian space officials have announced plans to send the aging space station crashing to Earth later this year. This view was captured in June 1998 by the crew of STS 91 — the last of nine Space Shuttle missions to visit Mir.

Mir

The orbiting Mir complex may be coming to the end of the road, a victim of Russia's financial woes. The on-again, off-again search for external funding to carry on operations took one last lurch in May: an unsuccessful deal with a British businessman. RSC Energiya, the company that now operates Mir, has finally announced that it plans to abandon the station in August, when the current crew completes its six-month mission and comes home. This will mark the first time in almost 10 years that there have been no humans in space. Energiya officials claim that a Progress transport craft will be sent up for one final orbital maneuver — to redirect the complex into the Pacific Ocean — but some observers fear that Mir's flaky attitude-control system may fail if left untended. If that happens this enormous assembly, by far the largest artificial structure in orbit, may fall to Earth out of control. Mir was launched on February 20, 1986, and its first occupants arrived the next month. Three successive expeditions of cosmonauts occupied the station continuously from February 1987 to April 1989, at which point it was abandoned for five months. A fifth crew arrived in September 1989 to begin what might have become a permanent human presence in space — if plans to occupy the International Space Station before Mir's demise had only worked out.

Originally scheduled for launch last year, the FUSE spacecraft finally reached space on June 24th.

Far Ultraviolet Spectroscopic Explorer

NASA celebrated the launch of the FUSE spacecraft on June 24th. FUSE specializes in the ultraviolet wavebands between those of the Hubble Space Telescope and the Extreme Ultraviolet Explorer. It carries high-resolution spectrographs to study emission and absorption lines in stars, galaxies, and the interstellar medium. In concept FUSE is a successor to the very successful International Ultraviolet Explorer, but it scrutinizes shorter wavelengths, where deuterium and highly ionized atoms like O VI (an oxygen atom missing five electrons) are spectrally active. Key goals include measuring the abundance of deuterium throughout the universe and studying the hot interstellar medium and galactic halo. Now in an equatorial, 768-kilometer-high orbit, FUSE is controlled from Johns Hopkins University in Baltimore, Maryland — just across the street from the Space Telescope Science Institute.

Deep Space 1

Launched last October 24th, the Deep Space 1 probe is due to fly past minor planet (9969) 1992 KD on July 29th. Images and other scientific data will be transmitted to Earth in the days thereafter.

A xenon-ion engine has successfully changed the spacecraft's solar orbit to intercept the asteroid, and the autonomous navigation software will help DS1 zero in on its target. Final approach maneuvers will be made with conventional hydrazine thrusters, and DS1 should skim only 10 km from its target — the closest asteroid flyby yet. In May the spacecraft's "Remote Agent" artificial-intelligence software successfully took control for a total of 35 hours, completing most of the mission's test objectives. (The asteroid flyby is considered a bonus test of the craft's cutting-edge sensors and navigation system.)

Lunar Prospector

NASA's Lunar Prospector probe is ready to go out with a bang. This spacecraft began orbiting the Moon in January 1998, and its global survey resulted in the possible discovery of ice at the lunar poles. Since this past February, LP has been operating in an extremely low orbit, at times dipping only 17 km from the lunar landscape and giving scientists the opportunity to probe gravity variations and obtain higher-sensitivity data. The Lunar Prospector team decided that since impact is inevitable, it might as well be deliberate. So they plan to smash the spacecraft into one of the permanently shadowed south-polar regions where deposits of ice are thought to exist. In July the craft's orbit will be changed to 17 by 200 km, then the velocity will be slowed while at the highest point to force a carefully timed collision. LP will plunge into a 50-km-wide polar crater on July 31st at 9:51 Universal Time, angling into the surface about 7° from horizontal at 4,700 km per hour. It's hoped that the smashup will vaporize enough ice to create a plume of water vapor or its byproduct, OH, large enough to be detected by ground-based telescopes.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL

HST Servicing Mission 3A

The Space Shuttle *Discovery*, back from its June flight to the International Space Station, is being refurbished for the third servicing mission to the Hubble Space Telescope. SM-3A was not initially on the shuttle flight manifest — it is being flown in October primarily to replace Hubble's gyroscopes, now an urgent necessity because three of the six onboard have failed. Astronauts Steven Smith, Michael Foale, Claude Nicollier, and John Grunsfeld will make spacewalks to carry out the telescope servicing. The new equipment will be borne by a Spacelab pallet in the cargo bay, which will also contain a docking fixture to receive HST once the crew has grappled it with the orbiter's Canadian-built robotic arm. On the first spacewalk, the astronauts will replace the three gyroscopes used for slewing the observatory and install electronics to protect spacecraft batteries when the telescope is in safe mode. On the second sortie, astronauts will install a new 486 computer (tested on John Glenn's shuttle flight last year) and replace one of the three Fine Guidance Sensors. The FGSs are actually sensitive electronic cameras used to point the observatory precisely at its desired targets. The third spacewalk calls for the installation of a backup digital recorder and a new S-band radio transmitter, as well as repairs to HST's external insulation blankets. The next servicing mission, now planned for December 2000, will install a new general-purpose survey camera.


NASA

Astronauts Steven L. Smith and Mark C. Lee make repairs to the Hubble Space Telescope during the second servicing mission in February 1997. A third visit will occur in October.

Wide-field Infrared Explorer

Things looked bleak for the WIRE satellite when all the solid-hydrogen coolant for its infrared telescope was lost shortly after launch in early March (June issue, page 30). NASA's investigation later revealed that designers had failed to allow for the electrical surges made by a commercially obtained component when it switched on. The power surge inadvertently triggered the system that blows off the telescope cover. The tumbling craft was eventually brought under control, but at the time project officials believed that it could be used only for engineering tests. Then Derek L. Buzasi (University of California at Berkeley) realized that WIRE's star tracker, designed to point the observatory, was itself a useful research instrument. Fed by a 2-inch f/1.8 telescope, the star tracker's CCD detector can take low-resolution images 10 times per second with remarkable photometric accuracy, measuring the brightness of stars to within 0.001 magnitude. Buzasi is interested in studying small brightness oscillations in convective stars, something WIRE's tiny telescope can do more efficiently than a large ground-based telescope like Keck. After a very successful series of calibration tests, regular observations started in May with Dubhe (Alpha Ursae Majoris). Although the new project doesn't compare with WIRE's ambitious original goals, which can never be met, it's an imaginative use of a resource that would otherwise go to waste.

Other Mission Highlights

Several other past, current, and future space projects made news recently. Japan's Lunar A mission has again been delayed, this time until 2003. Lunar A is to orbit the Moon and deploy penetrator rockets that will slam into the surface. However, tests show that the rockets are not up to the job, so the mission design is being reworked. Meanwhile, despite its recent downsizing and redesign (August issue, page 28), the Champollion comet lander has been canceled by NASA. It has fallen victim to the budget ax, because the space agency has been unable to absorb unanticipated costs associated with other programs like the upcoming Hubble servicing mission and the long prelaunch delays of the Chandra X-ray Observatory. German space officials have decided to abandon the ABRIXAS astronomy satellite after efforts to revive it failed. The spacecraft malfunctioned after reaching orbit on April 28th, and its solar panels failed to charge the onboard batteries during well-illuminated orbits in late June. Galileo made another flyby of Callisto on July 1st, part of a series of gravitational assists designed to reduce the craft's perijove in anticipation of close flybys of Io in October and November (March issue, page 30). Cassini flew past Venus on June 24th at a distance of 603 km, on its way to an Earth flyby in August. And Europe's Giotto comet probe, placed in electronic hibernation in 1992 after its encounter with Comet 26P/Grigg-Skjellerup, flew past Earth on July 1st at a distance of roughly 200,000 km. No contact was made with the probe.

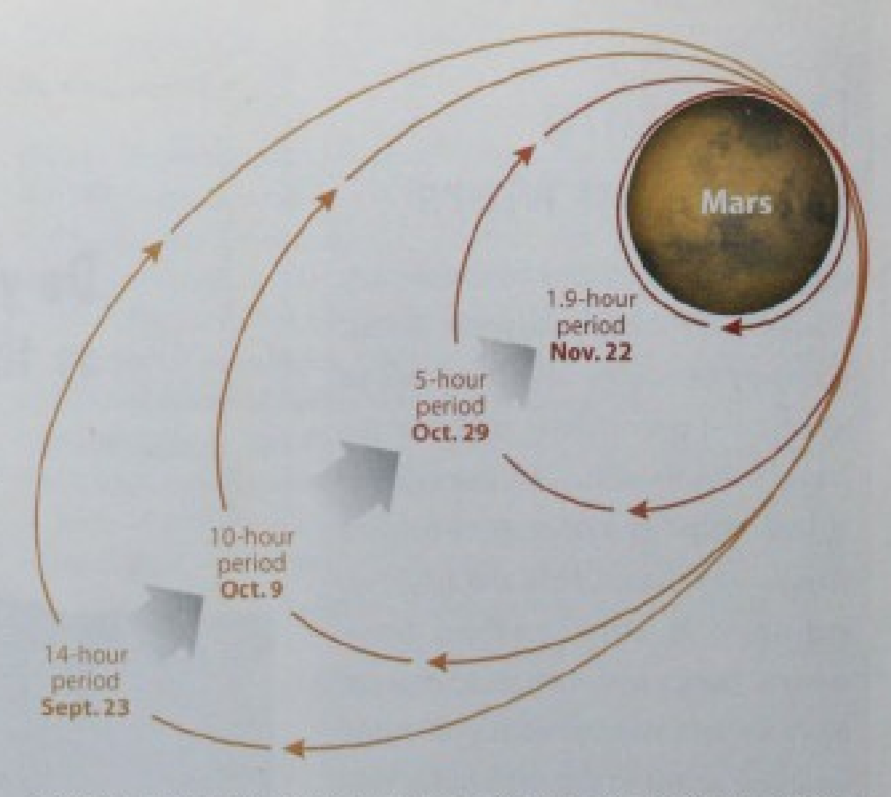

EUROPEAN SPACE AGENCY

Although its mission officially ended in mid-1992, the comet-chasing Giotto spacecraft (seen here without its outer shell) passed near Earth on July 1st.

Jonathan McDowell *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

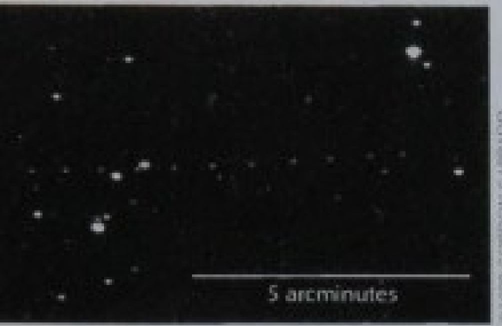
BY JONATHAN McDOWELL



NASA's Mars Climate Orbiter will use atmospheric friction to attain a tight, circular polar orbit around the planet. Courtesy NASA/JPL.

Cassini

The Saturn-bound Cassini spacecraft made a close and controversial flyby of Earth on August 18th, passing 1,166 kilometers over the South Pacific Ocean at 3:28 Universal Time. The crucial gravity-assist maneuver drew criticism from those who feared an accidental collision with Earth could release the 33 kilograms of radioactive plutonium in Cassini's power generators. Before the close brush, the spacecraft's orbit had a perihelion of 0.7 astronomical unit, near the orbit of Venus, and stretched out into the asteroid belt to 2.6 a.u. Cassini approached Earth at a speed of 16 km per second and left at 20 km per second, an energy boost that extended the craft's aphelion to 7.2 a.u., between Jupiter and Saturn. Cassini and its European-built Huygens probe (for Titan) will pick up one final gravity boost from Jupiter in December 2000, then coast toward their July 2004 arrival at Saturn.

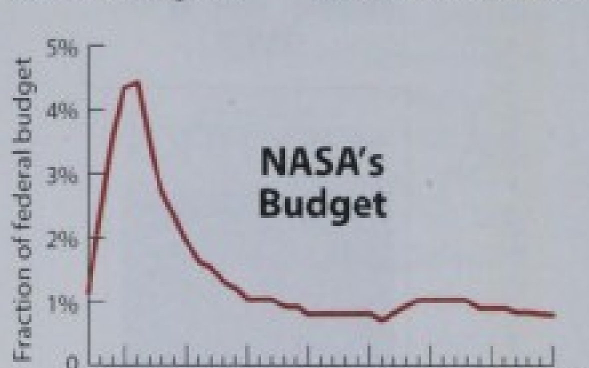


Eleven exposures, taken 10 minutes apart (final pair: 8 minutes), show the Cassini spacecraft during its close flyby of Earth on August 18th. Veteran Australian observer Gordon Garradd used a 0.45-meter f/5.4 Newtonian and a CCD camera.

Mir

The continuous human occupation of the Mir space station came to an end in August as Viktor Afanasyev and Sergei Avdeev returned to Earth. In the weeks before the Russian cosmonauts made two lengthy spacewalks. On July 23rd they emerged from the Kvant 2 module and spent six hours attempting to deploy an experimental high-quality antenna 6 meters in diameter. Devised by engineers in Russia and Georgia, the antenna refused to unfurl, and the defeated spacewalkers returned to the safety of the station as their oxygen supplies ran low. Five days later they emerged again, completed the planned tests, then unhooked the antenna and pushed it away (it will plunge into the atmosphere within a few months). They also retrieved experimental packages installed on the station's exterior to study the effects of exposure to vacuum and radiation. During the spacewalks, French astronaut Jean-Pierre Haigneré remained inside the Mir complex. Finally, on August 27th, the trio crawled into their Soyuz-TM 29 transport and closed the hatch to the Mir core module — perhaps for the last time. A few hours later, after a fiery reentry, the descent capsule touched down in Kazakstan.

Mir's story is not quite over, as one of the cosmonauts' final tasks was to install a new computer that should improve the station's chances of remaining stable under automatic control until early next year. At that time a final crew may visit the station to supervise preparations for forcing the giant complex from orbit over the Pacific Ocean.



During the height of funding for the Apollo program, NASA's annual funding exceeded 4 percent of the federal budget. Now it is only about 0.8 percent. Courtesy NASA.

Mars Climate Orbiter

A successful trajectory correction maneuver on July 25th put the Mars Climate Orbiter on course for its upcoming rendezvous with Mars. On September 23rd, after a 16-minute burn of its British-built main motor, MCO will drop into an elliptical polar orbit that ranges in altitude from 160 to 40,000 km. Within a day, ground controllers will command the craft to reduce its periapsis by 50 km, low enough to skim into the Martian atmosphere. The plan is to use aerobraking to circularize the orbit gradually, just as Mars Global Surveyor did over a 17-month period. In MCO's case, the process will take only 60 days. The orbiter carries an infrared radiometer and a color imager.

NASA Budget

In July the U.S. space agency's science budget came under its severest attack in many years. The House of Representatives voted to withhold $1.3 billion from NASA's overall request of $13.6 billion. Space-science funding was reduced by $640 million — a cut of more than 30 percent. Many NASA observers were surprised by the extent to which science programs were singled out, despite years of belt-tightening, the move to cheaper spacecraft designs, and spectacular successes from recent missions. An immediate outcry resulted in restored funding for some key programs like the SIRTF infrared telescope. But many other future missions remained in jeopardy, among them the Explorer program of Earth-orbiting scientific satellites and the Discovery program of interplanetary probes. Also threatened are the GLAST gamma-ray telescope and other missions comprising the agency's Structure and Evolution of the Universe initiative. Congress planned to revisit the budget issue in September.

JONATHAN McDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics and writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Mars Polar Lander

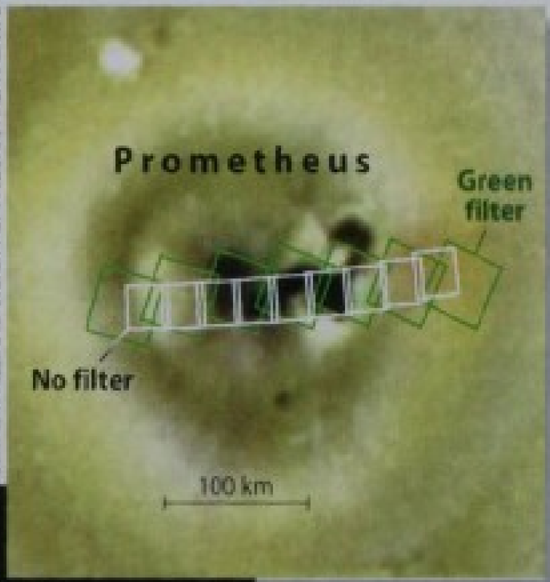
NASA scientists and engineers debated long and hard over where the Mars Polar Lander will touch down when it reaches the red planet on December 3rd. They wanted a spot where MPL could land safely, with no cliffs or jagged peaks, but one still offering interesting local topographic features. Engineering constraints required the chosen site to have rocks covering no more than 15 percent of the ground, slopes shallower than 10°, and to be no higher than 6,000 meters in elevation. The outcome? MPL is headed for a spot at 195° west, 76° south, roughly 800 km from the planet's south pole and its permanent ice cap. This target zone lies on "layered polar terrain," which is thought to contain stacked beds of fine dust and ice laid down over millions of years. Digging into the surface with MPL's mechanical claw could thus reveal a record of the planet's climatic history.

Galileo

The Galileo orbiter's final flybys of the Jovian moon Callisto were carried out on June 30th, August 14th, and September 16th. One consequence of these close passes was the reduction of Galileo's perijove (its closest point to Jupiter) to only 400,000 km, just inside the orbit of dynamic Io. The new trajectory carries the spacecraft through neutral and ionized atoms, ejected by volcanoes on Io, that occupy a broad torus along the moon's orbit. Galileo's historic exploration of the Jovian system culminates in two flybys of Io on October 11th and November 26th. Unless NASA managers infuse the project with extra funding for fiscal year 2000, the 13-year mission will draw to a close soon thereafter, once the resulting images and other data are relayed to Earth.

Mars Climate Orbiter

The 291-kilogram Mars Climate Orbiter was lost when it reached the red planet on September 23rd. The spacecraft fired a braking rocket at 9:01 Universal Time, and telemetry indicated all was well as the spacecraft passed behind Mars and out of touch with Earth. However, MCO's radio beacon was not received when it should have reappeared about 20 minutes later. According to project manager Richard Cook, data obtained several hours before arrival indicate that the spacecraft passed only 60 km from the Martian surface, rather than the planned close approach of 140 to 150 km. Since engineers consider 85 km the minimum safe altitude, it appears that MCO seriously overheated as it passed through the planet's upper atmosphere and perhaps broke apart from aerodynamic stress.



CYNTHIA PHILLIPS (UNIVERSITY OF ARIZONA) AND NASA/JPL

Far Ultraviolet Spectroscopic Explorer

Checkout tests continue for the FUSE satellite, which reached orbit on June 24th. The satellite had to be thoroughly "baked out" to purge trapped gases that might cause contamination or electrical breakdown once the high-voltage spectrographs were turned on. This procedure has now been completed, though the residual pressure dropped more slowly than expected — perhaps the satellite soaked up too much Florida humidity before its launch! The shakedown effort also ran behind schedule due to ground-station and guide-star problems. Nonetheless, the telescope doors have been opened, and ground controllers ramped up the voltage on the spectrographs at the end of August. The next step is to align and focus the quartet of primary mirrors in preparation for first light, which project scientists hoped to achieve by October 1st.

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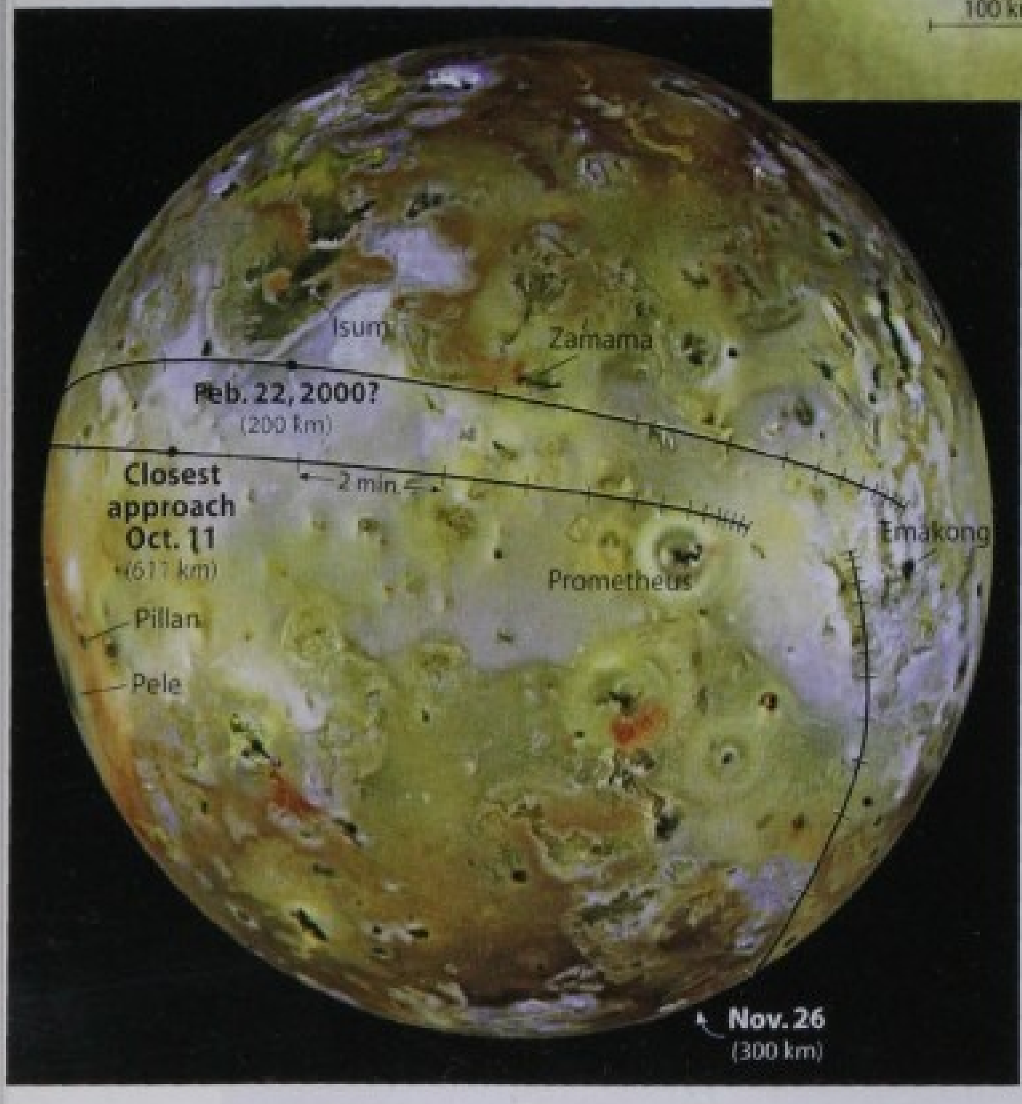


NASA / JPL

In October and November, Galileo is to scrutinize the hemisphere of Io pointing away from Jupiter. Io's equator runs horizontally through the disk's center, and lines indicate the locations directly below the spacecraft during each pass. Several of the moon's prominent volcanoes are noted. *Inset:* When Galileo flies 611 kilometers from Io on October 11th, 14 images (squares) will record details down to about 40 meters across within the eruptive bull's-eye of Prometheus.

MISSION UPDATE

BY JONATHAN McDOWELL

After several years of high-profile undertakings to explore the solar system and deep cosmos, the year 2000 should see the launch of numerous small- to medium-size spacecraft whose scientific objectives cover a wide array of disciplines.

Astronomy Satellites

The year should open with Europe's X-ray Multi-mirror Mission observatory in space and undergoing an initial checkout, assuming its launch goes as planned in December. The orbiter carries three large X-ray telescopes, and like NASA's Chandra X-ray Observatory it has both CCD cameras for imaging and gratings for high-resolution spectroscopy. XMM's pictures won't be as sharp as Chandra's, but the observatory will have a larger collecting area (*S&T:* August 1999, page 56).

In February XMM and Chandra will be joined in orbit by Astro E. It will replace ASCA (formerly Astro D), the previous entry in Japan's series of X-ray astronomy satellites, which is nearing reentry. ASCA was the first spacecraft to utilize CCDs for imaging high-energy targets, and Astro E carries these electronic imagers as well. However, its main instrument is the X-Ray Spectrometer, which will deliver unprecedented wavelength resolution without dispersing, or spreading out, the incoming light. Instead the XRS measures the temperature rise that occurs when a tiny piece of cryogenically cooled silicon absorbs an X-ray photon. If this new technology works well, it likely will be used widely on future missions. Developed by NASA, XRS had been part of Chandra's instrument suite before that mission was cut back in the early 1990s.

The second High Energy Transient Experiment mission should reach orbit in early 2000. (The first one was lost in a launch failure in 1996.) Carrying ultraviolet, X-ray, and gamma-ray detectors, HETE 2 will detect gamma-ray bursts and locate their optical counterparts. Its predecessors, the Rossi X-ray Timing Explorer and BeppoSAX, showed that at least some of these energetic outbursts are extragalactic. HETE 2 will be the first mission dedicated entirely to getting accurate positions for gamma-ray bursts. The spacecraft will ride to orbit aboard the first Pegasus flight from the Kwajalein Missile Range in the Pacific Ocean.

October sees the launch of the relativity mission known as Gravity Probe B into a polar orbit from Vandenberg Air Force Base near Lompoc, California. In development for decades, GPB carries an important fundamental physics experiment developed by Stanford University. This ambitious mission will attempt to demonstrate the existence of frame dragging, also known as *gravitomagnetism.* Einstein's general theory of relativity predicts that a rotating mass will drag space-time around with it. One consequence is that two objects traveling in the same direction will have slightly less gravitational attraction between them than objects traveling in opposite directions. In this sense frame dragging is the gravitational equivalent of magnetism, which is a relativistic side-effect of the electrical force caused by moving charges.

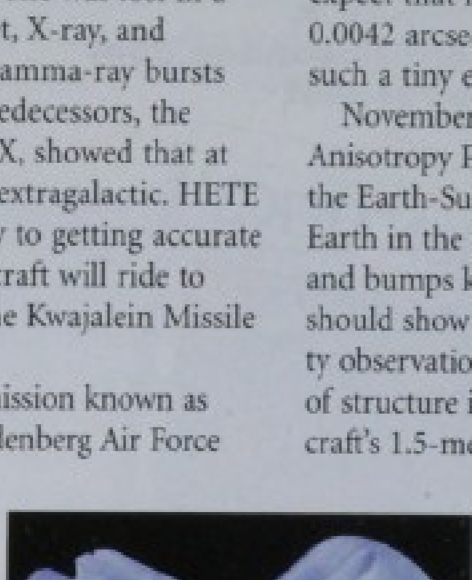
The GPB experiment involves a spinning gyroscope floating inside an otherwise empty chamber that protects it from outside forces like atmospheric drag and solar-radiation pressure. Over the course of a year, if Einstein was correct (and we all expect that he was), the gyro's spin direction will change by 0.0042 arcsecond, about one-millionth of a degree. Measuring such a tiny effect will be an immense challenge.

November is the scheduled launch date for the Microwave Anisotropy Probe. MAP will be the first spacecraft stationed at the Earth-Sun L_2 Lagrangian point, 1½ million kilometers from Earth in the direction opposite to the Sun. The vague lumps and bumps known to exist in the cosmic background radiation should show up clearly in MAP's high-resolution, high-sensitivity observations, allowing cosmologists to get a detailed picture of structure in the early universe. To accomplish this the spacecraft's 1.5-meter reflector will measure the sky's temperature with an angular resolution of around 30 arcseconds and an accuracy of 0.00002° Kelvin.

To be launched in July on a Pegasus rocket, the High Energy Solar Spectroscopic Imager will study solar flares in the "hard" X-ray band

EUROPEAN SPACE AGENCY

Europe's X-ray Multi-mirror Mission observatory will complement the capabilities of the Chandra X-ray Observatory.



STANFORD UNIVERSITY

Four high-precision quartz spheres, each 39 millimeters across, form the heart of the gyroscopes aboard Gravity Probe B. Once spun up within their electrically levitating enclosures, the spheres will rotate with so little friction that they should spin freely for 4,000 years.

Astronomy and Planetary Mission Highlights in 2000			
Date	Spacecraft	Event	WWW home page
December (1999)	XMM	launch from Kourou, French Guiana	sci.esa.int/xmm/
January 23	HETE 2	launch from Kwajalein Island	space.mit.edu/HETE/
February	Astro E	launch from Kagoshima, Japan	www.astro.isas.ac.jp/xray/mission/astroe/astroe.html
February 14	NEAR	encounter with 433 Eros	near.jhuapl.edu
February 22	Galileo	final flyby of Io? (200-km altitude)	galileo.jpl.nasa.gov
February	IMAGE	launch from Vandenberg AFB, California	image.gsfc.nasa.gov
May	Odin	launch from Svobodniy, Russia	www.ssc.se/ssd/ssat/odin.html
May	TIMED	launch from Vandenberg AFB, California	www.timed.jhuapl.edu/home.htm
June	Cluster 5/6	launch from Baikonur, Kazakstan	sci.esa.int/cluster/
July	Cluster 7/8	launch from Baikonur, Kazakstan	sci.esa.int/cluster/
July	HESSI	launch from Vandenberg AFB, California	hessi.ssl.berkeley.edu
October	Gravity Probe B	launch from Vandenberg AFB, California	einstein.stanford.edu
November	MAP	launch from Cape Canaveral, Florida	map.gsfc.nasa.gov
December 30	Cassini	flyby of Jupiter at 10,800,000 km	www.jpl.nasa.gov/cassini/

Above: **The "space event log" for 2000 demonstrates that exploration of the universe continues to be an international enterprise.**

(3,000 to 400,000 electron volts) with excellent spatial and spectral resolution. Bringing such energetic X-rays to a sharp focus is difficult, so HESSI will utilize what's termed a transform imaging telescope. It creates images with 2-arcsecond resolution by comparing the photons passing through a variety of spinning slits. HESSI is a part of NASA's Small Explorer series.

In May Sweden plans to orbit Odin, its first astronomy satellite, on a Start rocket (a refurbished ballistic missile) fired from Russia's easternmost "cosmodrome" at Svobodniy. Odin has a 1.1-meter dish antenna for submillimeter (500-gigahertz) observations of giant molecular clouds.

Magnetospheric Satellites

Earth's magnetosphere will be probed by several satellites this coming year. February sees the launch of the Imager for Magnetopause-to-Aurora Global Exploration mission. From its elliptical polar orbit, IMAGE will take ultraviolet pictures of the aurora and map the boundary of the magnetosphere using radio transmitters. It also carries a new kind of instrument that will create "pictures" using the three-dimensional distribution of neutral atoms. IMAGE is NASA's first Medium-class Explorer (MIDEX) mission.

KEVIN MACAULEY / LOCKHEED MARTIN MISSILES AND SPACE

Right: **NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) spacecraft should reach orbit in February.**

In May NASA hopes to launch a satellite from California to study the lower regions of Earth's extended atmosphere. Instruments aboard the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite will measure the flow of energy between the top of the mesosphere (about 80 km high) and the region of the ionosphere above it. It also carries an ultraviolet auroral imager.

June and July are the scheduled dates for launching two pairs of Cluster spacecraft using Russia's Soyuz-Fregat rockets. One of the European Space Agency's cornerstone projects, Cluster involves placing four satellites in similar orbits to make simultaneous measurements of the surrounding charged particles and electromagnetic fields. These data should allow researchers to distinguish between time and space variations in magnetospheric phenomena. The first four Cluster satellites were lost during an Ariane 5 failure in 1996.

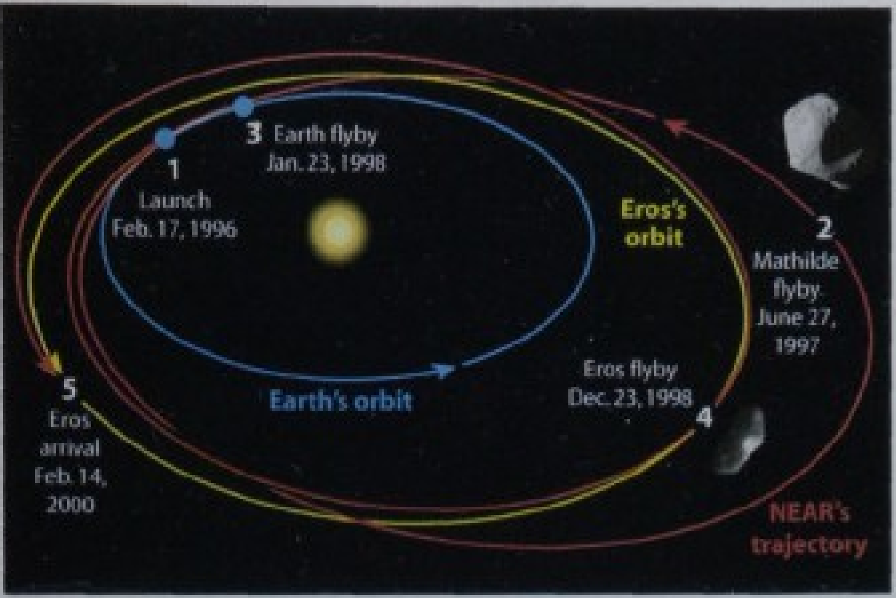
Interplanetary Missions

No planetary voyagers are scheduled for launch in 2000, but several will reach important goals. In mid-February, the Near Earth Asteroid Rendezvous spacecraft makes its second attempt to rendezvous with 433 Eros. The project team aborted its first try in late 1998 because of an engine problem. If NEAR succeeds this time it will enter a close orbit around the asteroid and study it for about a year. A week later Galileo scientists hope to squeeze in one more close flyby of the Jovian moon Io before the mission ends (*S&T:* December 1999, page 28). The comet-bound Stardust probe will reach aphelion and begin collecting interstellar dust with its aerogel (foamed silica) collectors. The year ends as Cassini encounters giant Jupiter. The December 30th flyby will mark the beginning of the craft's final 3½-year cruise to Saturn.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL



Scientists with the NEAR project are hoping for better luck when the spacecraft once again tries to orbit 433 Eros in February.

Near Earth Asteroid Rendezvous

The NEAR mission is approaching its second try at minor planet 433 Eros. After a February 2nd rendezvous burn, NEAR will become the first probe to orbit an asteroid 12 days later on Valentine's Day — appropriate for an Eros encounter. The first try in late 1998 went awry when the engine misfired. The probe did manage to get some images of Eros as it flew past at a distance of 3,900 kilometers on December 23, 1998 (*S&T:* March 1999, page 18), but an extra trip around the Sun was needed to catch up with Eros once again. NEAR carries cameras, a laser rangefinder to map surface topography, X- and gamma-ray spectrometers to study Eros's composition, and a radio transmitter to determine the characteristics of NEAR's orbit and in turn the asteroid's mass.

Mars Polar Lander and Deep Space 2

NASA's Mars Polar Lander was lost during its landing near the Martian south pole on December 3rd. Flight controllers at the Jet Propulsion Laboratory believe that the lander reached the Martian surface at 76.1° south, 195.3° west at 20:01 Universal Time, but for several days thereafter they searched in vain for the expected radio signals. Last contact came just before the spacecraft entered the planet's atmosphere, when the lander was to separate from its cruise stage and the two small Deep Space 2 surface penetrators that were also aboard. Because Mars Polar Lander was not designed to transmit to Earth during its descent, we may never learn what went wrong. The cruise stage or the aerodynamic heat shield may not have separated; the parachute may not have deployed properly; the braking rocket engines may have failed to fire or fired erratically; or the lander may have crashed on rough ground or sunk deeply into the planet's "layered polar terrain," which is thought to contain stacked beds of fine dust and ice laid down over millions of years.

The Deep Space 2 microprobes, recently named Scott and Amundsen, were to slam into the Martian surface at 600 kilometers per hour about 60 km northwest of the main landing site. Although they were designed to survive the 30,000-g impact and relay information back via the orbiting Mars Global Surveyor, nothing was heard from them either. The failure of MPL and DS2, together with the (avoidable) loss of Mars Climate Orbiter last September, leaves NASA's 1999 Mars effort a complete washout. The next pair of missions to the red planet are scheduled for launch in the spring of 2001, but the space agency's entire Mars-exploration strategy will now undergo reevaluation.

Stratospheric Observatory for Infrared Astronomy

The 2.7-meter primary mirror for the SOFIA airborne infrared telescope is now being ground. After the mirror blank was cast in Germany and cut in France, its back side was hollowed out in a honeycomb pattern, which reduced its mass from 4,500 to 880 kilograms. Grinding and polishing should be completed in late 2000. The mirror will become the heart of an f/19.6 Cassegrain telescope installed on a modified Boeing 747-SP aircraft. Test flights of this U.S.-German joint project should commence from NASA's Ames Research Center near San Francisco in 2002.

KAYSER THREDE (REOSC)

This "lightweight" 2.7-meter-wide disk of glass, weighing nearly a ton, is destined to be the primary mirror for a flying observatory called SOFIA.

NASA Budget

After worrisome debate in August and September over a threatened billion-dollar budget cut, Congress eventually restored — and in fact slightly exceeded — the $13.6 billion requested for NASA in fiscal 2000 by the Clinton administration. But even though full funding is now assured, it's not all in the same places — some has been reallocated to future launch-vehicle development and other projects earmarked by Congress. Currently approved spacecraft such as the Deep Impact comet penetrator will not be affected, but planning efforts for future Explorer, Discovery, and Mars-exploration missions were cut by $90 million. Future technology development and research grants also took a hit. Nevertheless, the result is much less dire than was feared in mid-1999.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

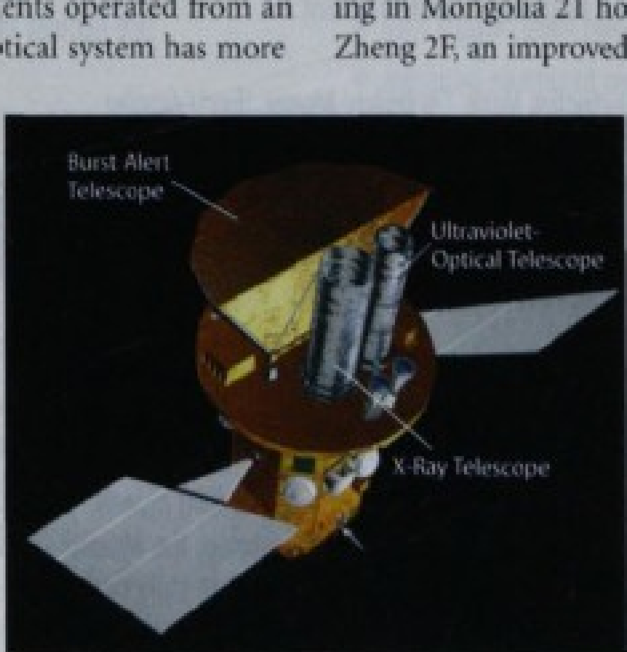
The X-ray Multi-mirror Mission observatory is depicted looping near Earth at the perigee of its 850-by-114,000-kilometer orbit. The 3.9-ton spacecraft is the largest scientific satellite yet developed by the European Space Agency. Courtesy ESA.

X-ray Multi-mirror Mission

The European Space Agency's XMM spacecraft rode an Ariane 5 rocket to orbit on December 10th. (The Ariane 5 had only one fully successful mission to its credit in three previous attempts, so the astronomical community had its collective fingers crossed for a successful launch.) XMM, which will observe from a highly elliptical orbit around the Earth, has three X-ray telescopes and an ultraviolet-optical telescope (*S&T:* August 1999, page 56). The spacecraft will be controlled from Darmstadt, Germany, with the science instruments operated from an ESA facility in Madrid, Spain. XMM's optical system has more collecting area but a shorter effective focal length than that of NASA's Chandra X-ray Observatory, so the resulting images will record fainter objects but with less detail. XMM's instruments were kept dormant for their first few weeks in space, then activated after the spacecraft reached its final orbit and the control center in Spain was ready for operation.

Swift

In late 1999 NASA managers selected the third and fourth Midex (Mid-sized Explorer) missions for development. Preparations for one of the winners, the Swift Gamma-Ray Burst Explorer, began in early November at NASA's Goddard Space Flight Center, the home base of principal investigator Neil Gehrels. Swift's Burst Alert Telescope (BAT) will detect "hard" X-rays, those with energies of 10,000 to 150,000 electron volts. Although its collecting area of 5,200 square centimeters is only half that of the BATSE detectors on the Compton Gamma Ray Observatory, BAT will be five times more sensitive and offer a tenfold improvement in angular resolution. When BAT detects a gamma-ray burst, the X-ray and ultraviolet-optical telescopes will be pointed at the burst for follow-up observations. Swift will be launched in 2003 into an equatorial orbit 600 kilometers high.



The combination of event detectors and telescopes aboard Swift will provide astronomers with a powerful new tool to explore enigmatic gamma-ray bursts. Courtesy NASA/Goddard Space Flight Center.

Full-sky Astrometric Mapping Explorer

FAME, the fourth Midex mission, builds on the success of Europe's Hipparcos spacecraft and will measure 40 million stars with a positional accuracy of 50 microarcseconds. The mission, led by the U.S. Naval Observatory and built by the Naval Research Laboratory, will operate from geostationary orbit beginning in 2004. (Hipparcos was to occupy such an orbit as well but became stranded in a lower, elongated path when its apogee motor failed.) FAME will obtain distances to stars brighter than 15th magnitude and out to 8,000 light-years. This extended range should permit astronomers to calibrate the brightnesses of Cepheid variable stars (used as "standard candles" for gauging the distances of other galaxies) and of relatively old subdwarf stars (allowing better distance estimates to globular clusters).

Chinese Space Program

For at least a decade space watchers have speculated that the People's Republic of China has been planning a human spaceflight program. These rumors took concrete form when the two Chinese astronaut candidates, Li Quinlong and Wu Ji Li, trained at Russia's Star City complex in 1996. Then, with unprecedented publicity, an unoccupied Shenzhou ("Divine Ship") spacecraft was orbited from the Jiuquan Space Center in the Gobi Desert at 22:30 Universal Time on November 26th, followed by a landing in Mongolia 21 hours later. The launch utilized the Chang Zheng 2F, an improved version of the rocket used to loft satellites for Western communications companies; a new vehicle-assembly building reminiscent of the Space Shuttle facility in Florida; and a new mission-control center. Similar to Russia's Soyuz, Shenzhou consists of a descent capsule sandwiched between laboratory and propulsion modules. The descent capsule is identical to the Soyuz and probably uses actual hardware purchased from the Russians. The first launch of a Shenzhou with astronauts aboard may occur late this year.

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BY JONATHAN McDOWELL


RUSS UNDERWOOD, LOCKHEED MARTIN MISSILES & SPACE

The giant cryogenic dewar that surrounds the Gravity Probe B payload will carry 1,500 liters (400 gallons) of liquid helium into orbit — a two-year supply.

Gravity Probe B

The long and controversial saga of the Gravity Probe B mission took another unfortunate twist late in 1999. With the experiment module nearly ready to be added to the main spacecraft, the science team discovered that one of three crucial heat-dissipation probes wasn't working correctly. If the heat-dissipation system were to fail after launch, the liquid helium keeping GPB's interior at 1.8° Kelvin would evaporate quickly. Fixing the problem requires opening up the delicate payload for surgery, and by mid-December engineers had begun their disassembly. However, the experiment wasn't designed to be reopened, and the repairs will delay the mission's launch (which was to occur this October) by 11 months. Meanwhile, Edward J. Weiler, NASA's associate administrator for space science, has allowed the $30 million repair effort to begin but has also initiated a complete review. In the end he may cancel the $440 million mission outright — even though it has been in various stages of planning for more than 20 years. The four ultraprecise gyroscopes aboard GPB are able to measure a tiny torquing on the spacecraft caused by Earth's gravity (just 44 milliarcseconds per year) that is predicted by Einstein's general theory of relativity.

Active Cavity Radiometer Irradiance Monitor Satellite

The third Active Cavity Radiometer Irradiance Monitor has been placed in orbit to gauge the Sun's energy output and thus to provide data crucial for models of climate change. ACRIMSat weighs 115 kilograms and carries a single instrument that measures the absolute solar flux from 2000 angstroms in the ultraviolet to 20,000 angstroms (2 microns) in the infrared. An ACRIM previously flew on the Solar Maximum Mission in 1980 and the Upper Atmosphere Research Satellite in 1991. The series' third instrument was originally to ride on a large Earth Observing System vehicle but ended up on a small satellite of its own as part of NASA's "faster, cheaper, better" revolution. Built by Orbital Sciences and operated from the Jet Propulsion Laboratory's Table Mountain Observatory, ACRIMSat was launched December 20, 1999, on a Taurus rocket. It now occupies a polar orbit with an altitude of 685 kilometers.

Cosmic Hot Interstellar Plasma Spectrometer Satellite

The Sun is near the edge of a small cloud that sits inside a large but thin bubble of hot gas. Several hundred light-years across, the bubble emits mostly extreme-ultraviolet (EUV) radiation — a waveband that remains relatively unexplored. To investigate this bubble's properties, astronomers at the University of California at Berkeley have undertaken CHIPSat, a spacecraft that will obtain spectra of the diffuse cosmic background in the range of 90 to 260 angstroms. The Berkeley group's new effort builds on the success of its Extreme Ultraviolet Explorer (EUVE) mission, which looked at energetic point sources. Unlike EUVE, however, the CHIPS instrument lacks an imaging telescope; instead it records the spectrum of a single 5°-by-26° field of view. Therefore, its all-sky map will not be very detailed, consisting of only 316 swaths of sky. But CHIPSat's sensitivity will give it the upper hand in detecting the general distribution of hot gas in our interstellar vicinity. One of the project's key goals is to determine which spectral lines dominate the emission, which should reveal the gas's ionization state and how it cools. To be built by the start-up company SpaceDev, CHIPSat is the first of NASA's new small, university-class Explorer missions. Current plans call for the 85-kg satellite to be lofted into a 600-km-high orbit as a secondary payload during the launch of a Global Positioning System satellite in April 2002.

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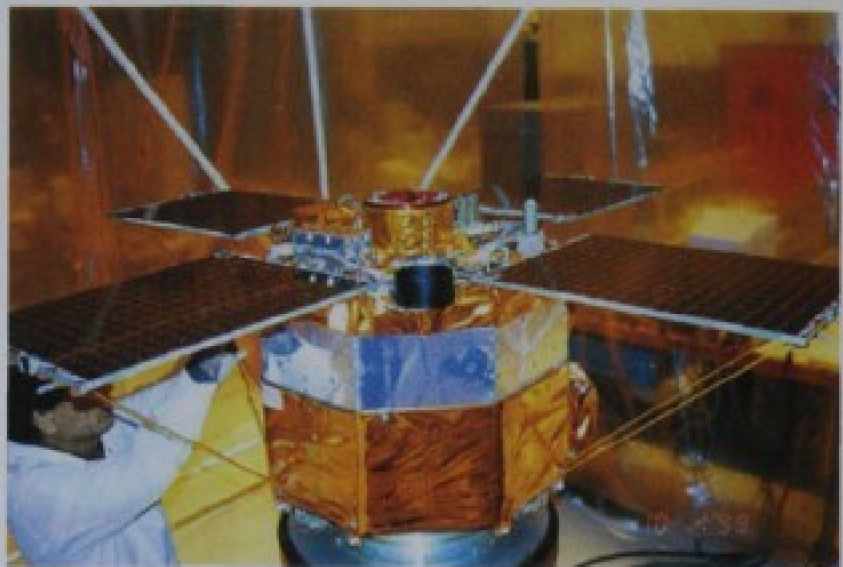
RONALD J. ZENONE, JPL/NASA

With the recent launch of the third Active Cavity Radiometer Irradiance Monitor, NASA scientists can look forward to continued measurements of the Sun's luminous output.

MISSION UPDATE

BY JONATHAN McDOWELL

Astro E

Japan's latest X-ray astronomy satellite was lost when the first stage of its solid-fueled Mu V rocket malfunctioned and veered off course about 40 seconds after lifting off at 1:30 Universal Time on February 10th. Although the second and third stages partially corrected the trajectory, Astro E ended up with a perigee of only 80 kilometers and probably fell back into the atmosphere before completing even one orbit. The launch was made from Kagoshima, an island off the coast of Kyushu in southwestern Japan. Astro E was to complement NASA's Chandra X-ray Observatory and the European Space Agency's X-ray Multi-mirror Mission (now called Newton), which are already in orbit. Its payload of five coaligned telescopes included the first one to use a calorimeter, a detector that can determine the energy of individual X-ray photons with great precision.

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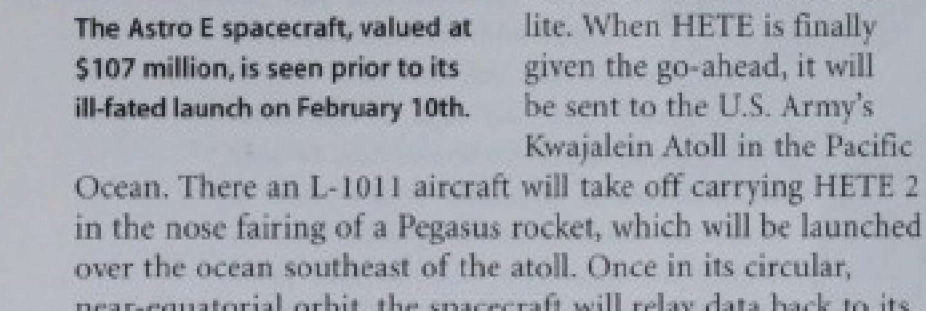
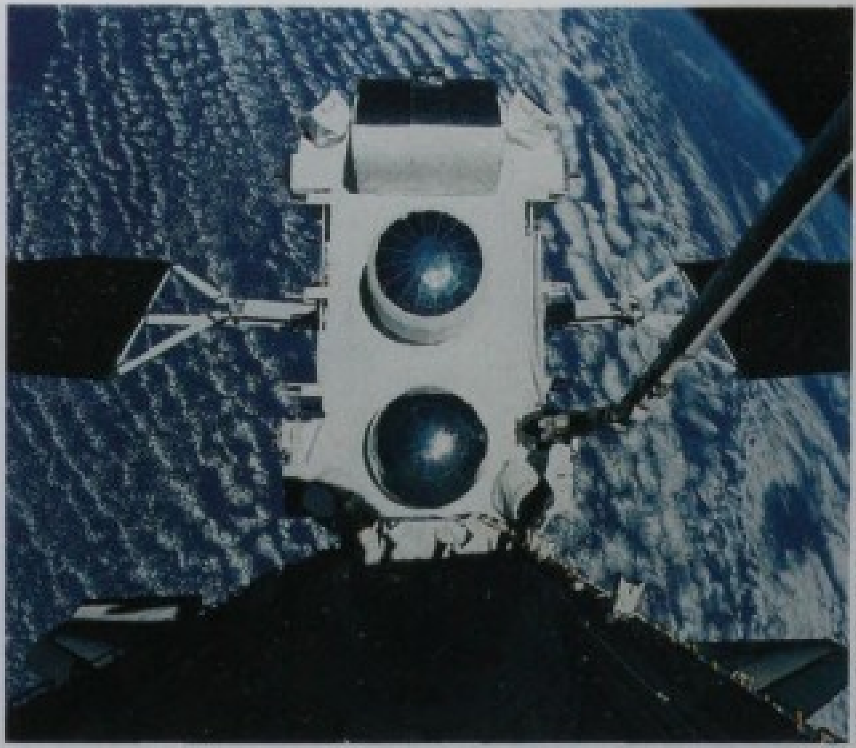
The Astro E spacecraft, valued at $107 million, is seen prior to its ill-fated launch on February 10th.

High-Energy Transient Explorer 2

January's planned launch of the second HETE satellite has been delayed. At the last moment NASA managers, worried by recent failures of two Mars missions, decided to run more tests on the satellite. When HETE is finally given the go-ahead, it will be sent to the U.S. Army's Kwajalein Atoll in the Pacific Ocean. There an L-1011 aircraft will take off carrying HETE 2 in the nose fairing of a Pegasus rocket, which will be launched over the ocean southeast of the atoll. Once in its circular, near-equatorial orbit, the spacecraft will relay data back to its science team at the Massachusetts Institute of Technology via a worldwide network of small receiving stations. HETE 2 replaces a similar satellite lost during launch in November 1996. It carries a gamma-ray detector and ultraviolet and optical imagers to pinpoint mysterious high-energy bursts from deep space.



Once launched into an orbit inclined 2° to the equator, the High-Energy Transient Explorer 2 spacecraft will transmit data whenever within range (circles) of one of its 11 receiving stations (dots). Courtesy MIT.



NASA / JOHNSON SPACE CENTER

The Compton Gamma-Ray Observatory eases away from the Space Shuttle *Atlantis* in April 1991.

Compton Gamma-Ray Observatory

When one of CGRO's three gyroscopes failed last November, NASA officials grew concerned that the spacecraft was just one problem away from becoming a giant hunk of space debris. So they decided to bring down the 15-ton satellite while it was still reliably under control, thus ending nine successful years of operation. (Although simple star sensors orient the spacecraft while observing, the rough ride during a rocket firing normally requires gyros to keep a steady aim.) Fortunately, the mission got a stay of execution in mid-February, because project engineers believe they can ensure a safe deorbit by slowly spinning the spacecraft during rocket firings. NASA managers must now decide whether the observatory will be allowed to continue its observing program or be forced into the atmosphere in early June. Meanwhile, the BATSE instrument remains the most sensitive detector of gamma-ray bursts in space, while the medium-energy OSSE and COMPTEL telescopes continue their studies of the galactic plane, quasars, and supernovae, and the EGRET high-energy detector monitors occasional solar flares. When the end comes, CGRO's capable propulsion system will dump the spacecraft safely in the ocean, avoiding another Skylab-style scare.

Stardust

The comet-bound Stardust probe recently passed a crucial test. Between January 18th and 22nd, the spacecraft fired its engine three times so that it can swing past Earth in January 2001. This flyby will increase the aphelion of Stardust's orbit to 2.7 astronomical units (400 million km), paving the way for an encounter with Comet 81P/Wild 2 in 2004. Meanwhile, Stardust is now moving such that interstellar dust grains strike it at relatively low velocity. The "sticky" aerogel collectors on Stardust's return capsule have been exposed to space, which should allow them to capture some of the prized interstellar material.

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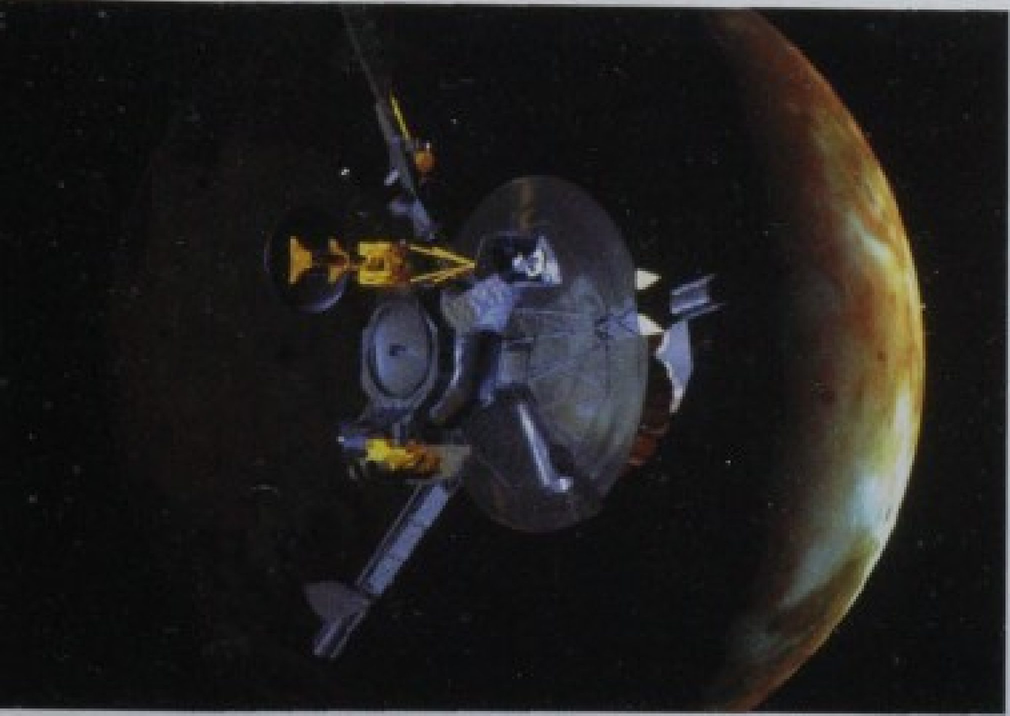
MISSION UPDATE

BY JONATHAN McDOWELL



Galileo made its fourth — and perhaps last — flyby of Io on February 22nd. Courtesy NASA/JPL.

Galileo

Following a November encounter with Io and a January pass of Europa, the Galileo spacecraft survived its closest brush with Io on February 22nd. This flyby, at an altitude of only 198 kilometers, concentrated on studies of volcanoes and the plasma torus generated along the moon's orbit by volcanic ejecta. Improved software allowed Galileo to carry out the encounter without getting switched off by radiation-induced glitches, which had marred prior visits to Io. However, the spacecraft temporarily lapsed into safe mode two days after the flyby and briefly interrupted the playback of data to Earth. February's close approach also provided an energy kick that redirected the spacecraft into a more elongated orbit stretching out 11 million kilometers from Jupiter and increased its orbital period to three months. Now that NASA managers have agreed to extend operations through the end of 2000, the Galileo mission resumes its exploration of the Jovian system with a flyby of Ganymede on May 20th.

Koronas F

Russia's Koronas F satellite is now scheduled for launch in October. This is the second in a pair of solar-research satellites and the first Russian scientific payload since 1996 (not counting Earth observers). Koronas I, with instruments largely from Moscow's Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation (abbreviated IZMIRAN in Russian, hence the "I"), was launched in 1994 but lost attitude control after a few months. The 12 instruments aboard Koronas F include an arcsecond-resolution solar X-ray telescope from the Lebedev Physical Institute (abbreviated FIRAN, hence the "F"). Weighing in at 2,260 kilograms, Koronas F is the latest in a long series of scientific missions that is the Russian counterpart to NASA's Explorer program. It will be launched from the Plesetsk spaceport on a Tsiklon rocket and will observe the Sun continuously from a near-polar orbit 500 km high.

Nozomi

Japan's first planet-bound spacecraft continues its delayed voyage to Mars. When Nozomi (formerly Planet B) was launched in 1998, a faulty rocket depleted much of its fuel and sent the spacecraft into the wrong trajectory around the Sun. Project engineers came up with a plan to save the mission using gravity-assist flybys of Earth. Nozomi completed its first 16-month-long orbit of the Sun in May, returning to perihelion near Earth's orbit, and its next perihelion will be in August 2001. During the third one, in December 2002, the spacecraft will meet up with Earth and be kicked out of the ecliptic plane for a few months. Nozomi will intercept Earth one more time on the way down, a final encounter designed to place it on course for an arrival at Mars — four years late — at the end of 2003.

Highly Advanced Laboratory for Communications and Astronomy

HALCA (formerly Muses B), a Japanese radio-astronomy satellite, endured multiple problems in late 1999. After losing an attitude-controlling reaction wheel in October, HALCA resumed observations in December but lost control of its orientation a second time later that month because of a commanding error. The satellite was left spinning and could not be recovered immediately because of limited electrical power. In late February ground controllers again brought the satellite under control, and observations resumed on March 8th. HALCA's 8-meter antenna is used in conjuction with telescopes on the ground to make high-resolution images at 1.6 and 5.0 gigahertz. Most of its targets are radio-loud quasars and galaxies.

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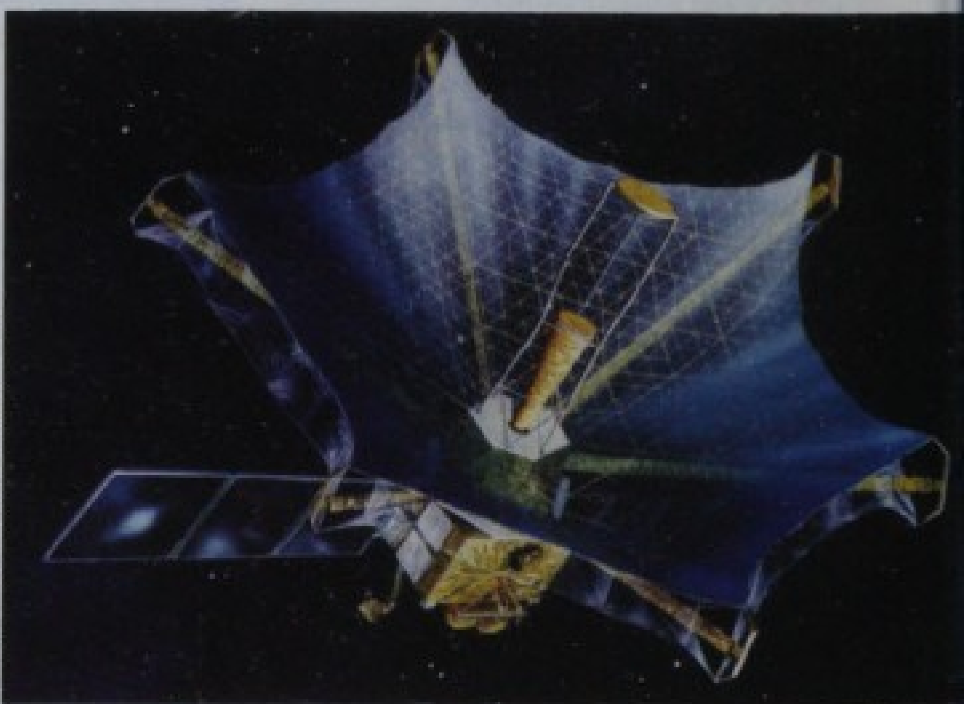

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Eight meters across, the Highly Advanced Laboratory for Communications and Astronomy (HALCA) observes in concert with radio telescopes on Earth. The spacecraft is also called Haruka, Japanese for "far away," which aptly describes the satellite's 21,000-kilometer apogee.

MISSION UPDATE

BY JONATHAN McDOWELL

Imager for Magnetopause-to-Aurora Global Exploration

NASA has a powerful new tool for exploring Earth's magnetosphere. The IMAGE satellite was launched from Vandenberg Air Force Base on March 25th, becoming the first of the Midex (Midrange Explorer) scientific satellites to leave the pad. A three-stage Delta 7326 rocket placed IMAGE in a 1,000-by-46,000-kilometer orbit that reaches apogee over Earth's North Pole and takes the spacecraft through the most intense part of our magnetosphere's radiation belts. In addition to having two ultraviolet auroral cameras, IMAGE carries innovative "neutral-atom imagers" that will map the three-dimensional distribution of energetic particles. One other experiment, designed to measure radio waves generated in the magnetospheric plasma, uses a set of four wire antennas 250 meters long — making IMAGE one of the largest satellites ever launched.

As several thousand spectators looked on, the IMAGE spacecraft was launched from California on March 25th at 20:34:43 Universal Time. Courtesy Pamela A. Taubman, 30th Space Wing, Vandenberg Air Force Base.

The winning design for NASA's Gamma-ray Large Area Space Telescope, as portrayed by Timothy M. Carnahan. Courtesy NASA/ Goddard Space Flight Center.

Gamma-ray Large Area Space Telescope

As NASA's next big high-energy astronomy mission, GLAST represents a partial replacement for the soon-to-be-lost Compton Gamma Ray Observatory (see page 48). Launch on a Delta-class rocket is planned in 2005. GLAST's main instrument, the Large Area Telescope, is being developed by a Stanford-led international team that was selected in February. It will have 50 times better sensitivity than Compton's EGRET imager, an angular resolution of a few arcminutes, and a detection range from 10 million to 1 billion electron volts. GLAST should be able to pin down the properties of known gamma-ray quasars and a population of as yet unidentified galactic gamma-ray sources. A secondary instrument, approved in March, is the Gamma Burst Monitor. A team at NASA's Marshall Space Flight Center will develop it in collaboration with German scientists at the Max Planck Institute for Extraterrestrial Physics. GBM will be only a third as sensitive as Compton's BATSE burst detector. But its energy range, from 5,000 to 30 million electron volts, overlaps the low-end range of GLAST's Large Area Telescope to permit bursts seen by the latter to be compared with the database of bursts previously recorded.

Mars Polar Lander

The independent panel studying last year's Mars Polar Lander failure issued its report in March. Since the lander had no way of sending signals during the descent phase — a design decision criticized by the panel — we will never be sure what really went wrong, but the review discovered a probable cause for the failure. Preflight tests indicate that unfolding the craft's landing legs probably triggered the sensor designed to detect touchdown. Eighty seconds later, when still 2 km above the surface, the descent engines were to switch on and keep firing until landing. However, because the software didn't reset the touchdown sensor after leg deployment, MPL may have thought it had already landed and therefore never fired its braking rockets. If so, it would have been in free fall during the descent's final 30 seconds, impacting the surface at 14 meters per second. More broadly, the report concluded that the failure was caused by significant underfunding and by having too few people working each part of the project. For example, the review panel felt that the two Deep Space 2 surface probes, which had accompanied MPL to Mars, were not flightworthy at the time they were launched.

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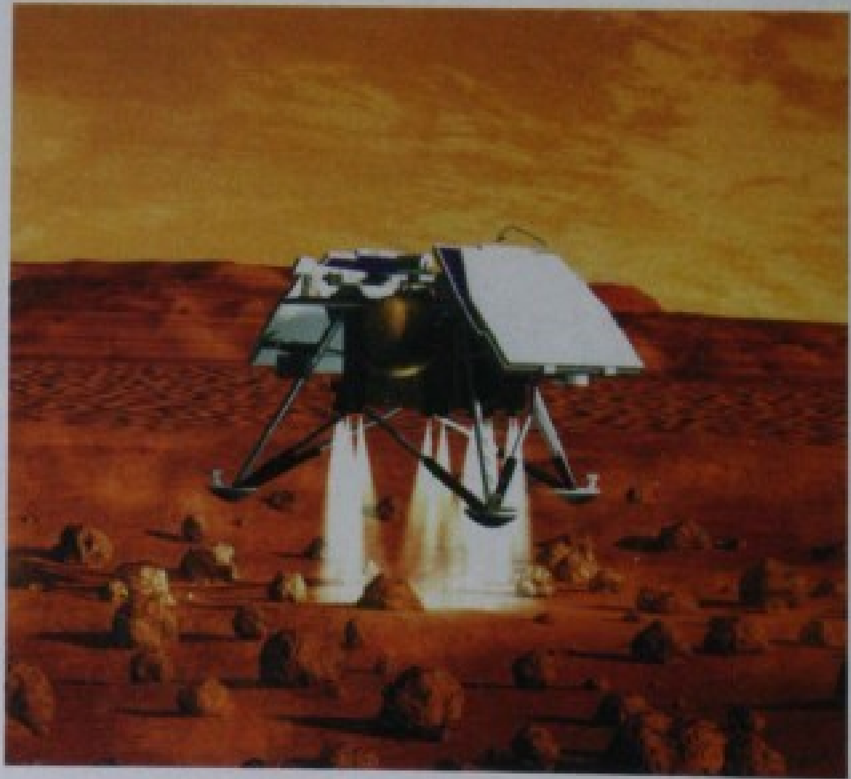
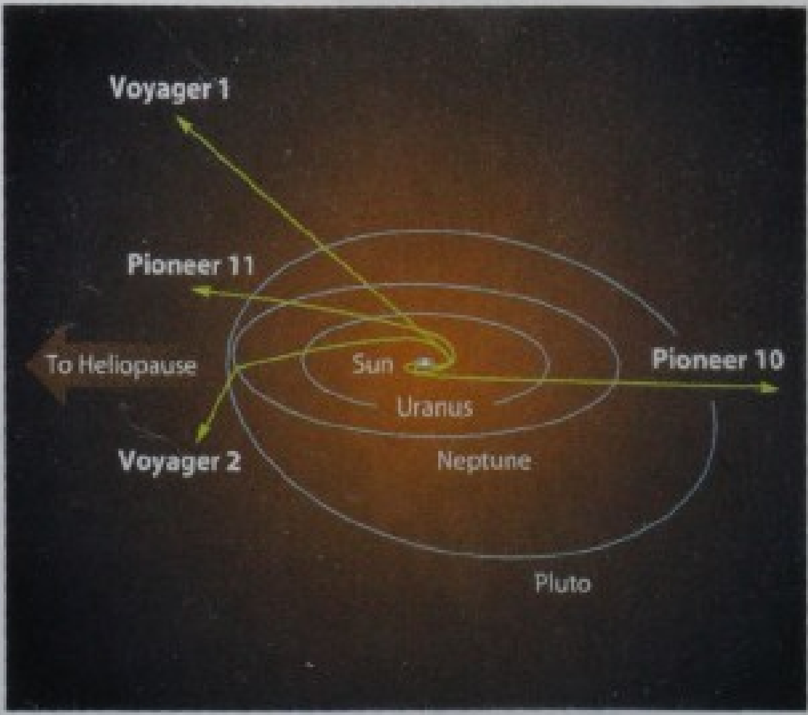


What went wrong when Mars Polar Lander tried to touch down on December 3, 1999? A review panel believes that software problems — and underfunding — doomed the mission. Courtesy NASA/JPL.

BY JONATHAN McDOWELL

This month's column provides status updates (as of June 1st) for many space-science missions that have been out of the spotlight recently but continue to return valuable data.



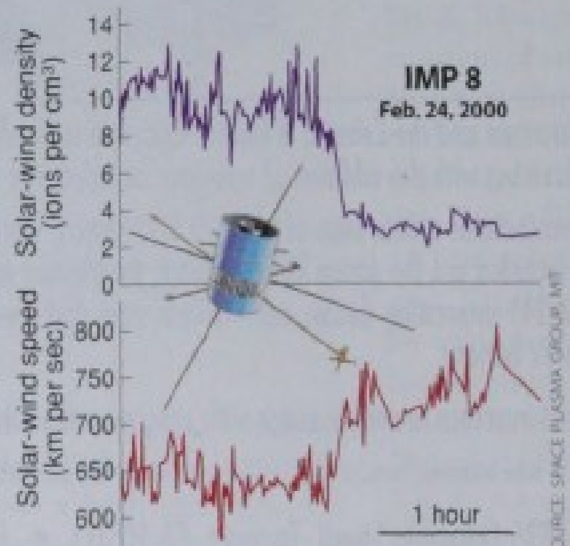
Paths of the four most-distant spacecraft. Pioneer 11 is headed most directly toward the heliopause, but the Voyagers are moving faster. Courtesy NASA/JPL.

The Outer Solar System

Still functioning 28 years after launch, **Pioneer 10** is now 75 astronomical units (11.2 billion kilometers) from the Sun, heading out nearly in the ecliptic plane toward Taurus, away from the galactic center. It's being used as a training tool for spacecraft controllers. Three other outer-planet probes are heading more toward the center of the galaxy —though their velocities are much too small to actually take them far from the Sun's orbit around the galactic center. Now 52 a.u. from the Sun and 14 a.u. north of the ecliptic plane, the defunct **Pioneer 11** is moving toward Scutum in the direction opposite that of its twin. It has been passed by the Voyager probes, now 10 years into their "interstellar" mission, which were launched later but are traveling faster. **Voyager 2** is 61 a.u. away in Telescopium, 26 a.u. south of the ecliptic plane. **Voyager 1**, our most distant emissary, is headed for Ophiuchus. It is now 76 a.u. from the home star (more than 10 light-hours away) and 44 a.u. north of the ecliptic plane. The Voyagers carry particle and radio-wave detectors that are searching for the *heliopause* — the boundary between the solar wind and the interstellar medium.

The Inner Solar System

Headed for an encounter with Comet 81P/Wild 2 in 2004, **Stardust** completed its first sampling of the interstellar medium on May 1st. The collector, which had been exposed to space for 10 weeks, was stowed in the return capsule, and the spacecraft reverted to its cruise mode. Now about 2.1 a.u. from the Sun, Stardust is arcing back in to intercept Earth next year. Japan's **Nozomi** Mars probe, placed in the wrong orbit around the Sun due to a navigation error, recently passed through its first perihelion just inside Earth's orbit but at a point more than 90° in solar longitude from us. It will cruise back out to 1.4 a.u. twice more before intersecting Earth in 2002 on the first swingby to set it back on track for Mars. Europe's solar sojourner, **Ulysses,** is about 2.5 a.u. south of the asteroid belt and headed inward from the orbit of Jupiter. It will swing underneath the solar south pole later this year in advance of its second perihelion in May 2001. There are no Venus or Mercury missions active at the moment, so the only spacecraft still operating closer in to the Sun is the ancient **Pioneer 6,** which was launched in 1965 to monitor the solar wind. Now on its 40th circuit of the Sun, this amazing space-age survivor reached its perihelion of 0.8 a.u. in June.



The Interplanetary Monitoring Platform 8, in solar orbit since 1973, continues to provide useful data about the solar wind. This graph shows an unusual, abrupt drop in the wind's density (top) and a jump in speed (bottom), clues that the shock from a magnetic polarity reversal was passing by.

Near-Earth Space

A million kilometers sunward of Earth is the L_1 Lagrangian point, where the European Space Agency's **Solar and Heliospheric Observatory** monitors the Sun (see page 20) and NASA's **Advanced Composition Explorer** (ACE) studies cosmic rays and solar-flare events. ACE data is regularly used to warn ground controllers of increased solar radiation that could damage other spacecraft. The first satellite to reach the L_1 point, in 1978, was the International Sun-Earth Explorer 3. This hardy craft was relocated to Earth's magnetotail in the early 1980s before being renamed the **International Cometary Explorer** and sent into solar orbit to fly through the tail of Comet 21P/Giacobini-Zinner. ICE was finally shut down in 1997. For a time the **Wind** spacecraft also inhabited the L_1 region, but since 1998 it has been strolling around Earth's magnetosphere. Two other veteran spacecraft remain in distant orbits — Japan's **Geotail** and NASA's **Interplanetary Monitoring Platform 8.** The latter was lofted into a circular, 200,000-km-high orbit in 1973 to study the solar wind and, as seen at left, it still functions well.

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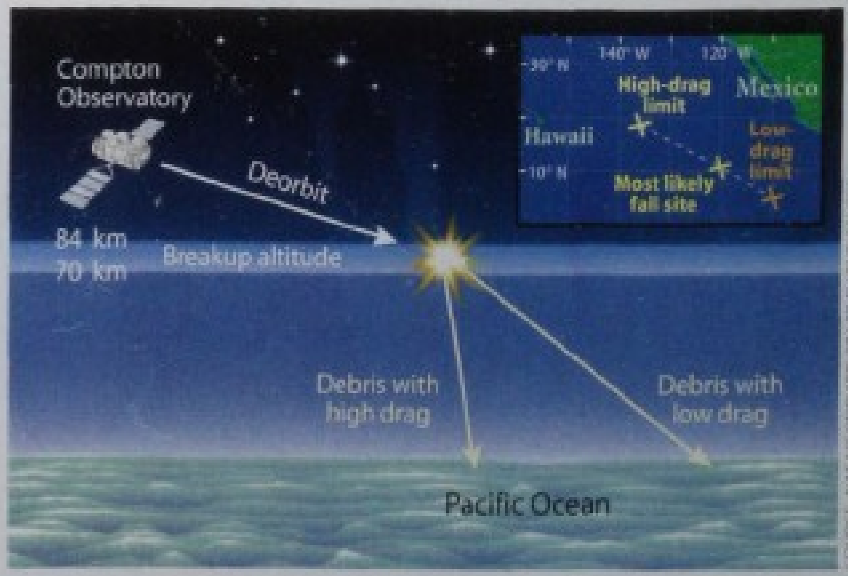
BY JONATHAN McDOWELL

Compton Gamma Ray Observatory

Commanded out of orbit by NASA flight engineers, the Compton Gamma Ray Observatory (CGRO) plunged to destruction on June 4th. It thus becomes the first of NASA's four Great Observatories to complete its mission (July issue, page 48). CGRO was launched aboard the Space Shuttle *Atlantis* in April 1991, just a year after the Hubble Space Telescope reached orbit. It carried four instruments: the BATSE gamma-ray burst detector, which disproved earlier theories that these energetic blasts come from our own galaxy; the OSSE and Comptel medium-energy gamma-ray telescopes, which studied emissions in the Milky Way and from nearby active galaxy nuclei; and the EGRET high-energy detector, which discovered a range of new sources, including gamma-ray quasars.

NASA decided to end the mission because of concerns that a second gyroscope failure might make it difficult to bring the spacecraft down safely. (With a dry mass of 13.8 metric tons, Compton is one of the heaviest objects to fall from orbit in recent years.) In early May, CGRO was observing solar-flare gamma rays from its 485-kilometer-high, 28.5°-inclination orbit. Controllers shut down the science instruments on May 27th, and the first descent burn occurred four days later. Early on June 4th, a third burn lowered perigee to only 148 km, and one orbit later, the fourth and final burn dropped CGRO's perigee to a mere 28 km. At 6:09 Universal Time the spacecraft began tumbling, and its internal temperature soared. Loss of radio contact came one minute later, and the surviving debris hit the Pacific Ocean southeast of Hawaii at 6:18 UT.



The Compton Gamma Ray Observatory was so massive that several dozen large pieces probably survived its fiery reentry on June 4th. The most likely crash site was about 3,900 kilometers southeast of Hawaii.

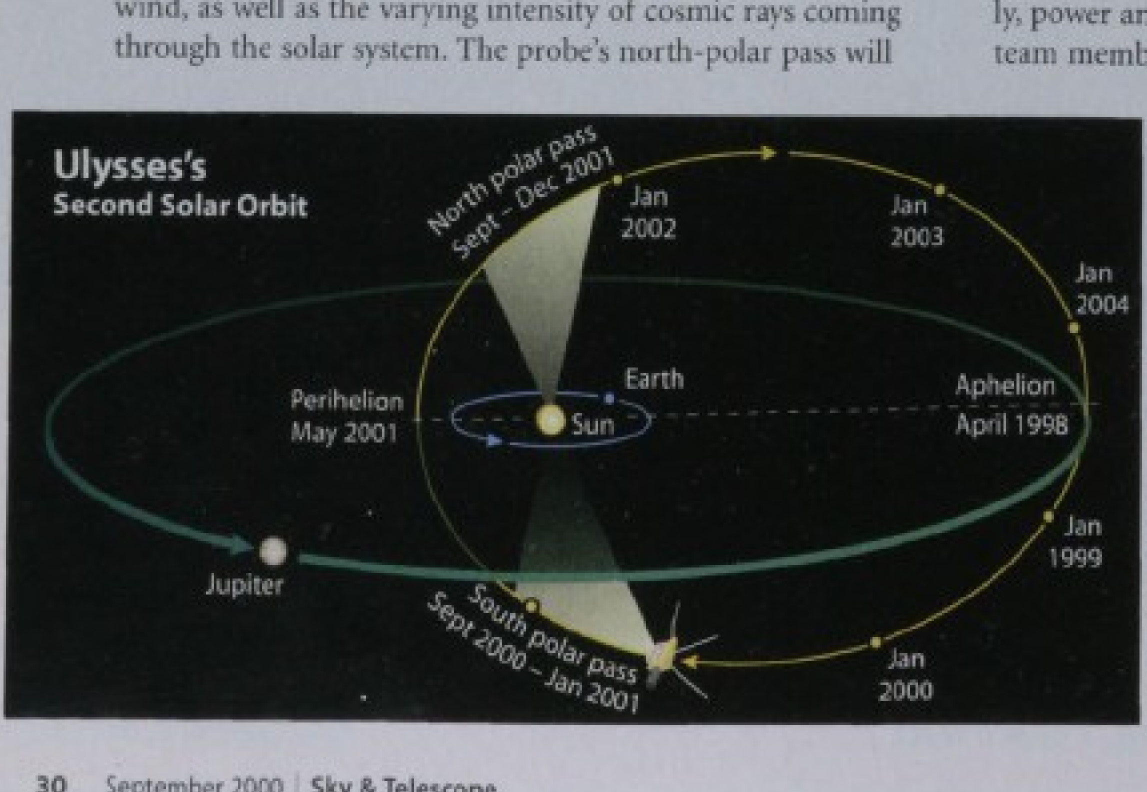
Ulysses

The European Space Agency's Ulysses spacecraft is poised to begin its second traverse of the Sun's polar regions. The probe will be within 7° of the south pole (though several hundred million kilometers away) from September 8th until next January 16th. This should be an especially rewarding pass, as the Sun is now going through the most dynamic portion of its 11-year activity cycle. Throughout this year's solar maximum Ulysses has been studying the Sun's magnetic field and the solar wind, as well as the varying intensity of cosmic rays coming through the solar system. The probe's north-polar pass will occur next year from September 3rd to December 12th. Ulysses is also used to help triangulate accurate positions for the brightest gamma-ray bursts from extragalactic space. In early June ESA managers approved an extension to the mission, which means Ulysses will continue operating until returning to the vicinity of Jupiter in late 2004. (After its launch in 1990, the spacecraft skirted close to Jupiter in February 1992 and, in doing so, was flipped into its current high-inclination orbit around the Sun.) However, by then the slowly declining power output of the craft's plutonium radioisotope generators will require that a few instruments be switched off periodically.

Alexis

The terrible fire that ravaged northern New Mexico in May was a close call for the Alexis extreme-ultraviolet astronomy satellite. Launched in May 1993, Alexis is normally controlled by a small team at the Los Alamos National Laboratory, and its operations are highly automated. Lab employees were evacuated on May 6th, expecting to be back within a few days, but were unable to return permanently until May 22nd. Fortunately, power and computing services remained on, and the Alexis team members were able to log in remotely — they even commanded a crucial spin-up maneuver on May 20th. Despite occasional thermal problems, Alexis continues scanning the sky with six small telescopes. These optics, which utilize multilayered molybdenum-silicon coatings to enhance their reflectivity at very short wavelengths, are gathering data on the soft X-ray background and transient cosmic sources.

JONATHAN McDOWELL, an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).



Over the next 15 months the Ulysses spacecraft will spend much of its time over the Sun's polar regions.

MISSION UPDATE

BY JONATHAN McDOWELL

Deep Space 1

The Jet Propulsion Laboratory has pulled off a remarkable rescue in solar orbit. Last November, after flying past the asteroid 9969 Braille (*S&T:* October 1999, page 28), the Deep Space 1 probe lost the use of its star tracker — a failure that threw a planned bonus comet encounter into doubt. The star tracker was needed to tell the probe which way it was pointing, and without it navigation seemed impossible. However, clever engineers have since reprogrammed the spacecraft to use its science camera, the Miniature Integrated Camera Spectrometer, as its guiding eye. But it's still a tricky task: MICAS was not designed to work with the orientation system, and its field of view has one-hundredth the area of the failed tracker's. Ground controllers have to find a bright star that's roughly in the right direction and command the experimental "autonomous navigation system" software to process and transfer the MICAS images to the main onboard computer in a form it recognizes. Fortified with this new software, Deep Space 1 was able to resume using its ion-propelled engine on June 21st, setting course for a flyby of Comet 19P/Borrelly in September 2001. In the coming year the craft's orbit size will evolve from 1.10 by 1.34 astronomical units to 1.29 by 1.44 a.u.

JET PROPULSION LABORATORY

The Deep Space 1 mission is part of NASA's New Millennium program to develop advance technologies for robotic spacecraft.

Cluster II

Two successful test launches of the new Soyuz-Fregat rocket set the stage for the launch of the European Space Agency's Cluster II space-science fleet. The Fregat upper stage, involved in the ill-fated Phobos and Mars 1996 space probes, performed perfectly during the test flights in February and March, which placed dummy satellites in orbit. Then, on July 15th and August 9th, the recertified rocket delivered the Cluster payloads to elliptical, 200-by-18,000-kilometer transfer orbits inclined 65° to the equator. Cluster consists of four identical probes that will fly in formation to study the time and spatial variations of particles and fields in Earth's magnetosphere. The cylindrical, 3-meter-wide satellites were stacked in pairs on two rockets. In an unusual launch scheme, the Cluster craft use onboard engines to change their initial orbits radically, eventually reaching 125,000-km apogees and even steeper 90° inclinations. Each satellite then deploys four 50-meter-long wire antennas and begins flying in a tetrahedral formation with separations varying from a few hundred to tens of thousands of kilometers. The craft will monitor the magnetospheric bow shock, the cusp region over each magnetic pole, and the magnetotail. The new Cluster — named Rumba, Salsa, Samba, and Tango — replaces four earlier satellites that were destroyed seconds after launch from French Guiana in 1996 on the first test flight of the Ariane 5 rocket.

EUROPEAN SPACE AGENCY

After losing its first quartet of Cluster spacecraft in 1996, the European Space Agency decided to build and launch replacements.

Russian engineers prepare the Zvezda module for launch. With a length of 13 meters and a mass of 19,000 kilograms, it is a near-twin of Mir's core module. Courtesy NASA/Johnson Space Center.

Zvezda

Early on the morning of July 12th, Russia launched a crucial component for the International Space Station. Zvezda ("star") will serve as the station's service module, providing the crew with living quarters and other key functions. This is actually the eighth in the DOS series of long-duration orbital stations, whose first entrant (Salyut 1) was lofted in 1971. Vehicle 8 is almost identical in outward appearance to its predecessor, the Mir station core module. Like all the DOS stations, Zvezda consists of a narrow cylinder with a control center connected to a larger 4-meter-diameter cylinder with living area and experiments. Like Mir, it features a single rear docking port for Progress and Soyuz transport craft and a spherical docking complex at the front with five docking ports for space-station modules. Zvezda was scheduled to link up with the Russian-built (but American-owned) Zarya module at 00:45 Universal Time on July 26th. The launch of Zvezda was years late, a victim first of Russian budgetary problems, then of mutliple failures with the Proton-K launch vehicle. After a robot cargo craft and two Space Shuttle missions dock to complete the station's initial outfitting, three astronauts will ride a Soyuz vehicle to orbit in October to begin Zvezda's occupation.

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BY JONATHAN McDOWELL

Mars Surveyor 2003

Following the failures of both Mars Surveyor 1998 missions, earlier this year NASA decided to postpone its next landing mission and instead to send a single orbiter to Mars in April 2001, with arrival six months later. Mars Surveyor 2001 is similar in design to the now-lost Mars Climate Orbiter — but presumably it will be calibrated more consistently in metric units. The orbiter will study the planet's surface composition and geology using a gamma-ray spectrometer and a visible-infrared camera.

The 2003 mission, announced in July and expanded in August, will feature two Mars Exploration Program Rovers (MEPRs). The delivery method is similar to that for Mars Pathfinder, with the payload encased in an airbag landing system and petals that open outward to turn the craft upright no matter which way it comes to rest once on the surface. Pathfinder had a stationary lander attached to the petal system and a tiny rover, Sojourner. In contrast, the 150-kilogram MEPR (also known as the Mars Mobile Lander) fills the volume inside the petals, replacing the base station entirely. The MEPR is much faster than Sojourner, traveling a kilometer every 10 days. Its miniature geologic laboratory includes a tool to scrape rocks so that their interiors can be examined, an infrared imager, and a high-resolution camera.

The twin spacecraft will be sent to different regions of Mars, though the landing sites have yet to be selected. A logical strategy would be to send them to locales where pools of water once existed, or to one of the places where Mars Global Surveyor has found evidence for recent flows of water (September issue, page 56). Launches using Delta II rockets are planned in May and June 2003, with arrivals 18 days apart in January 2004.

One of NASA's twin Mars rovers leaves behind its collapsed lander (far right) after touchdown in January 2004. This image is from a computer-generated video created by Dan Maas, a 19-year-old undergraduate at Cornell University.

High-Energy Transient Explorer 2

The HETE 2 spacecraft is ready for another try at getting into space. In January the satellite was aboard its Pegasus rocket at Vandenberg Air Force Base, ready for ferrying to its Pacific launch site, when NASA ordered a stand-down because two of the three primary ground stations, in French Guiana and Singapore, were not ready. In the wake of the early post-launch failures of two other Pegasus-launched satellites, it seemed prudent to make sure HETE 2 can stay in contact with mission controllers as much as possible during its first few hours of flight. Extra thermal-vacuum and vibration testing was performed in the past few months, and the satellite has now been slated for an airborne launch in early October near Kwajalein Atoll in the Pacific Ocean. HETE 2, an MIT-led project, will use gamma- and X-ray detectors to find accurate locations for gamma-ray bursts. A network of small ground stations straddling the equator will relay the spacecraft's data back to the MIT control center (May issue, page 26).

Advanced Satellite for Cosmology and Astrophysics

Japan's ASCA X-ray astronomy satellite (also named Asuka in Japanese) has fallen victim to the biggest solar flare in a decade. After the July 14th blast, Earth's uppermost atmosphere ballooned upward so much that drag on the spacecraft overwhelmed ASCA's attitude-control system. The satellite went into a tumble, and once the solar-cell panels were no longer pointing at the Sun the batteries quickly discharged. Efforts by Japanese ground controllers to revive the ASCA satellite are continuing. Launched in February 1993, the spacecraft was expected to reenter within the coming year anyway. Even so, X-ray astronomers will be disappointed if the last few months of observations are lost. The Chandra observatory, though equipped with a better mirror and CCD imagers like the ones that ASCA pioneered, is seldom used for the long observations of sources that ASCA frequently conducted.

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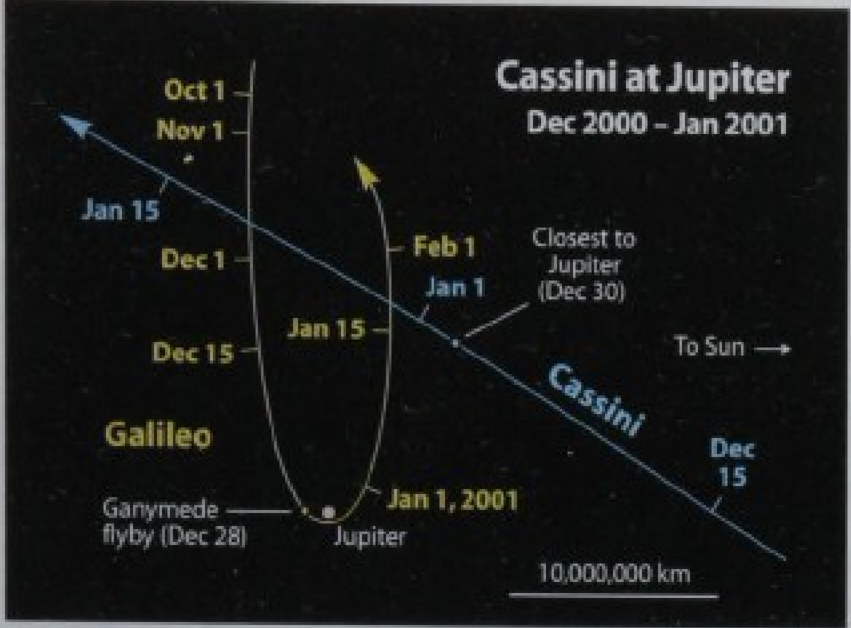
CENTER FOR SPACE RESEARCH/MIT

The second High-Energy Transient Explorer is seen attached to the nose of its Pegasus XL rocket last January.

BY JONATHAN McDOWELL



Late this year, NASA's exploration of Jupiter will offer a double feature, as the Saturn-bound Cassini spacecraft briefly joins the Galileo orbiter for joint studies. Source: NASA/JPL.

Galileo and Cassini

The closing days of the 20th century will see an unprecedented double encounter with Jupiter. The Galileo orbiter, which passed its farthest from Jupiter at 20 million kilometers on September 8th, falls inward to make a close pass by the planet on December 29th. One day later, the Cassini probe will swing past on its way to Saturn, giving us a close-up stereo view of the Jovian system. Cassini is studying the planet from early October to March, even though its closest approach will be only 9.8 million kilometers — well outside the outermost moons. But this is still close enough for Jupiter's enormous gravity to increase the probe's velocity by 2.2 km per second. In fact, Jupiter's gravitational *sphere of influence* (dominance) is 48 million kilometers, more than the distance between the orbits of Earth and Venus. During the double encounter Galileo will be inside Jupiter's magnetosphere (465,000 km from the planet), Cassini well outside, and the pair will study how changes in the solar wind affect conditions in near-Jovian space. Cassini will then swing on toward Saturn, arriving there in mid-2004. Galileo's fate thereafter is still being decided; eventually NASA will order its destruction in Jupiter's atmosphere, to prevent an accidental crash with Europa from contaminating that moon and compromising any future search for life there.

Space Infrared Telescope Facility

The launch of SIRTF has slipped from December 2001 to mid-2002 because one of its instruments, the Infrared Array Camera, is behind schedule. IRAC has four detectors, each of which covers a different wavelength band and images a 5-arcminute square of sky. The camera itself is working well and ready for delivery, but the electronics that transfer data from the camera to the spacecraft have run into problems. Meanwhile, SIRTF's 85-centimeter-wide primary mirror is complete, and its two other scientific instruments (a midinfrared spectrometer and an imaging photometer) are being integrated with the super-cooled detector assembly for tests. SIRTF will ride into solar orbit atop a Delta 7920-H rocket; this one-of-a-kind launch vehicle combines a Delta II core with the bigger solid-fuel auxiliary motors from the new Delta III.

Technicians examine the mirror assembly for NASA's Space Infrared Telescope Facility. Courtesy Ball Aerospace and Technologies.

Stardust

The Stardust probe makes its second visit to Earth on January 15th, completing its first orbit around the Sun two years after launch. The probe will fly 3,700 km from Earth's surface, close enough to alter Stardust's orbit and increase its most distant point from the Sun (aphelion) from 2.2 to 2.7 astronomical units and its inclination to the ecliptic from almost zero to 3.6°. In January 2004, Stardust will meet up with its main target, the periodic comet 81P/Wild 2. Long before then, mission planners hope to solve a mysterious problem with the main camera, which earlier this year was found to have some kind of contaminating film on one of its optical surfaces. Efforts are under way to clean the optics using heat, but if these should fail the planned photography of the comet will be jeopardized — as will navigating to a close, 150-km flyby distance.

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MISSION UPDATE

BY JONATHAN McDOWELL

The year 2001 should see a number of key exploration missions take wing and the International Space Station (finally) assume center stage as the successor to Russia's aging space habitat Mir.

The nine germanium detectors inside the High Energy Solar Spectroscopic Imager, depicted here in orbit, will record the energy of X-rays and gamma rays emitted by solar flares. Courtesy Michael Matranga (Spectrum Astro).

Astronomy Satellites

The Hubble Space Telescope once again steals astronomers' attention in 2001, with Servicing Mission 3B scheduled for May. Spacewalking astronauts will remove the European-built Faint Object Camera, which has served for 10 years, and replace it with the new Advanced Camera For Surveys (actually three cameras with different resolutions and wavelength ranges). The crew will also install a new solar-cell panel and restore the NICMOS infrared camera to operation by giving it a new cooling system. Meanwhile, work on Hubble's successor, the Next Generation Space Telescope, is under way. NGST will not be launched until about 2009, but this coming year NASA will select one of three competing designs and a prime contractor for the billion-dollar undertaking.

The Sun's activity will remain high into 2001, so we can expect more spectacular flare images from space-based solar observatories. These craft will be joined this year by the High Energy Solar Spectroscopic Imager, which will record the Sun at gamma- and X-ray wavelengths. Last year HESSI's debut was delayed when the spacecraft sustained damage in a test accident, but launch is now expected in the spring aboard a Pegasus rocket fired over the Atlantic Ocean near Cape Canaveral.

Solar sentinels like Europe's Solar and Heliospheric Observatory and NASA's Advanced Composition Explorer have found a favorite spot at L_1, the first Lagrangian point, between the Earth and the Sun. In this location spacecraft hover at a balance point between Earth and solar orbit. The Genesis probe, due for launch in February, will be sent to L_1 for a two-year mission to collect samples of the solar wind.

However, the L_1 point isn't so good for a telescope that wants to look at distant galaxies, because observing faint objects from there is compromised by having the Sun on one side and the bright Earth on the other. The new prime real estate for deep-sky observers is L_2, a similar balance point in Earth's shadow. From the L_2 point sensitive detectors can look straight out into a nice, dark sky — the astronomer's dream. L_2's first tenant, and likely the first of many, will be the most-awaited new mission of the year: the Microwave Anisotropy Probe. MAP is due for launch in May 2001 and, upon reaching its station a million kilometers over midnight on Earth, will take the best images yet of vestigial lumps in the Big Bang fireball. A smaller mission that also should generate exciting cosmological results is the Galaxy Evolution Explorer (GALEX), a half-meter ultraviolet telescope developed as part of NASA's Small Explorer Program. The European Space Agency's XMM-Newton observatory will reach full steam in 2001 and should join the Chandra X-ray Observatory in churning out spectacular pictures of the high-energy universe.

Planetary Exploration

The year opens with the Cassini-Huygens spacecraft exiting the Jovian system and embarking on the final leg of its journey to Saturn. In February, the Near-Earth Asteroid Rendezvous (Shoemaker) spacecraft will conclude its year in orbit around 433 Eros in spectacular fashion, dropping onto the asteroid's surface. However, the centerpiece of planetary exploration in 2001 will be NASA's attempt to recover from its Mars debacles in 1999. To be launched in April, the 2001 Mars Odyssey orbiter will reach the red planet in October and immediately begin aerobraking, gradually lowering its orbit to start its surveying work by the end of the year. Similar in design to the unlucky Mars Climate Orbiter, Mars Odyssey carries instruments to map the chemical composition of the planet's surface. Comets also get some attention; in January, the Stardust probe swings by Earth to set up its trajectory for a flyby of periodic Comet 81P/Wild 2, but it won't get there until 2004. In September, however, Deep Space 1 — resurrected from what seemed to be a mission-ending camera failure in mid-2000 — will cap a successful extra test of its ion drive by flying past Comet 19P/Borrelly at close range.

NASA / JOHNSON SPACE CENTER

JET PROPULSION LABORATORY

Left: In 2001 NASA will dispatch its Mars Odyssey spacecraft to study the red planet with three instruments. A lander was built to accompany the orbiter, but the space agency decided last year not to launch it. *Top:* With its first key components finally together in orbit last October, the International Space Station received its first trio of long-term inhabitants a few weeks later.

NASA / JPL/UNIVERSITY OF ARIZONA

The Cassini spacecraft's first color view of Jupiter shows a wealth of detail, including the moon Europa (far right) and its shadow on the planet's clouds. Imaging-team leader Carolyn Porco, a die-hard Beatles fan, released this image last October 9th to mark what would have been the 60th birthday of John Lennon.

Human Spaceflight

This should be the year that the torch is finally passed from Russia's Mir to the long-awaited International Space Station. Mir was struggling on at the end of 2000, buttressed with funding from the commercial enterprise MirCorp. Undaunted, Dennis Tito, an American business executive and former NASA engineer, bought himself a ticket for a week-long tourist flight to the station. Then MirCorp began discussions with television executives about possibly offering a trip to this orbiting institution as a prize. Nevertheless, there is at least an even chance that 2001 will see the end of the venerable orbital outpost. In contrast, hopes for the Space Station were high in late 2000, with the successful docking and outfitting of the Zvezda core module and plans to launch the Expedition One crew before year's end. The coming year will see NASA's Destiny laboratory module and the Leonardo cargo module added to the assembly, as will the station's airlock and a Russian-built docking module. Flights to build up the enormous solar-panel truss will follow in 2002. There were, however, still clouds on the station's horizon, with software and integration problems making further launch delays almost inevitable, and fears that Russia could not afford the promised quarterly Progress resupply flights.

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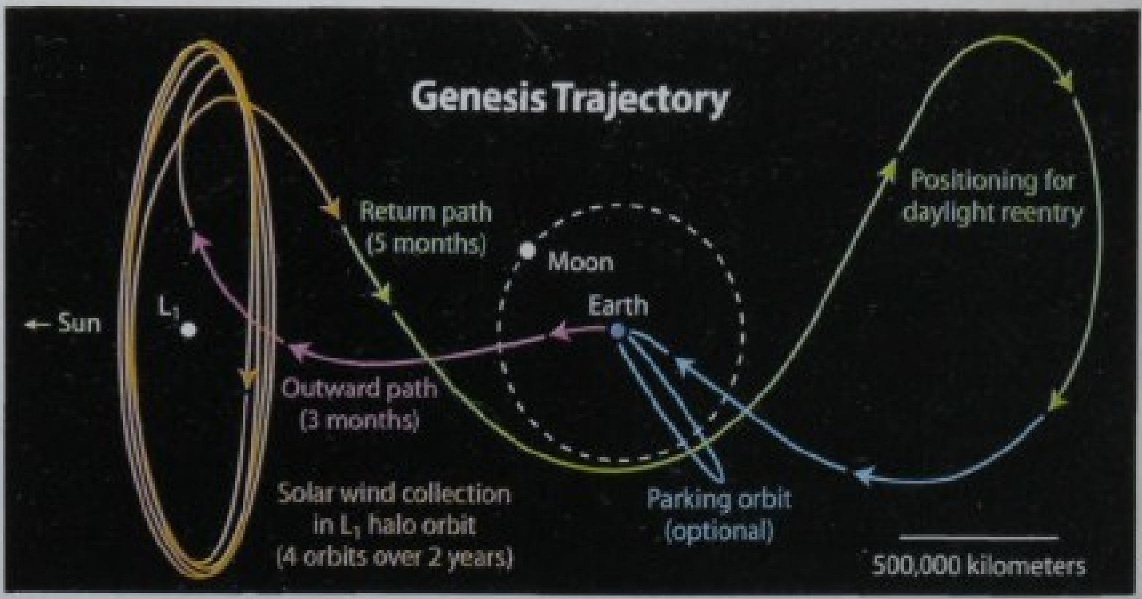
Astronomy and Planetary Mission Highlights in 2001

Date	Spacecraft	Event	WWW home page
Dec. 30 (2000)	Cassini-Huygens	flyby of Jupiter (9,800,000 km)	www.jpl.nasa.gov/cassini/ sci.esa.int/huygens/
January 15	Stardust	flyby of Earth (3,700 km)	stardust.jpl.nasa.gov
February 14	NEAR	landing on 433 Eros; mission ends	near.jhapl.edu
February	Genesis	launch from Cape Canaveral, Florida	www.jpl.nasa.gov/genesis/
March 28	HESSI	launch from near Cape Canaveral, Florida	hessi.ssl.berkeley.edu
April 7	2001 Mars Odyssey	launch from Cape Canaveral, Florida	mars.jpl.nasa.gov
May	MAP	launch from Cape Canaveral, Florida	map.gsfc.nasa.gov
May	STS 108 (Hubble SM-3B)	launch from Cape Canaveral, Florida	hubble.gsfc.nasa.gov
September	Deep Space 1	flyby of Comet 19P/Borrelly	nmp.jpl.nasa.gov/ds1/
September	GALEX	launch from Cape Canaveral, Florida	www.srl.caltech.edu/galex/
October 20	2001 Mars Odyssey	arrival at Mars, enters orbit	mars.jpl.nasa.gov/2001/

BY JONATHAN McDOWELL

Genesis



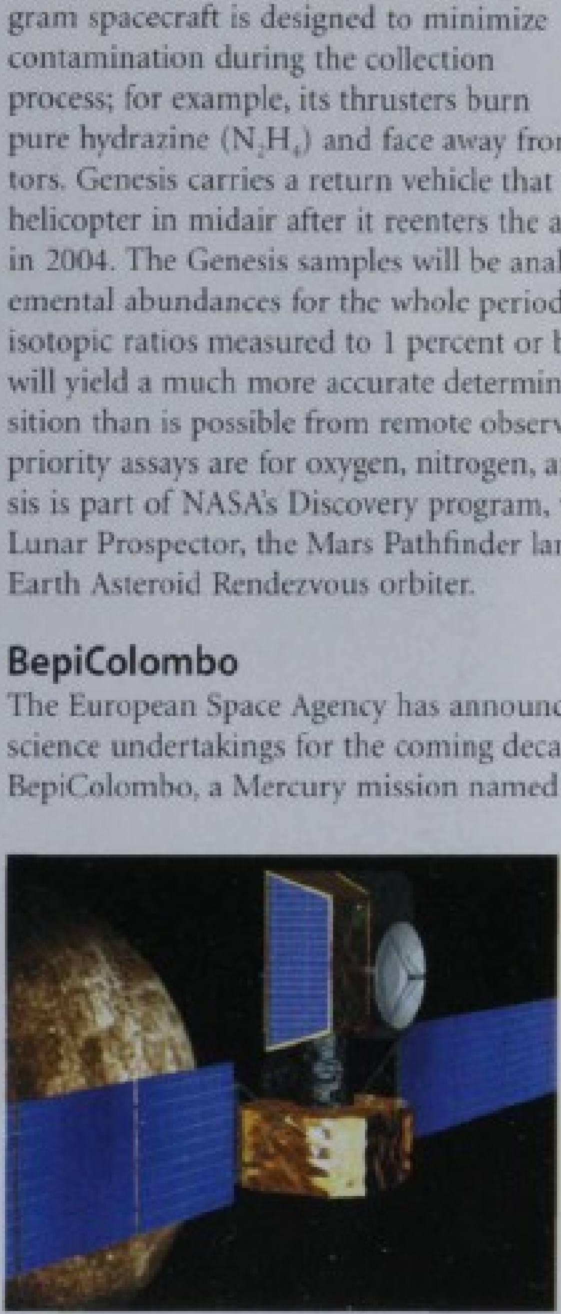
NASA/JPL

The convoluted trajectory for NASA's Genesis mission. After collecting solar-wind samples for two years (loops at left), the spacecraft will dispatch a capsule to Earth for a daring midair recovery.

NASA's Genesis spacecraft, planned for launch from Cape Canaveral on February 10th, has been postponed until early to mid-June. This unusual mission will retrieve samples of the solar wind for study on Earth. A follow-on to experiments done three decades ago during Apollo lunar-landing missions, Genesis will spend two years at the L_1 Lagrangian point along the Earth-Sun line starting in September 2001. There it will expose wafers of silicon and other materials to soak up the particles flowing outward from the Sun. The 636-kilogram spacecraft is designed to minimize contamination during the collection process; for example, its thrusters burn pure hydrazine (N_2H_4) and face away from the sample collectors. Genesis carries a return vehicle that will be snared by a helicopter in midair after it reenters the atmosphere over Utah in 2004. The Genesis samples will be analyzed to determine elemental abundances for the whole periodic table, with critical isotopic ratios measured to 1 percent or better. This approach will yield a much more accurate determination of solar composition than is possible from remote observations. The highest-priority assays are for oxygen, nitrogen, and noble gases. Genesis is part of NASA's Discovery program, which also sponsored Lunar Prospector, the Mars Pathfinder lander, and the Near Earth Asteroid Rendezvous orbiter.

BepiColombo

The European Space Agency has announced its major space-science undertakings for the coming decade. The flagship is BepiColombo, a Mercury mission named after Giuseppe "Bepi" Colombo, inventor of the space-tether concept. This will be only the second spacecraft sent to the innermost planet; in 1974–75 Mariner 10 mapped one hemisphere of Mercury following a Venus flyby (the first use of a gravity assist). The new European mission will use an ion engine, as well as a flyby of Venus, to reach Mercury. Upon arrival a conventional liquid-fuel engine will place the craft into orbit, whereupon it will split into three pieces. The main portion will skim within a few hundred kilometers of the surface to map the mysterious unseen hemisphere and explore the polar regions' putative ice deposits. A smaller craft, in a more elliptical orbit, will study Mercury's magnetosphere and the planet's interaction with the solar wind. Finally, a small lander will drop to the surface and measure the heat flowing from the interior; it might carry a tiny rover equipped with a spectrometer to study rock composition. After BepiColombo, ESA intends to launch Gaia, an astrometry satellite to build on the success of Hipparcos. ESA also plans to be NASA's partner in developing the Next Generation Space Telescope and the LISA (Laser Interferometer Space Antenna) gravity-wave observatory.



The European Space Agency hopes to dispatch the BepiColombo spacecraft to Mercury in 2009. Courtesy ESA.

Mars Exploration Program

NASA officials have unveiled the agency's revamped strategy for Martian exploration, which replaces the Mars Surveyor program of small missions with a broader, slower-paced program. Two rovers planned for launch in June 2003 will be followed in 2005 by the Mars Reconnaissance Orbiter, which will scrutinize the planet's surface to a resolution of 20 centimeters — much better than current civilian Earth satellites can achieve. A Mars Mobile Science Laboratory will follow in 2007, extending the rover concept with a more ambitious suite of instruments. The new strategy alternates launches of orbiters and landers, allowing extra time to recover should one of the vehicles fail. But the plan puts off the return of Martian surface samples until 2014, disappointing those who had hoped for a more aggressive program. The year 2007 will also inaugurate a separate Mars Scout program, a series of miniaturized payloads that will piggyback their way to Mars aboard other missions' launches, as well as a mission undertaken jointly with France and Italy. The latter, which will test elements of the sample-return mission, includes an orbiter to be aerocaptured by Mars's atmosphere, a new lander, a communications-relay satellite, and four small weather-station landers.

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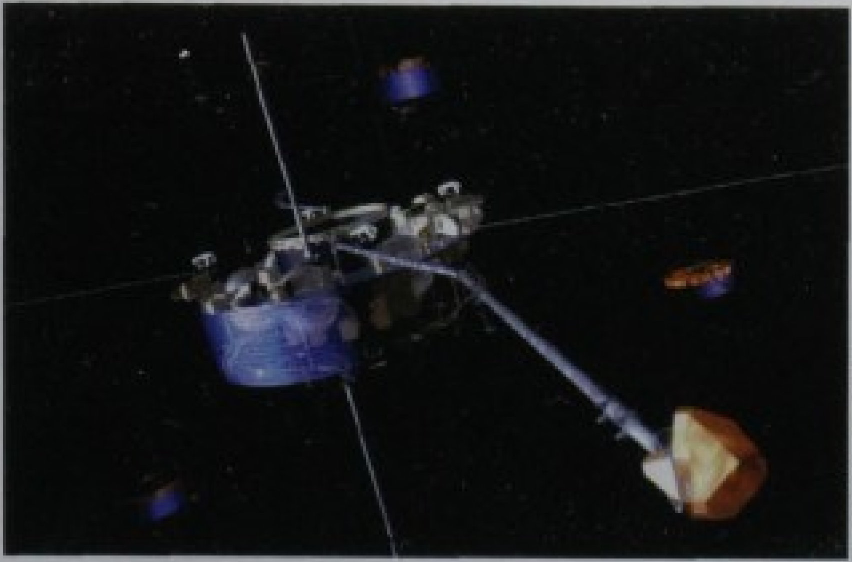
MISSION UPDATE

BY JONATHAN McDOWELL

This month's column highlights spacecraft that are studying the Sun and solar-terrestrial relationships.



EUROPEAN SPACE AGENCY

The four Cluster II spacecraft orbit Earth in a tetrahedral formation to obtain three-dimensional snapshots of the state of the magnetosphere.

Cluster II

The four Cluster II spacecraft — named Rumba, Salsa, Samba, and Tango — began operations late last year, flying together as a 600-kilometer-wide tetrahedron outside Earth's radiation belts in high-altitude polar orbits. The Cluster and SOHO (Solar and Heliospheric Observatory) projects were meant to be launched at the same time to study solar-terrestrial interactions, but the first foursome was lost in a launch failure. While most of SOHO's instruments are imagers studying the light from the Sun, Cluster measures trapped magnetospheric particles and their effects on Earth's electromagnetic fields.

Yohkoh

The remarkable Yohkoh solar observatory has now been in orbit for almost 10 years. Launched in August 1991 from the spaceport at Kagoshima, Yohkoh was the first Japanese satellite to provide continuous data to the world's scientific community. Its Lockheed-built SXT telescope continues to return daily X-ray images of the solar disk, which are available at ftp://umbra.nascom.nasa.gov/pub/images/current/latest.html. In June Yohkoh made its first nonsolar observation, turning its X-ray imager on the Crab Nebula. Japanese space scientists hope that Yohkoh continues to function until 2010, thus completing most of a full 22-year solar cycle.

Solar and Heliospheric Observatory

The SOHO spacecraft completes its fifth year of operations in April. Launched in December 1995 near solar minimum, SOHO headed for the Earth-Sun L_1 Lagrangian point and completed its commissioning phase in April 1996. The spacecraft survived a near-death experience in mid-1998, when ground controllers accidentally sent incorrect commands and triggered a deep electronic coma. SOHO continues to send back spectacular images of solar flares as the Sun reaches its maximum activity, catching a series of large eruptions in late November that drenched Earth in high-energy particles. In December SOHO began a series of stereo solar-wind studies with the Ulysses probe, which is cruising high over the solar south pole (*S&T:* September 2000, page 30). NASA and the European Space Agency undertook the SOHO mission jointly, and it's operated from NASA's Goddard Space Flight Center in Geenbelt, Maryland.

High Energy Solar Spectroscopic Imager

NASA/GSFC; ISAS; EUROPEAN SPACE AGENCY

Solar sentinels *(from top)*: NASA's High Energy Solar Spectroscopic Imager; Yohkoh, from Japan's Institute of Space and Astronautical Science; and the European Space Agency's SOHO (Solar and Heliospheric Observatory).

Due for launch in March, HESSI is designed to make high-resolution images of the Sun in both X- and gamma rays. Since "hard" (short-wavelength) X-rays are difficult to focus, HESSI uses a trick called transform imaging, in which the incoming radiation passes through a rotating pattern of holes and the image is inferred from the changing pattern of light and shadow. The cylindrical satellite will spin 15 times per minute, with its four solar-cell wings twirling like windmill blades. HESSI will scrutinize solar flares at energies above 100,000 electron volts (eV), which should help pin down exactly where solar-flare particles are accelerated and how they heat the corona, and it should deliver sharper pictures than the Japanese Yohkoh satellite at lower energies down to 3,000 eV. The launch of HESSI comes after an agonizing delay caused by an accident one year ago. In a brief, 0.2-second mishap during a shake test, the satellite was subjected to 20 *g* of acceleration instead of the planned 2 *g*, wrecking the solar-cell panels and the telescope's support ring and damaging the cryogenic cooler. Fortunately, the main instruments survived and the spacecraft was rebuilt.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL

2001 Mars Odyssey

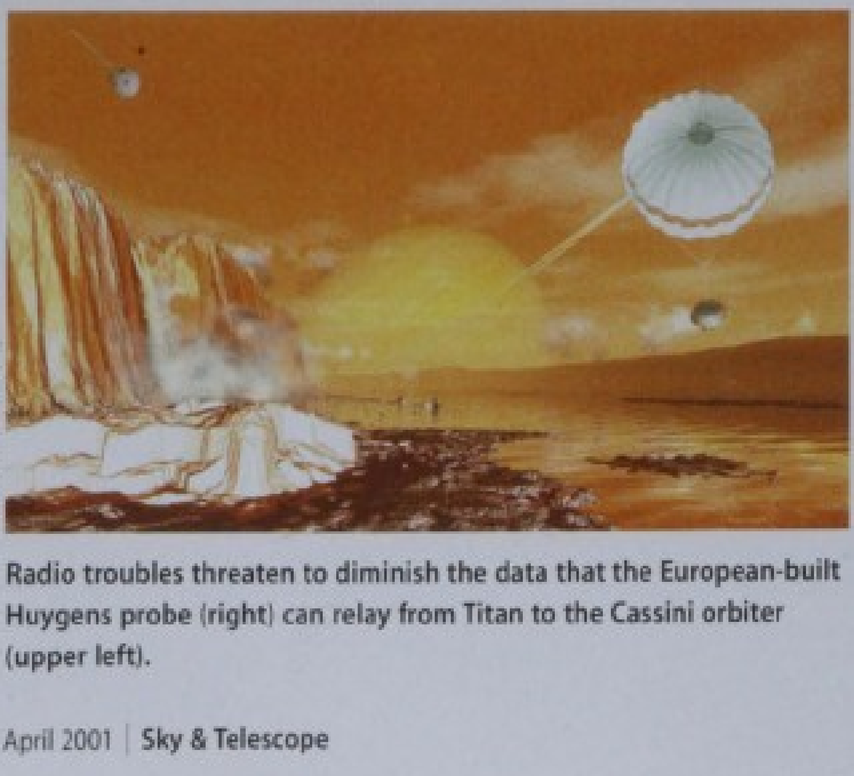
The 2001 Mars Odyssey spacecraft, scheduled for launch on April 7th, follows two complete mission failures in 1999 and is thus critical for NASA's Mars Exploration Program. Odyssey is similar to the ill-fated Mars Climate Orbiter; its planned companion lander was canceled so that the Jet Propulsion Laboratory could concentrate on getting this one right. The vehicle is shaped like a box, with the main engine at the top and the platform of science instruments at the bottom. A solar-cell panel and the large dish antenna for communications stick out from the engine end, while a distinctive 6-meter-long boom on the science platform carries the gamma-ray spectrometer. (The long boom is necessary because the spectrometer detects radiation created when cosmic rays hit the Martian surface; a few gamma rays come from the spacecraft for the same reason.) The probe will reach Mars on October 20th and enter a 25-hour elliptical orbit. Like Mars Global Surveyor before it, Odyssey will lower its orbit by aerobraking (repeatedly dipping into the planet's thin atmosphere to bleed off speed and altitude by friction). By January the spacecraft should be in its intended 400-kilometer-high polar orbit, ready to begin mapping the mineral content of the Martian surface.


NASA / JPL

The Mars Odyssey 2001 orbiter carries three science instruments: the Thermal Emission Imaging System (THEMIS), Gamma Ray Spectrometer (GRS), and Mars Radiation Environment Experiment (MARIE).

Pluto Mission

The Pluto-Kuiper Express project was effectively canceled last September, but a voyage to Pluto is on the table once again thanks to efforts by proponents in both the scientific community and the public. Somewhat in the spirit of a TV network that's persuaded by fans to give a cult show another chance, NASA managers announced that they will consider mounting a Pluto mission if someone can come up with a cheap, scientifically productive plan that reaches the planet by 2015 — where "cheap" means less than $500 million. This would be NASA's first outer-planet mission selected by open competition, rather than being assigned directly to one of the NASA centers. Because Pluto has begun its century-long trek to aphelion, scientists hope to examine this distant world at close range soon, before its atmosphere freezes onto the surface. A launch could occur as soon as December 2004, with arrival perhaps by 2012.


DAVID SEAL (NASA / JPL)

Radio troubles threaten to diminish the data that the European-built Huygens probe (right) can relay from Titan to the Cassini orbiter (upper left).

Huygens

Europe's most ambitious planetary mission, the Huygens probe to Titan, has run into trouble. Incorrect specifications on one communications component mean that Cassini, on which Huygens rides, will have trouble detecting the Doppler-shifted signal from the probe and thus receiving its precious Titan data. After a seven-year voyage to Saturn as an inert passenger on NASA's Cassini orbiter, Huygens will be active for only around 2½ hours on November 27, 2004, when it falls into Titan's atmosphere traveling at 20,000 km per hour relative to Cassini. However, a European Space Agency review board has recommended a number of workarounds to fix the problem. For example, delaying the probe's release date will allow the science team to assess the wind direction on Titan first, so that the spacecraft's velocity during its descent (and the resulting Doppler shifts) can be predicted accurately. Releasing Huygens's parachute early, thus allowing the aerodynamically shaped capsule to fall faster toward Titan's surface, would cause the loss of some science data but maintain a steadier velocity during the descent. Modifying the probe's telemetry stream should improve Cassini's "hearing," and a combination of these approaches may be enough to ensure success. Alternatively, Cassini's orbital tour of Saturn could be redesigned to place the spacecraft farther from Titan during Huygens's brief performance, thus reducing the magnitude of the Doppler shift. However, the review board doubted that enough time remains to make such wholesale changes.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, works with the Chandra X-ray Observatory.*

MISSION UPDATE

BY JONATHAN McDOWELL

Lockheed Martin's concept for the Next Generation Space Telescope, one of two under study, will need to be revised because NASA has decided to reduce the primary mirror's size. Courtesy Lockheed Martin.

Next Generation Space Telescope

Designed as the successor to the Hubble Space Telescope, the Next Generation Space Telescope will now be a little smaller than astronomers had hoped. NGST was to have a 4-meter-wide aperture when conceived in 1995, but the success of segmented-mirror designs encouraged astronomers to pursue an ambitious 8-meter goal. This was recently scaled back to around 6 meters, a size that allows NASA to launch the mirror in one piece on an Atlas 5 (or similar) rocket and avoids the difficult problem of deploying such a precise optical surface. To cut costs, a planned technology-development mission has been canceled and the size of the detector arrays reduced. Although the new version of NGST will operate at warmer-than-optimal temperatures, its ability to observe at thermal-infrared wavelengths out to near 30 microns — a spectral region key to understanding star formation and other phenomena — will be retained. Launch is now expected around 2009, and NASA hopes to select the company that will build NGST and to procure the primary-mirror blank at the end of this year.

CENTER FOR EUV ASTRONOMY, UNIVERSITY OF CALIFORNIA, BERKELEY

Although operating well, on February 2nd the Extreme Ultraviolet Explorer spacecraft was turned off due to lack of funding.

Mars Global Surveyor

On January 31st Mars Global Surveyor completed its primary mission: mapping the red planet for a full Martian year of 687 days. The work began in March 1999 after a one-year trip to Mars and a further 18 months of orbital positioning. MGS now begins its extended mission as NASA's only surviving Mars probe. Although currently funded until April 2002, MGS is expected to operate beyond that date as a communications relay for the 2004 landings of the Mars Exploration Rovers. The orbiter is in good shape after five years in space, though one reaction wheel, used to keep the spacecraft pointed, failed on January 18th. A backup wheel took over, but mission managers will be watching carefully for other signs of age. The laser altimeter and thermal-emission spectrometer have mapped the whole planet, while the high-resolution Mars Orbiter Camera has covered its intended 1 percent of the surface. Recent images include a reconnaissance of the planned touchdown site for Britain's Beagle 2 lander, which should drop onto Isidis Planitia at 11° north, 270° west, in December 2003. MGS will soon be joined by the 2001 Mars Odyssey probe now awaiting launch in Florida, but a successor camera will not reach Mars until 2006.

Extreme Ultraviolet Explorer

Launched in June 1992, the Extreme Ultraviolet Explorer satellite is still in perfect working order. However, last year NASA terminated the funding needed to continue gathering its data, so the satellite has been shut down. The last science observations, a study of the nearby interstellar medium, were made on January 26th. After a few end-of-life tests, which included turning on the never-used backup high-voltage power supplies and checking the remaining battery capacity, EUVE was pointed away from the Sun and sent into a safe hold on the night of January 31st. The mission came to an end late on February 2nd when team members at the Center for EUV Astrophysics in Berkeley, California, commanded the spacecraft's transmitters to turn off. During its early years, EUVE followed up previous observations from Europe's Röntgensatellit, or Rosat, by completing the first detailed all-sky map of very "soft" (low-energy) X-rays in January 1993. The following eight years were spent observing targets chosen by astronomers across the world using EUVE's deep-survey instrument, a 1.4-meter-focal-length telescope with a 2° field of view and both an imager and a spectrometer. EUVE is expected to stay in orbit until early 2002, when it will reenter the atmosphere.

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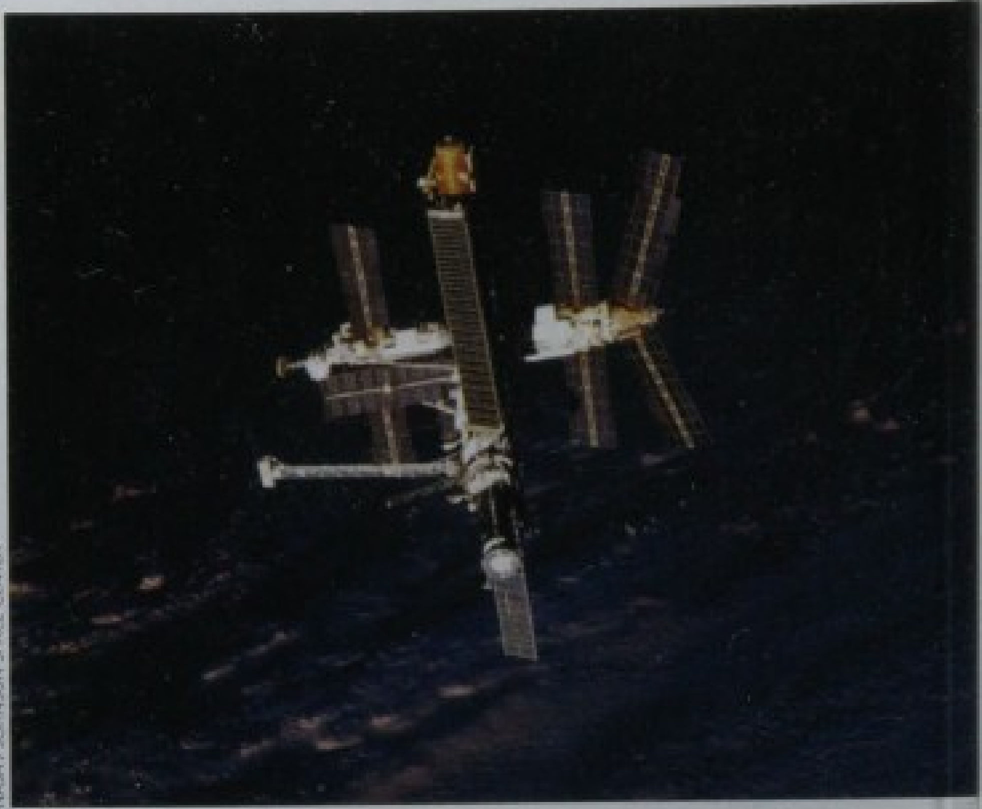
BY JONATHAN McDOWELL

Mir

The 15-year mission of the Mir orbital complex came to an end on March 23rd in a rain of bright, flaming debris over the South Pacific Ocean. Russian flight controllers pulled off the mission-ending sequence after the spacecraft had descended to an altitude of 214 kilometers, at which point it was powered up and oriented after two months of dormancy. The Progress M1-5 cargo ship, which had docked to the complex's Kvant module, fired its thrusters three times within four orbits to lower the perigee to only 80 km. Passing east of Papua New Guinea the complex began to break up as friction robbed it of its residual orbital velocity. Just before 6:00 Universal Time the remaining fragments plowed into the ocean well east of New Zealand near 160° west, 40° south.

Mir's core module reached orbit on February 20, 1986, the Soviet Union's 10th launch of a space station (succeeding three military Almaz and six civilian Salyut craft). Throughout Mir's 86,330 trips around Earth, visiting cosmonauts and astronauts were onboard for a total of 4,591 days, during which they ventured outside the hull for 79 spacewalks. The station survived minor (Soyuz TM-17, 1994) and major (Progress M-34, 1997) collisions and a serious fire. But its crews set numerous endurance records — capped by physician Valeriy Polyakov's 437-day stay — and they came within 11 days of inhabiting the station continuously for an entire decade.



NASA / JOHNSON SPACE CENTER

The crew aboard NASA's STS-79 Space Shuttle mission recorded this striking view of Mir at sunset in September 1996.

Odin

Swedish space scientists are celebrating the launch of the newest astronomy satellite. Odin was built by Svenska Rymdbolaget (Swedish Space Corp.) and boosted into orbit on February 20th by a Russian Start-1 refurbished intercontinental missile from the Svobodniy missile base in eastern Russia. Odin carries a 1.1-meter-diameter radio telescope — twice the size of the one on NASA's Submillimeter Wave Astronomy Satellite — that will study galactic circumstellar and molecular clouds at submillimeter wavelengths. Like SWAS, Odin will measure emissions from several molecules (including water) in the 500-gigahertz region, and its 119-gigahertz receiver will detect O_2 molecules in their ground state for the first time. Also aboard is an imaging spectrograph for monitoring ozone (O_3) and the catalytic chemical reactions that destroy it in Earth's upper atmosphere. Odin involves collaborating scientists in Canada, France, and Finland.

In mid-2000 Sweden's Odin spacecraft was tested under simulated space conditions at Intespace in Toulouse, France. The 250-kilogram astronomy satellite uses an offset Gregorian telescope with a primary reflector (at upper right) 1.1 meters across.

SWEDISH SPACE CORP.

Advanced Satellite for Cosmology and Astrophysics

On March 2nd a Japanese X-ray astronomy satellite plunged into the atmosphere over the Pacific Ocean near the Solomon Islands, ending its eight-year mission. Astro D was launched on February 20, 1993; upon reaching orbit it was renamed Asuka and given the homonymous acronym ASCA (Advanced Satellite for Cosmology and Astrophysics) for the benefit of English-speaking astronomers. ASCA was the first observatory to use CCDs as X-ray imagers, now standard on missions like the Chandra X-ray Observatory and XMM-Newton. Following a huge solar flare in July 2000, the satellite began to tumble and fell silent when its batteries ran down. The reentry of ASCA occurred one day after the death of Minoru Oda, a founder of Japan's X-ray astronomy program and the former director of the Institute of Space and Astronautical Science. ASCA's successor, Astro E, failed to reach orbit last year (*S&T:* May 2000, page 26); a replacement is being prepared for launch in early 2005.

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BY JONATHAN McDOWELL

Above: The 2001 Mars Odyssey mission got off to a good start with a trouble-free launch on April 7th aboard a Boeing Delta II rocket. Courtesy NASA/Kennedy Space Center. *Right:* The dramatic ascent to orbit was captured by a video camera mounted outside the Delta's second stage. The lower two frames show the jettisoning of slender strap-on boosters 67 and 137 seconds into the flight, by which time the vehicle had already climbed to altitudes of 19 and 57 kilometers, respectively. Courtesy NASA Television.

2001 Mars Odyssey

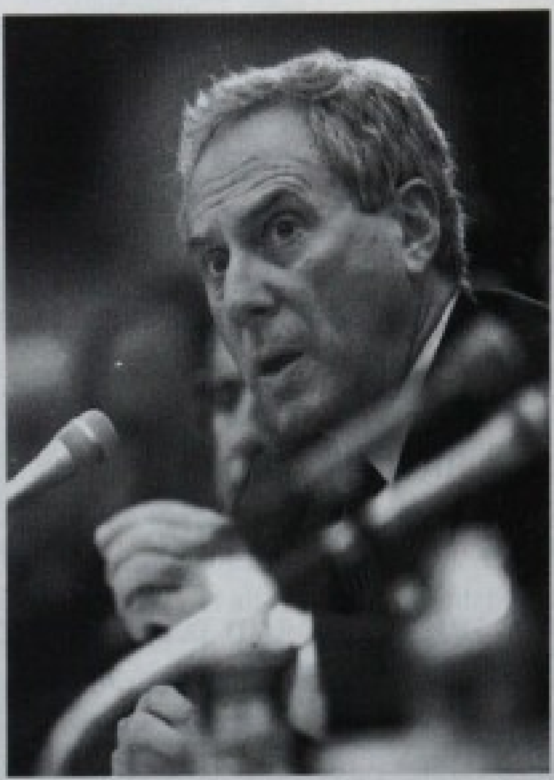
NASA's newest interplanetary probe was launched from Florida atop a Delta II rocket on the morning of April 7th. In a tip of the hat to Arthur C. Clarke and Stanley Kubrick's famed millennial movie, the 750-kilogram spacecraft has been named 2001 Mars Odyssey. The ascending vehicle tracked along the U.S. East Coast and into a high-inclination (52°) parking orbit — unusual for a planetary mission — before heading off to the red planet. Odyssey will reach Mars on October 24th after a 460-million-kilometer cruise and fire a braking rocket to slip into orbit. The following January, after a series of aerobraking passes similar to the ones made by Mars Global Surveyor, the spacecraft will settle into a two-hour-long, 400-km-high polar orbit and begin its two-year mapping mission. Odyssey represents both the last of the old Mars Surveyor line (in fact, it's a sister ship to the destroyed Mars Climate Orbiter) and the first entry in NASA's revamped Mars Exploration Program. It carries an infrared imager as well as a 6-meter-long boom tipped with a gamma-ray spectrometer to characterize the mineralogy of the Martian surface and to search for the hydrogen that would betray the presence of water at or near ground level.

Galileo

Fortified with extra funding from NASA headquarters, the Jet Propulsion Laboratory has planned the final phase of Galileo's long Jovian odyssey, which will concentrate on the volcanic (and very photogenic) moon Io. This world has received comparatively little attention since the spacecraft's December 1995 arrival because of the risk posed by intense radiation in the inner Jovian magnetosphere. After a May 25th swing to within 123 km of Callisto, Galileo makes a pair of close passes over the north and south poles of Io on August 5th and October 16th, respectively. Funding for additional flybys is unlikely at present, even though project scientists want to get another close look at the volcanic moon next January, followed in November by a pass only 500 km from the 250-km-long moon Amalthea. In any case, Galileo will make a suicidal plunge into the Jovian atmosphere in September 2003. This final, fatal move is designed to ensure that the derelict spacecraft doesn't crash into Europa, where it might contaminate a future search for life.

National Aeronautics and Space Administration

The advent of the new U.S. administration has triggered big changes at NASA. In the $14.5-billion budget proposed for fiscal 2002 by President George W. Bush, the X-33 and X-34 reusable rocket-plane projects have been eliminated. Spending for the International Space Station will be cut back, with the Habitation Module and the Crew Return Vehicle likely to be canceled in an attempt to recover from multibillion-dollar overruns. George Abbey, for decades one of the most powerful individuals in the agency, has been removed as director of the Johnson Space Center, and more management changes are expected. The recently revived mission to Pluto (May issue, page 28) has again been canceled, as has a related solar-probe proposal. But Congress has asked NASA to carry on with the Pluto spacecraft's selection process in case the mission is reinstated during forthcoming budget deliberations.



Having now served longer than any of his predecessors and under three presidents, NASA administrator Daniel Goldin (seen here during Congressional testimony) faces a number of budgetary challenges during fiscal 2002. Courtesy Bill Ingalls (NASA).

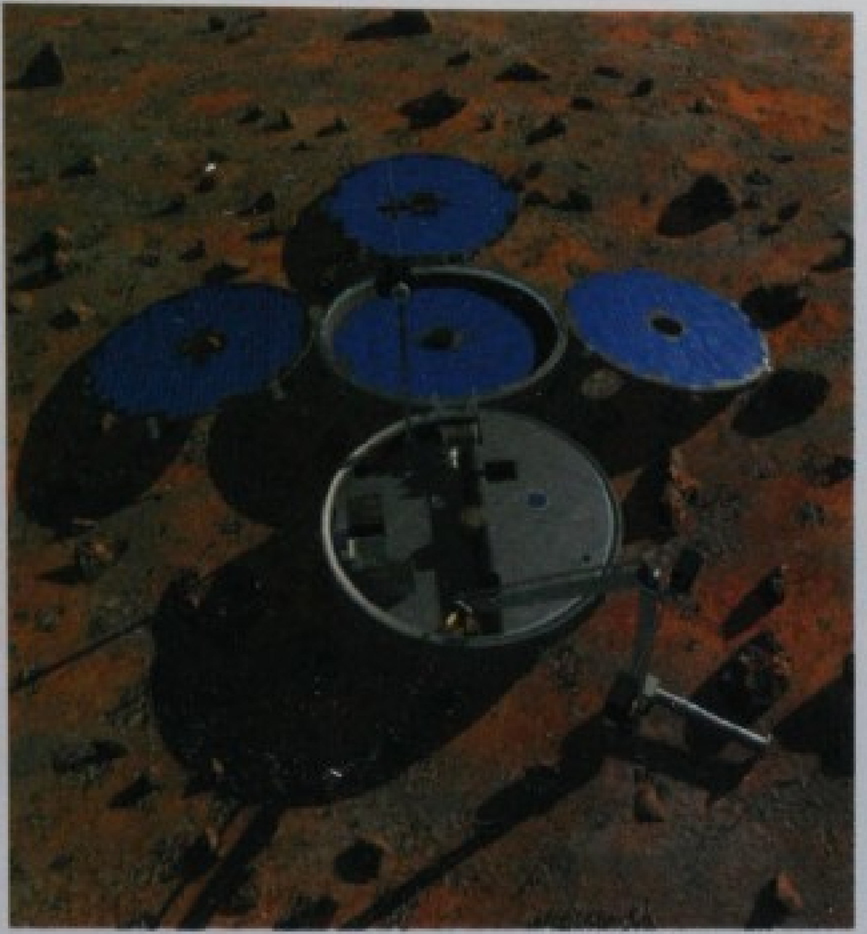
Pioneer 10

The venerable Pioneer 10 space probe, launched in March 1972 and now 11.5 billion kilometers from Earth, had not been heard from since last August 19th. So a concerted, last-ditch effort to reestablish contact was begun in March when the giant radio telescope in Arecibo, Puerto Rico, listened for Pioneer's 8-watt transmitter. Tracking stations in NASA's Deep Space Network joined the search a month later and recovered a feeble signal on April 28th. Managed by NASA's Ames Research Center, Pioneer 10 and its twin, Pioneer 11, were the first spacecraft to pass beyond the asteroid belt and flew past Jupiter in 1973 and 1974, respectively. The probes were powered by radioisotope thermoelectric generators, which use heat from decaying plutonium-238 to generate electricity. Pioneer 11, which also visited Saturn in 1979, fell silent in 1995. Funding for the project ended in March 1997, but contact with Pioneer 10 has continued occasionally under the guise of testing the DSN's ability to track a weak signal. Scientists are using cosmic-ray data collected by the spacecraft to explore the outermost regions of the heliosphere as Pioneer 10 continues to head out of the solar system at 12 km per second. Its current location in the sky is 3° north of the ecliptic, near the star 98 Tauri.

JONATHAN MCDOWELL *is an astronomer at the Harvard-Smithsonian Center for Astrophysics. He also writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL



The Beagle 2 project, led by British geochemists from the Open University, hopes to place an instrumented lander on Mars in late 2003. Copyright Beagle 2 Consortium.

Beagle 2

When the British-built lander Beagle 2 reaches Mars in 2½ years, project officials have decided that it will touch down on Isidis Planitia, located northeast of Syrtis Major, at 10.6° north, 270° west. The hope is that the sedimentary plain at Isidis preserves evidence of ancient Martian life, while being warm enough during local spring for Beagle 2 to survive. Instruments will spend at least six months looking for water, carbonate minerals, and organic material, as well as studying the site's environment. The 30-kilogram lander is hitchhiking to the red planet with the European Space Agency's Mars Express mission, to be launched in June 2003. When it arrives the following December, the main spacecraft will jettison Beagle 2 before firing its engine to enter Martian orbit. A heat shield and parachute will lower the lander to the ground, and Pathfinder-style airbags will cushion the impact. Before it leaves Earth, though, Beagle 2 will be thoroughly sterilized to make sure that terrestrial "bugs" don't contaminate the search for life.

Technicians ready NASA's FUSE spacecraft prior to its launch on June 24, 1999. Courtesy NASA/Kennedy Space Center.

Lunar A

After years of delays Japan's Institute of Space and Astronautical Science (ISAS) now plans to launch its Lunar A probe in 2003. From a low-altitude lunar orbit, the spacecraft will fire two penetrators into the surface near the equator, one near the Apollo 12 landing site in Mare Insularum and one on the far side. The penetrators, which have been designed to survive an impact deceleration of 10,000 *g* and may last for up to a year, will transmit their measurements of moonquakes and heat flow via the orbiter. Lunar A's seismometers are five times more sensitive than the ones flown on Apollo, an improvement needed to determine the size of the lunar core. The orbiter also carries a camera for surface mapping.

Selene

Japan's second lunar mission of the new century is Selene, a contraction of Selenological and Engineering Explorer. To be launched around 2004, the three-ton craft is a joint project by Japan's two space agencies, NASDA and ISAS. Its orbiter will carry on the work started by Clementine and Lunar Prospector by studying mineral distribution and surface structure with an imager, X- and gamma-ray spectrometers, laser altimeter, radar sounder, and particle detectors; a small, low-orbiting relay satellite will map the Moon's gravity field. After a year in orbit, a lander will separate and touch down. It will attempt to survive on the lunar surface throughout two months of day-night heating and cooling cycles.

Far Ultraviolet Spectroscopic Explorer

NASA's FUSE ultraviolet observatory is beginning its third year in orbit. Early in the mission, thermal problems and pointing difficulties hindered instrument calibration and alignment, but FUSE has been observing smoothly for the past year. One reaction wheel shut down in August 2000 when a piece of tape started rubbing against it, but the problem was quickly fixed and the spacecraft systems are working well. Recently published studies detail the dynamics of ionized oxygen in the filaments of the Cygnus Loop supernova remnant and the discovery of absorption lines from highly excited molecular hydrogen in the Dumbbell Nebula. FUSE has also ruled out the presence of abundant intergalactic molecular hydrogen, which thus limits how much baryonic (normal) matter can exist in the universe. The spacecraft is operated by Johns Hopkins University using ground stations in Puerto Rico and Hawaii.

Jonathan McDowell, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE
BY JONATHAN McDOWELL

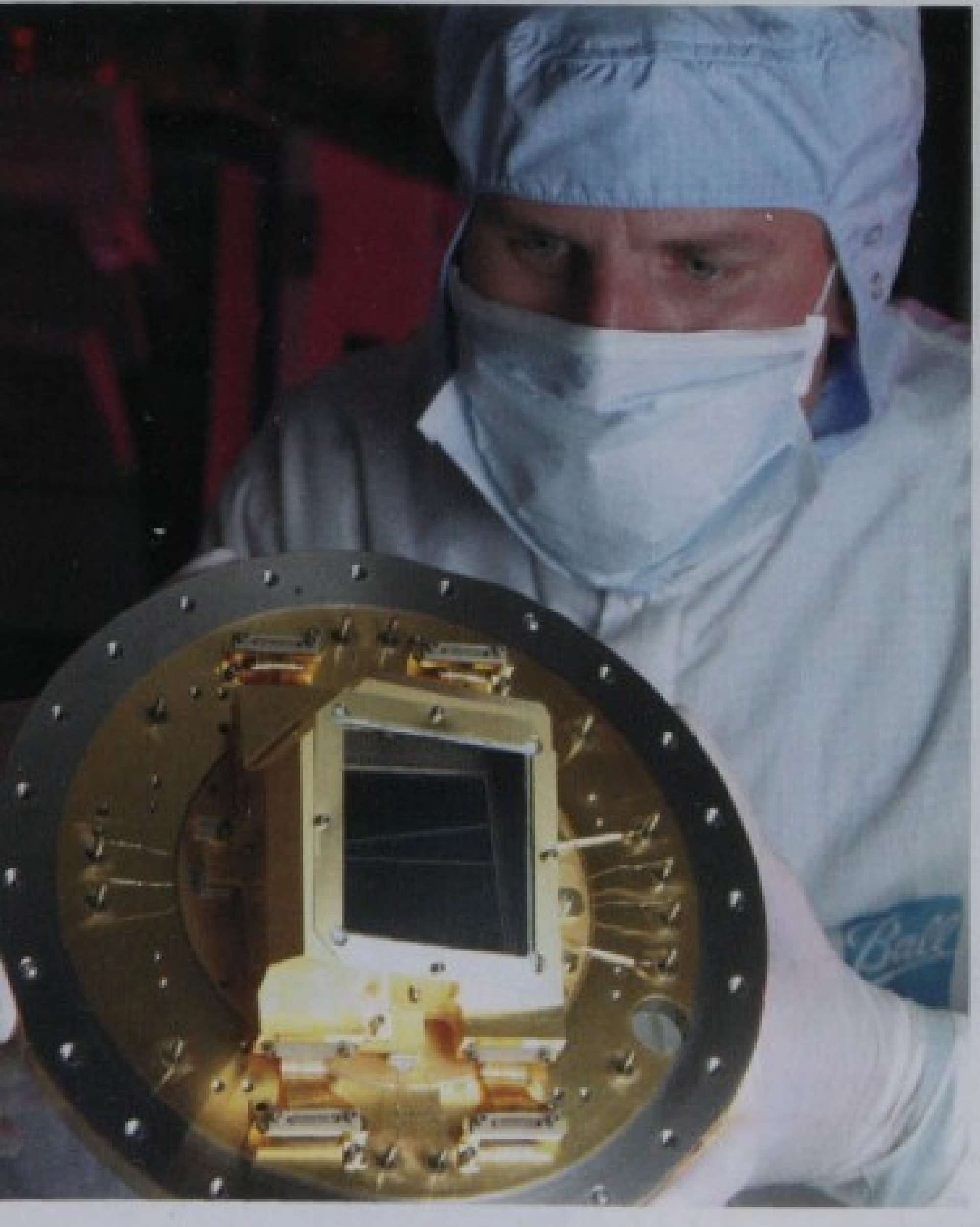
Hubble Space Telescope

One of HST's two main science instruments, the Space Telescope Imaging Spectrograph (STIS), ran into a prosaic kind of trouble on May 16th when a fuse blew. The failure came in the midst of spectral observations of some nearby Type Ia supernovae, part of a project to refine the cosmic distance scale. The blown fuse cut off one of two power lines to the spectrograph; before switching to the backup line, Hubble engineers want to understand what went wrong. Operations with STIS are expected to resume in mid-July, but until then almost all observations are being made with the Wide-Field and Planetary Camera 2.

HST Servicing Mission 3B

Meanwhile, the next Hubble servicing mission has now been delayed until January 2002. The Space Shuttle *Columbia*, which returned to Florida from a year-long refurbishment in May, has been reassigned from a previously scheduled research mission to handle the Hubble house call. *Columbia* will carry the new Advanced Camera for Surveys, which is actually three payloads in one: a wide-field optical camera, a high-resolution optical/near-ultraviolet camera, and a far-ultraviolet camera. Also aboard will be a new cooling system designed to keep the Near Infrared Camera and Multi-Object Spectrometer cold enough for its thermally sensitive detectors to operate. A design problem caused NICMOS to warm up soon after its installation in February 1997. (A more capable Aft Shroud Cooling System has been delayed to a later mission; it will cool the entire instrument area, reducing detector noise and thus making Hubble even more sensitive.) On January's first two space walks, astronauts will install new solar panels for the spacecraft. Next they will replace the rarely used Faint Object Camera with the ACS. NICMOS will be repaired on the fourth and final sortie.

A technician shows off one of the CCD detectors for the Advanced Camera for Surveys, to be installed in the Hubble Space Telescope next year. Courtesy Ken Hutchinson, Ball Aerospace & Technologies.



Deep Impact

NASA officials have approved construction of Deep Impact, a Discovery-class mission that will attempt to hit a comet nucleus in 2005. Managed by the Jet Propulsion Laboratory, the mission consists of a flyby spacecraft and an impactor to be built by Ball Aerospace & Technologies. Deep Impact will be launched from Cape Canaveral in January 2004 and make a close flyby of Earth a year later to get a gravity assist on the way to comet 9P/Tempel 1. One day prior to arrival, the 350-kilogram copper impactor will separate and, using autonomous navigation software pioneered on the Deep Space 1 mission, will close in for a 10-km-per-second collision with Tempel 1's nucleus. The anticipated 20-meter-deep crater should break through the outer crust and expose fresh material underneath. The crater and ejecta will be imaged by the flyby probe's telescopic camera-spectrometer and by Earthbound astronomers, providing spectacular extraterrestrial fireworks timed for July 4, 2005. If comets become dormant once their ices are exhausted, the display will soon be over. But if dormancy results from the buildup of a surface "crust" that blocks the volatiles' escape to space, Tempel 1 may continue to dazzle us as it "erupts" from the impact area.

Galileo

NASA's Galileo orbiter made this year's first close approach to Jupiter on May 23rd, and as the spacecraft passed behind the planet as seen from Earth its fading radio signal was used to study the structure of the Jovian atmosphere. Two days later, as the orbiter began the long "uphill" climb to its 9.7-million-kilometer apojove, it made its closest satellite flyby yet: a 123-km pass above the surface of Callisto. That brush altered Galileo's orbit, so that its next dive into the inner Jovian system will be deeper still, allowing a swing past the innermost Galilean satellite, Io. Galileo is starting to show its age, with radiation damage causing occasional problems. The day before the Callisto encounter its camera switched off, but controllers successfully reactivated it in time to save most of the flyby coverage, including high-resolution images of craters near the day-night terminator and of the region directly opposite the huge Valhalla impact crater. A radio occultation by Callisto should yield measurements of the density of charged particles near this dark, icy moon.

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MISSION UPDATE

BY JONATHAN McDOWELL

To survive the blistering sunlight in Mercury's vicinity, the Messenger spacecraft will be equipped with a lightweight thermal shade. Miniaturized instruments will occupy a payload platform facing Mercury. Courtesy the JHU Applied Physics Laboratory.

Messenger

In June the Applied Physics Laboratory of Johns Hopkins University got the go-ahead to build a Mercury orbiter as the next mission in NASA's Discovery series. Messenger, a contrived contraction of "Mercury Surface, Space Environment, Geochemistry and Ranging," should be launched in March 2004. It will make two flybys of Venus and two close (200-km-high) flybys of Mercury before entering a 12-hour orbit around the innermost planet in April 2009, arriving ahead of the European Space Agency's BepiColombo mission (February issue, page 32). Messenger will spend a year mapping the entire surface from as close as 200 km and with image resolutions down to 250 meters. Besides its color and near-infrared cameras, Messenger will carry a laser altimeter and gamma-ray spectrometer for surface studies, along with a magnetometer and charged-particle detectors to monitor conditions in the planet's magnetosphere. The only previous mission to Mercury, Mariner 10, imaged half of the surface during three flybys in 1974–75. More information is available at http://messenger.jhuapl.edu/.

Spektr-Rontgen-Gamma

The long and tragic saga of Russia's Spektr-Rontgen-Gamma mission (known in the West as Spectrum-X-Gamma) appears to be nearing an end. Conceived in the late 1980s, SRG was to be the first of an ambitious series of Soviet space-astronomy satellites. Among its international suite of instruments are a 12-meter-long Soviet-Danish telescope, a twin-telescope package from Germany and England, and an ultraviolet telescope supplied by Israel — all part of an impressive payload designed to make major contributions to high-energy astronomy. Today the spacecraft is almost complete, but it remains grounded due to lack of funding. Although SRG would still be a valuable addition to the Chandra X-ray Observatory and XMM-Newton, in many ways its potential has been diminished by these later missions. Russia's Space Research Institute had asked the European Space Agency for $20 million to help complete the project by 2003. But in June ESA managers announced that they would not provide further funding, thus likely sounding a death knell for the ambitious satellite. For more information, go to http://hea.iki.rssi.ru/SXG/SXG-home.html.

Microwave Anisotropy Probe

NASA's Microwave Anisotropy Probe (MAP) was launched on June 30th from Cape Canaveral, Florida. The satellite, built at the NASA/Goddard Space Flight Center, will continue the work of the Cosmic Background Explorer (COBE) satellite in studying the 3° Kelvin cosmic background radiation left over from the Big Bang. MAP carries dual microwave dishes to compare energy emanating from pairs of locations on the sky 140° apart at frequencies ranging from 22 to 90 gigahertz. Depending on the frequency, the spatial resolution of these measurements will vary from 13 arcminutes to 1° — much better than the 7° achieved by COBE — and they'll discern temperature variations of as little as 20 millionths of a degree. Such tiny differences correspond to structures in the early universe that grew by gravitational collapse into the superclusters and galaxies of the present day. In September MAP will begin its observing program from the L_2 point, a location suspended 1.5 million kilometers above local midnight on Earth. Looking outward into space, its view unobstructed by the Earth, Moon, or Sun, the satellite will be able to take readings over the whole sky every six months. To find out more, point your Web browser to http://map.gsfc.nasa.gov/.

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Astrophysicists from Russia and 11 other nations still hope to launch the Spektr-Rontgen-Gamma spacecraft into a highly elongated 500-by-200,000-kilometer orbit. The complex spacecraft weighs nearly six tons. Courtesy the Space Research Institute.

MISSION UPDATE

BY JONATHAN McDOWELL

Genesis

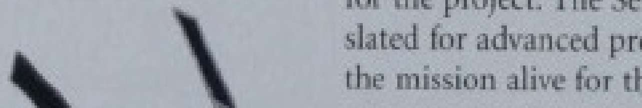
Recent weeks have seen a pair of astronomy payloads rocket into space. NASA's Genesis probe was launched on August 8th following a six-month delay. An hour after lifting off from Florida aboard a Boeing Delta vehicle, the spacecraft slipped into a highly elliptical orbit. It will take three months to travel the 1.6-million-kilometer arc to its final destination, the L_1 Lagrangian point along the Earth-Sun line (February issue, page 32). Genesis will open its sample collectors in October and soak up material from the solar wind until its return to Earth in 2004 — becoming the first spacecraft to "come home" after having traveled beyond the Moon. Genesis carries no cameras or other remote-sensing instruments, and during the flight its communications system will be confirming only the correct operation of the sample container and its ion concentrator (which preferentially allows heavier elements to enter but rejects the solar wind's abundant protons). Mission scientists will not get any results until they've analyzed the returned samples in Earthbound laboratories. The Genesis home page is http://genesismission.jpl.nasa.gov/.

Genesis participant Andy Stone holds one of the spacecraft's five collector arrays in a clean room at the NASA/Johnson Space Center. The hexagonal tiles, each measuring about 10 centimeters across, are made of various materials such as silicon, germanium, artificially grown diamonds, and metallic "glass."

KORONAS-F

July ended with a bonus for solar physicists as the Russians launched their first dedicated scientific satellite in five years. Now circling Earth in a 490-by-530-km polar orbit, KORONAS-F has a windmill shape and a mass of 2,260 kilograms. Its Sun-pointing payload includes a radio-burst detector, three ultraviolet sensors, and nine X-ray detectors including an extreme-ultraviolet telescope with Ritchey-Chrétien optics and 1.5-arcsecond resolution. These instruments will monitor dynamic processes on the Sun such as active regions, flares, and mass ejections — objectives similar to those of the highly successful SOHO (Solar and Heliospheric Observatory).

KORONAS is the Russian acronym for "Complex Orbital Near-Earth Observations of Solar Activity," and it continues a long tradition of missions developed by the Ukrainian company Yuzhnoye since the 1960s. The names of its most recent solar-pointing satellites reflect the research institutes of the original principal investigators for the experiment payloads. KORONAS-I (for the IZMIRAN geophysics institute) was launched in 1994 but lost attitude control after just a few months; it reentered the atmosphere last March. The Lebedev Institute (known as FIAN in Russian) initially oversaw the development of the KORONAS-F satellite, though its payload eventually included experiments from other Russian and European research centers. For details visit http://www.izmiran.rssi.ru/projects/CORONAS/.



Space physicists from Russia and other nations are celebrating the launch of a dedicated Sunwatching satellite in July — a full decade later than planned. Courtesy Russian Academy of Sciences/IZMIRAN.

Pluto–Kuiper Belt Mission

President Bush's proposed 2002 budget omitted money for a scaled-back mission to Pluto and the Kuiper Belt (February issue, page 8). But in late July Pluto fans won a reprieve when the U.S. Senate Appropriations Committee added $25 million for the project. The Senate plan diverts money that had been slated for advanced propulsion technology and keeps work on the mission alive for the time being. By July NASA also had awarded funds for three-month concept studies to the Johns Hopkins University's Applied Physics Laboratory for its proposal (called New Horizons) and to a team from the Jet Propulsion Laboratory and Lockheed Martin for its Pluto and Outer Solar System Explorer (POSSE). Both missions involve principal investigators from Boulder, Colorado: S. Alan Stern (Southwest Research Institute) and Larry W. Esposito (University of Colorado), respectively. If Congress can find the money, the Pluto–Kuiper Belt mission would launch in 2004 or 2006.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Ulysses

The 10-year-old Ulysses spacecraft is completing its second loop around the solar poles, returning data on the structure of the solar wind and the interplanetary magnetic field high above the ecliptic plane. After passing over the south solar pole last January, Ulysses swept through perihelion on May 23rd as it cruised northward through the Sun's equatorial plane at a distance of 1.3 astronomical units (195 million kilometers). On October 13th the spacecraft reached its maximum north solar latitude of 80°. Now it will head out to Jupiter's orbit once more, coming within 1 a.u. of the giant planet in February 2004 before falling back toward the Sun for a third polar pass beginning in November 2006. The European Space Agency has approved an extension of Ulysses' mission for another three years, though NASA funding runs out at the end of 2001.

Chandra X-ray Observatory

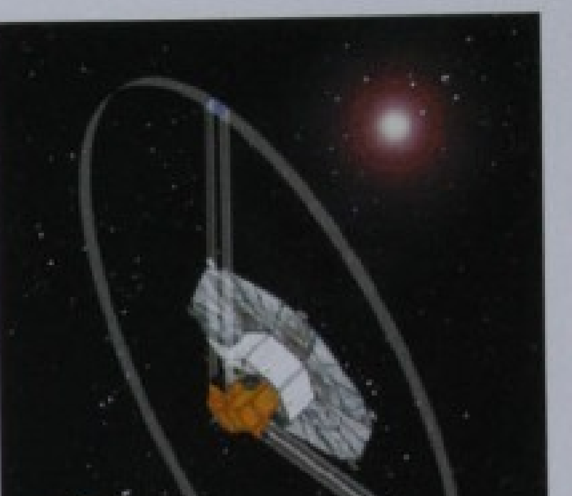
By contrast, NASA has extended the Chandra observatory's primary mission until 2009 — and the flight may continue thereafter. Launched in 1999, CXO was initially slated for just 5 years of operation, short for such a major observatory, but its wealth of discoveries have helped ensure a new commitment from the space agency's managers. Astrophysicists recently celebrated Chandra's second anniversary in space with a conference to showcase results of studies on everything from coronal loops in cool stars to the Sunyaev-Zel'dovich effect on temperatures in the microwave background. Meanwhile, the orbiting spacecraft is operating smoothly, with fewer intermittent shutdowns now that solar maximum has passed its peak and flare activity has subsided. Chandra was originally inserted into a 10,000-by-139,000-km orbit, but since launch perturbations by the Sun and Moon have raised its perigee by more than 16,000 km and swung its inclination upward from 28° to 40°.


NASA

In mid-1998, a year prior to its launch, the Chandra X-ray Observatory was tested to ensure that it could withstand the rigors of space.

Full-sky Astrometric Mapping Explorer

The FAME mission, designed to follow up the European Space Agency's highly successful Hipparcos observatory, is in trouble. The project has run seriously over budget, and NASA space-science chief Edward Weiler has threatened to cancel it if the program does not get back on track. Currently, the FAME team is considering a more modest design with a telescope having only 70 percent of the original aperture and fewer CCD cameras in the focal plane. A new, simpler thermal shield is also being assessed, though it might result in poorer thermal stability. (Tight temperature control is needed because the optical system must determine the center of a star's image to a few thousandths of a CCD pixel.) If FAME is launched in 2004, it should still be able to measure the distances of millions of stars out to at least 6,500 light-years while searching for extrasolar planets and brown dwarfs. However, the observations will take at least 5 years instead of only 2½. A decision on FAME's future will probably be made by the end of the year.


U.S. NAVAL OBSERVATORY

The Full-sky Astrometric Mapping Explorer (FAME) was picked in 1999 to be one of NASA's medium-class Explorer (Midex) missions.

Pluto Mission

In order to boost funding for future Mars probes, the Bush administration's proposed 2002 budget omitted money for a scaled-back mission to Pluto and the Kuiper Belt. But in late July Pluto fans won a reprieve when the Senate appropriations committee added $25 million for the project. The new cash diverts money that had been slated for advanced propulsion technology and keeps work on the mission alive for the time being. In June NASA awarded three-month concept studies to the Applied Physics Laboratory for its New Horizons proposal and to a JPL/Lockheed Martin team for its POSSE (Pluto and Outer Solar System Explorer). Both missions would have principal investigators from Boulder, Colorado: Alan Stern from the Southwest Research Institute and Larry Esposito from the University of Colorado, respectively. NASA managers will choose the winning proposal in November. If Congress can find the money, the Pluto–Kuiper Belt mission would depart Earth in 2004 or 2006.

Jonathan McDowell, *a high-energy astrophysicist, writes a weekly electronic newsletter about the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

MISSION UPDATE

BY JONATHAN McDOWELL

Although NASA's missions usually dominate the news-media spotlight, other spacefaring nations have developed and launched an assortment of astronomical payloads.

Space Science in Japan

The Japanese space program is undergoing a major upheaval as its two main agencies, the Institute of Space and Astronautical Science (ISAS) and the National Space Development Agency (NASDA), are becoming one. The controversial decision of the Minister of Education, Science, and Technology to merge these organizations and the National Aerospace Laboratory (which has done some shuttle-related work) beginning in 2003 seems likely to make it harder for space science to fight for its part of the Japanese budgetary pie.

Formed in the 1950s as a division of the University of Tokyo, ISAS focused on scientific projects and made Japan a world-class participant in space research. It also developed the Lambda rocket, which launched Japan's first satellite in 1970, and its successors the Mu and M-5. ISAS became only the third space agency, after NASA and the Russian Space Agency's predecessor, to launch interplanetary spacecraft: a pair of Halley's Comet probes in 1985. In X-ray astronomy, ISAS flew the Hinotori, Tenma, Ginga, and ASCA satellites; important infrared experiments flew on Kappa sounding rockets, and HALCA became the first true space-based very long baseline radio interferometer.

Meanwhile, rocket engineers at Japan's Science and Technology Agency formed the nucleus of NASDA, which gained its own satellite-launch capability in 1975 using rockets derived from the U.S.-built Delta. NASDA's satellites concentrated on applications like communications and weather monitoring.

A decade ago space scientists working with often-delayed NASA projects regarded the Japanese program — and its reputation for reliability and punctuality — with some awe. Launches scheduled even years in advance were unlikely to be more than one or two weeks late. (Admittedly, this was due partly to restrictions from local fishermen that confined launches to short periods in February and September.) Today this reputation is decidedly tarnished, with both ISAS and NASDA recovering from a series of failures. NASDA's huge H-II rocket was abandoned after multiple problems, though the replacement H-IIA made a successful initial flight in 2001. Scientific setbacks include the loss of Astro E (ISAS's flagship X-ray observatory), a four-year delay in Nozomi's arrival at Mars, and repeated redesigns of the Lunar A spacecraft.

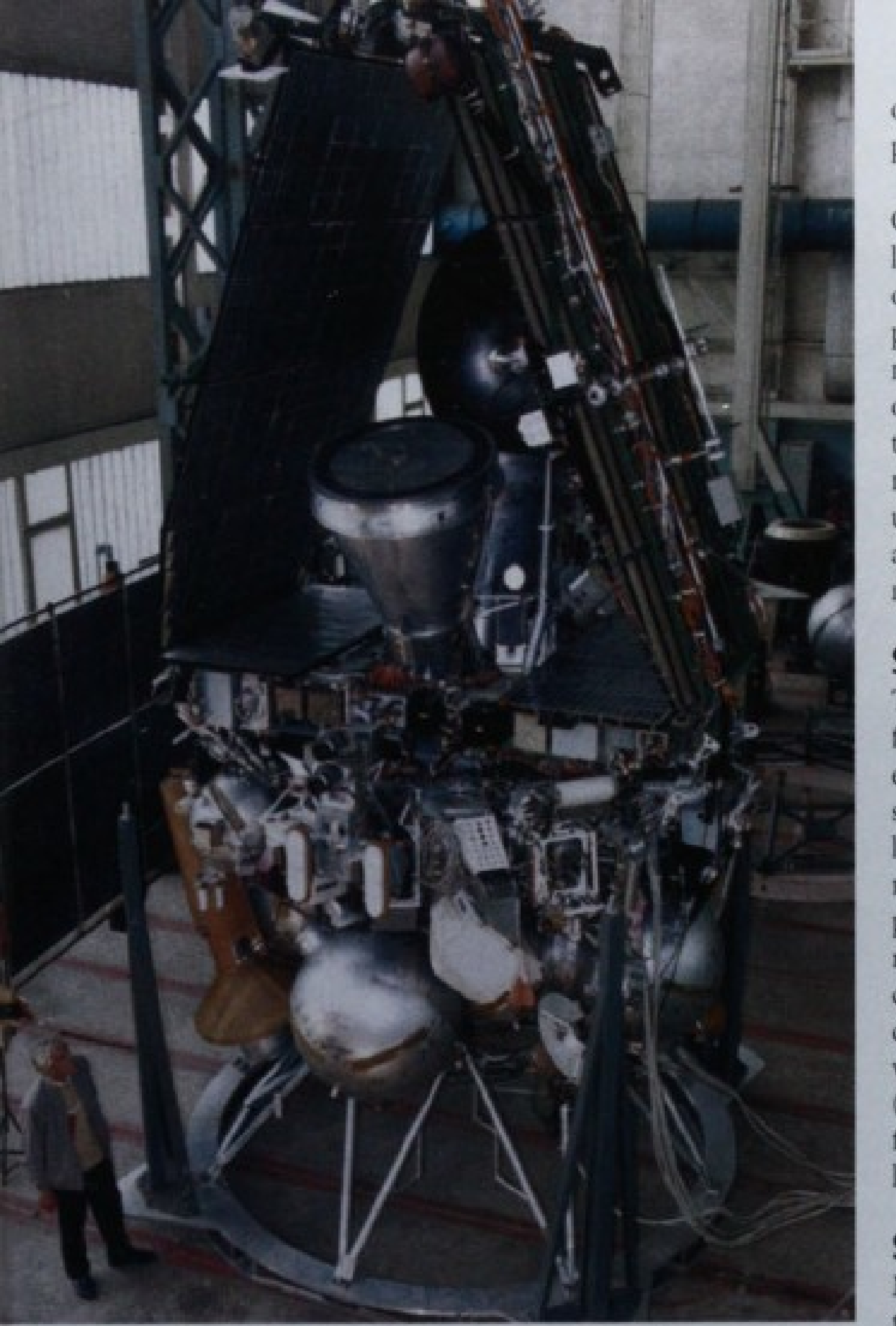
Space Science in Europe

In mid-2001 a major transition occurred at the European Space Agency (ESA), as David Southwood replaced Roger Bonnet as head of its space-science program. Southwood has a tough act to follow. During Bonnet's 18-year term, ESA

Left: Although intended to reach Mars more than a year ago, Japan's Nozomi spacecraft will now limp into Martian orbit in 2004 due to problems with its launch rocket.

Below: Japan's principal center for space-science research is the Institute of Space and Astronautical Science, which is headquartered about 40 kilometers west of Tokyo in the city of Sagamihara.

INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE (2)



Russia's planetary-exploration program suffered a devastating setback on November 16, 1996, when a malfunctioning rocket caused the ambitious Mars 96 spacecraft (seen here during construction) to crash into the Pacific Ocean near South America. Courtesy German Space Agency.

evolved from a junior partner of NASA's efforts to a world leader in space-science research. The agency's numerous successes in the past two decades include the Giotto probe of Halley's Comet, the Ulysses solar orbiter, Hipparcos's stunning comeback after being stranded in the wrong orbit, and rebuilding four Cluster magnetospheric probes after the original ones were lost during launch. Major contributions to space astronomy have been made by the Infrared Space Observatory and the high-energy XMM-Newton mission. Bonnet also transformed the European program's infrastructure, giving it a more systematic form with the selection of a mix of large "cornerstone" and medium-size missions planned well in advance.

Southwood inherits oversight of the forthcoming Bepi-Colombo mission to Mercury and the Gaia astrometry satellite, as well as European participation in the LISA gravity-wave observatory and the Next Generation Space Telescope. Several problems remain for him to tackle. Parceling out and coordinating tasks among the 15 ESA member nations represents an ongoing hurdle, and a perception remains among space scientists that the agency caters to the technological interests of European space industry rather than being responsive to the users of spacecraft data — a challenge that NASA confronted and surmounted during the 1980s, when observer support finally received high priority.

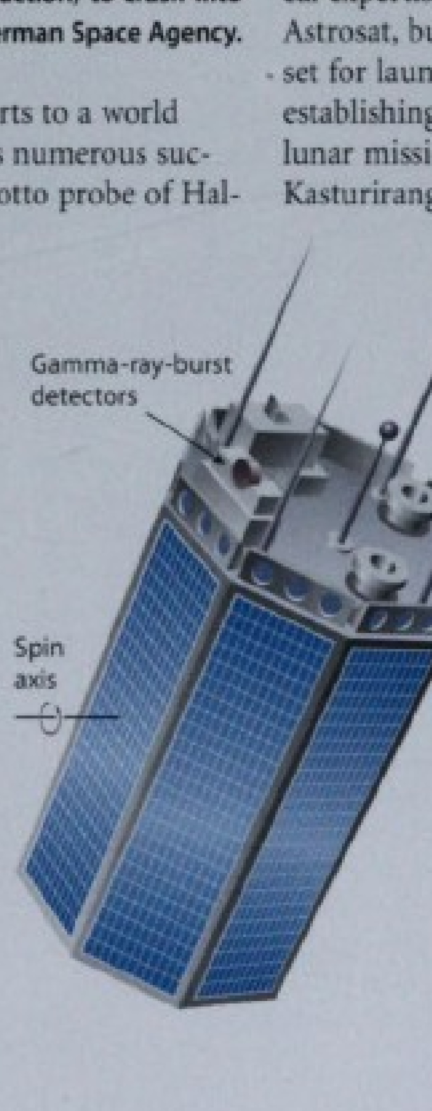
Space Science in Russia

The Russian space-science program continues its slow recovery from a decade-long free fall. After the disruption caused by the end of the Soviet Union, a large part of the remaining resources were poured into the prestigious Mars 96 probe. Its loss during launch was a hammer blow; the flights of two modest Koronas solar observatories (*S&T:* November 2001, page 28) were the only bright spots of the past decade. Science missions have a hard time competing with Western commercial payloads for access to the launch vehicles that are Russia's current success story. Nevertheless, Russia is still planning a variety of future orbital missions based on its Spektr platform (*S&T:* October 2001, page 28) and some modest planetary flights that can use the small Molniya rocket instead of the larger Proton-class payloads of the 1980s.

Space Science in the Developing World

Most developing countries with space programs are concentrating on Earth observation, but a few are also looking outward. India has had a small scientific-satellite program for decades, which has mainly helped develop Indian technological expertise rather than generate significant scientific results. Astrosat, building on earlier X-ray astronomy experiments and set for launch in mid-decade, will be a major step toward establishing Indian space science as a serious contender. A lunar mission is also in the works. Notably, Krishnaswamy Kasturirangan, who directs the Indian Space Research Organization, is a former astrophysicist.

China is also making tentative steps toward a space-science program, having placed a gamma-ray-burst payload on a test flight of its Shenzhou spaceship and a planned magnetospheric mission to be carried out jointly with Europe. Last October Chinese authorities announced plans to launch a lunar satellite, but they revealed few details. Argentina's inaugural X-ray payload was lost in a 1996 launch failure, and it isn't clear what will follow.



India's most productive space-science efforts to date were a pair of craft in the Stretched Rohini Satellite Series. Launched in 1992 and 1994, respectively, SROSS C and C2 carried gamma-ray-burst detectors. Source: Indian Space Research Organization.

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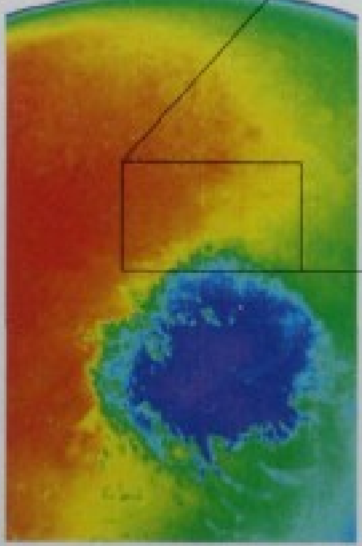
BY JONATHAN McDOWELL

2001 Mars Odyssey

NASA and Jet Propulsion Laboratory managers breathed a deep sigh of relief last October 24th when telemetry confirmed that 2001 Mars Odyssey had safely placed itself in exactly the right orbit. A 300-kilometer-high pass above the surface and a 20-minute engine burn slowed Odyssey just enough for the spacecraft to become captured by Mars and coast up to an apoapsis of 26,800 km over the next nine hours. Two days later another engine firing dropped the periapsis to 128 km, slightly within the atmosphere, and the long process of aerobraking began. Each time the spacecraft comes its closest to Mars, over the north pole, its solar-cell panel heats up to almost 180°C (355°F) as friction slows the vehicle and gradually circularizes the orbit. Odyssey's 2½-year survey of the planet's surface composition begins in January.



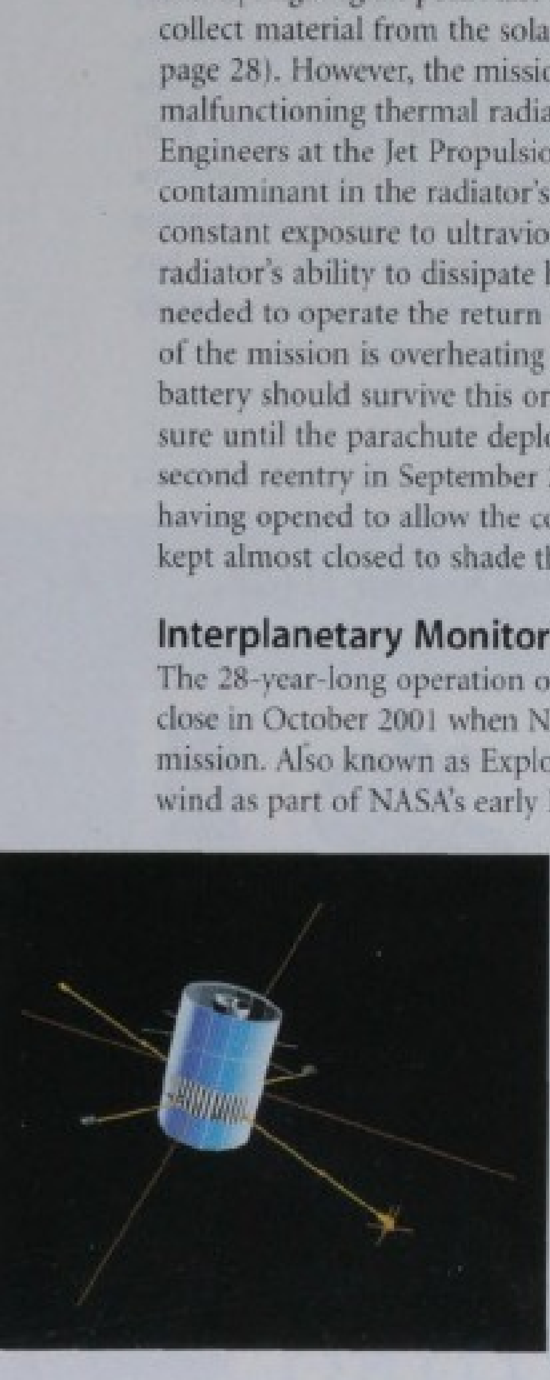
In an early test last November 2nd, the mapping spectrometer aboard NASA's 2001 Mars Odyssey spacecraft recorded temperatures across Mars's south polar cap *(left)*, which ranged from −120°C (blue) to 0°C (red), and a close-up of the cap's edge in visible light *(above)*. Courtesy THEMIS Science Team/ Arizona State University.

Genesis

The Genesis spacecraft reached its destination near the Earth-Sun L_1 Lagrangian point last November 16th and has begun to collect material from the solar wind (*S&T:* November 2001, page 28). However, the mission may be jeopardized due to a malfunctioning thermal radiator on the sample-return capsule. Engineers at the Jet Propulsion Laboratory believe that a contaminant in the radiator's white paint has degraded after constant exposure to ultraviolet sunlight, which has ruined the radiator's ability to dissipate heat. Consequently, the battery needed to operate the return capsule in the critical final hour of the mission is overheating well beyond its design limit. The battery should survive this ordeal, but no one will know for sure until the parachute deploys during Genesis's 10½-km-per-second reentry in September 2004. Meanwhile, the capsule's lid, having opened to allow the collector panels to deploy, is being kept almost closed to shade the battery as much as possible.

Interplanetary Monitoring Platform 8

The 28-year-long operation of the IMP 8 spacecraft came to a close in October 2001 when NASA managers decided to end the mission. Also known as Explorer 50, IMP 8 studied the solar wind as part of NASA's early Explorer satellite program. Besides the eight IMPs in Earth orbit, NASA dispatched two Anchored IMPs to the Moon. (AIMP E operated in lunar orbit for six years during the Apollo program, with almost no media attention.) Unlike all but one of its predecessors, IMP 8 occupies an almost circular orbit halfway to the Moon, ensuring an indefinite lifetime in space. Once in place, the small satellite deployed a 124-meter-long electric-field antenna to monitor radio noise and plasma waves. For almost three decades IMP 8 transmitted regular reports of solar activity, which became a standard measure of solar-weather forecasting. It also studied the way cosmic rays vary with time and detected "plasmoids" (ion concentrations) in Earth's magnetotail.



The Interplanetary Monitoring Platform (IMP) 8 spacecraft has radioed solar-wind conditions to Earth since 1973. The drum-shaped craft weighs 371 kilograms. Courtesy NASA/Goddard Space Flight Center.

High Energy Solar Spectroscopic Imager

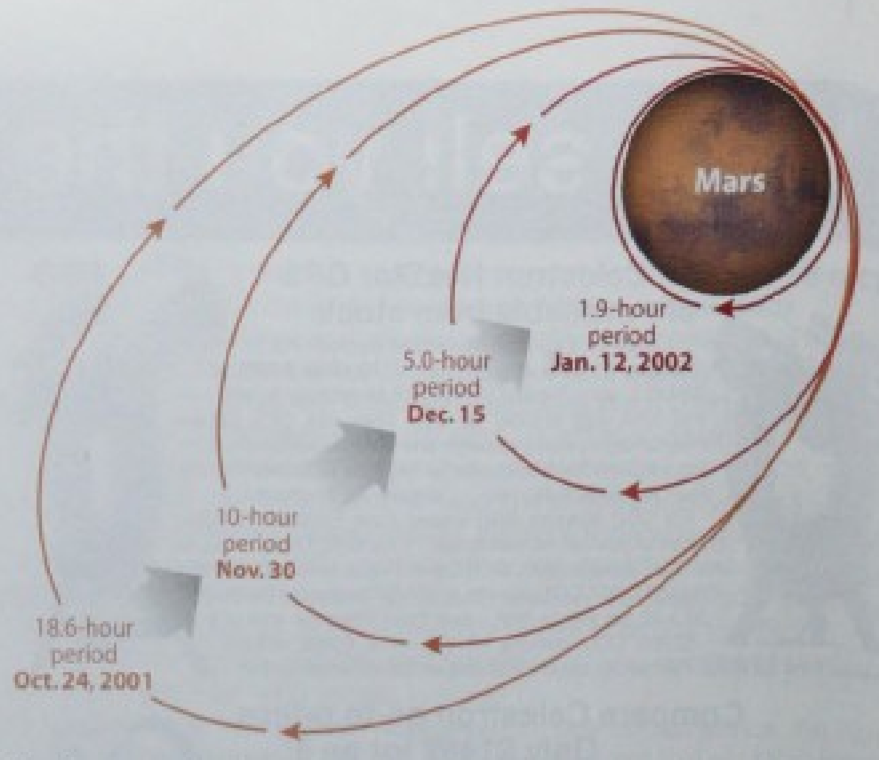
The failure of a Taurus rocket in September has been traced to a stuck steering thruster on the second-stage engine, which pushed the vehicle off course. This was not good news for NASA's HESSI satellite, which took another schedule hit after the failure because the first stage of its Pegasus launcher is similar to the Taurus's second stage. Originally slated to be launched in March 2000, HESSI was finally given the green light for a mid-January trip to orbit. Unfortunately, with solar maximum now past there will be fewer flares for the observatory to study once in orbit. But it still will be the best-available detector of "hard" (high-energy) X-rays from the Sun's active regions.

High-Energy Transient Explorer 2

After a year in orbit, HETE 2 has begun to detect gamma-ray bursts and afterglows. Early on, the craft was plagued by light leaking into its soft-X-ray camera, a problem that arose because atomic oxygen in the outer atmosphere eroded a crucial filter. The extra light can be removed by software, except at full Moon. The understaffed HETE team also had a challenge to tune the detectors and calibrate the satellite, but the many X-ray bursters in the galactic center, which passed through the field of view last summer, provided key data to bring HETE to full operation. However, nature had an unpleasant surprise: the bursts are less bright at soft-X-ray wavelengths than predicted. Although this is an important discovery, it means HETE is seeing about half the number of bursts expected.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL



Thanks to aerobraking (using atmospheric drag to slow down), NASA's 2001 Mars Odyssey can attain a tight, circular orbit around the red planet without expending precious rocket fuel. Courtesy NASA/JPL.

2001 Mars Odyssey

NASA's Mars Odyssey was due to complete its aerobraking sequence in mid-January. After the spacecraft began orbiting Mars on October 24th, controllers quickly dropped its closest-approach distance from 300 to 128 kilometers and then 103 km, bleeding off speed on each pass through the Martian atmosphere. Within one month the high point of the orbit had dropped from 28,000 to 15,000 km, and by January it was expected to come all the way down to 400 km, at which point the closest approach will be raised out of the atmosphere to match. The final stages of an aerobraking sequence are tricky, since only a couple of hours separate each pass and a sudden increase in atmospheric density could risk making the spacecraft burn up. Assuming all goes well, Odyssey will end up in a stable, circular mapping orbit about three months after arriving (in contrast, it took Mars Global Surveyor a year and a half to reach its final orbit). At that point the 6-meter-long boom for Odyssey's gamma-ray spectrometer can be fully deployed to begin mineralogical mapping, complementing the views from the infrared-sensing THEMIS (Thermal Emission Imaging System) camera.

Galileo

The veteran Galileo probe has begun its 13th year of operation and its seventh year in orbit around the giant planet Jupiter, reaching an apojove of 11.5 million kilometers last December 1st before falling back toward the inner Jovian system. On January 17th Galileo flies over the equator of Io at a height of only 100 km, complementing a series of two polar passes in the past year. The flyby is on the Jupiter-facing side of Io, which has not been observed at high resolution with Galileo, and scientists are looking forward to getting views much more detailed than those from the Voyager flybys in 1979. In particular, Galileo's camera is being trained on the giant volcano Pele and a number of rare "tholi" (pancake-domed volcanoes). However, last year NASA decided to terminate funding for mission operations at the end of December, a tiny amount of money compared to the total cost of the Galileo program, and proposed that no science data be returned from January's flyby. Fortunately, enough money has been scraped together within the project to execute this final Io encounter and to return most of the tape-recorded results. But the camera and other remote-sensing experiments will not be used when Galileo makes the first-ever flyby of the moon Amalthea, interior to Io, next November 5th. To eliminate any potential that the spacecraft could someday contaminate Europa, Galileo will be directed into Jupiter's atmosphere in September 2003.

Multiple flybys of the Jovian moon Io have subjected Galileo to more than 500,000 rads of charged particles in Jupiter's potent magnetosphere — several times the spacecraft's design limit.

Rosetta

The European Space Agency's Rosetta comet probe has passed a significant construction milestone. On December 3rd the lander and orbiter came together for the first time to begin a series of integration and thermal-vacuum tests at ESA's space-science center near Leiden, the Netherlands. During the preceding month the orbiter's payload and service modules were mated and trucked across Europe from a factory in Turin, Italy, while the lander was flown in from Munich, Germany. Rosetta will be the first mission to fly in formation with a comet, in contrast to earlier high-speed flybys. It will be launched into solar orbit a year from now, in January 2003, on an enhanced version of the Ariane 5 rocket. One flyby of Mars and two of Earth will place the spacecraft on a trajectory to rendezvous with periodic comet 46P/Wirtanen, whose orbit stretches from 1.06 astronomical units near the Earth out to 5.1 a.u. near Jupiter. Once Rosetta matches Wirtanen's inclination of 11.7°, it will rank as the second highest inclination mission (after Ulysses) around the Sun, just beating out the NEAR-Shoemaker spacecraft. To move so far out of the ecliptic plane — and to match the comet's speed for a rendezvous instead of a simple flyby — will be quite challenging. If all goes well, Rosetta's lander will touch down on the icy surface of the nucleus in late 2011.

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MISSION UPDATE

BY JONATHAN McDOWELL

Far Ultraviolet Spectroscopic Explorer

Just as it began its third year of observations, NASA's Far Ultraviolet Spectroscopic Explorer slipped into a "safe" (standby) mode on December 10, 2001, when the second of its four reaction wheels malfunctioned. (The first wheel went out of action on November 25th.) Mission engineers at NASA's Goddard Space Flight Center and Johns Hopkins University remain optimistic that they will be able to write new software to control the pointing of the satellite with the remaining two wheels. These devices orient FUSE by transferring angular momentum to and from the satellite's body, which turns in response around a given wheel's rotation axis. Three wheels are therefore needed to slew the satellite in an arbitrary direction; a fourth wheel provides backup. Problems with balky reaction wheels have plagued satellites for decades, so this isn't an unexpected failure. Until a fix is ready — probably several weeks if the wheels can be restarted, several months if a new control method is needed — FUSE will remain in electronic hibernation with its solar-cell panels pointed directly at the Sun for maximum power. The spacecraft also has a magnetic-torquing system, which uses Earth's magnetic field to change orientation, that may be called into play if the faulty wheels cannot be restored to use.

JOHNS HOPKINS UNIVERSITY

At the control center for NASA's Far Ultraviolet Spectroscopic Explorer, mission engineers are trying to restore the spacecraft to full operation.

Yohkoh

A second astronomical satellite ran into trouble at the close of 2001, when the 10-year-old Japanese solar observatory Yohkoh fell victim to December 14th's annular eclipse of the Sun. The greatly diminished sunlight confused the pointing system, and when the satellite's drift reached a half degree per minute it triggered a safe mode. By bad luck, the incident happened during a long communications gap — nine hours passed before contact resumed, by which time its solar-cell panels had long since stopped pointing at the Sun and its batteries had nearly drained themselves. There isn't enough power left to operate the attitude-control system, so Yohkoh continues to rotate slowly. Whenever the batteries are in shadow they chill to well below freezing. Eventually the spacecraft will rotate to an orientation in which the batteries warm up, at which point space engineers at the Institute of Space and Astronautical Science hope to recover the satellite. Initially called Solar A, Yohkoh reached orbit on August 30, 1991. It became Japan's second solar X-ray observatory, following the Hinotori (Astro A) mission that flew in 1981. Yohkoh was the first Japanese mission to include a major U.S. instrument: its soft (low-energy) X-ray telescope. The spacecraft also carries a hard-X-ray telescope and a pair of X-ray spectrometers.

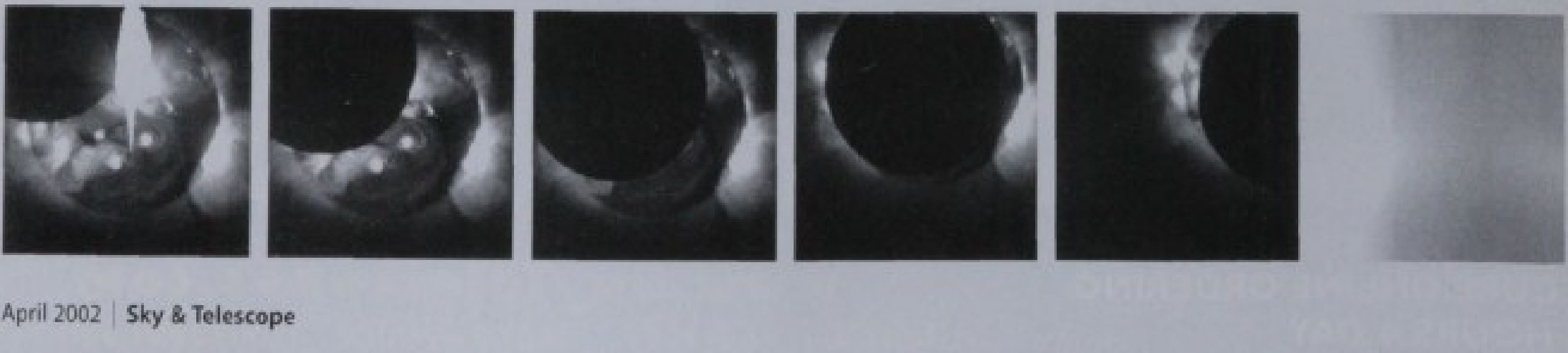
Deep Space 1

On December 18th engineers at NASA's Jet Propulsion Laboratory in Pasadena, California, officially concluded the Deep Space 1 mission by turning off the craft's xenon-fueled engine. Launched on October 24, 1998, this inaugural flight in NASA's New Millennium program proved the viability of a dozen new technologies, including an autonomous star tracker that enabled the craft to guide itself without human intervention, and the ion engine, which retired with 670 operating days under its belt. This type of propulsion has been adopted for the recently selected Dawn spacecraft, which will visit main-belt asteroids.

Deep Space 1 completed its primary mission of technology tests a few months after launch, then made a flyby of the minor planet 9969 Braille in July 1999. But soon after that encounter the navigation camera failed and a major rescue effort ensued, during which the multispectral imager was reprogrammed to handle the dual roles of science and navigation. The successful fix allowed the spacecraft to complete its rendezvous with periodic comet 19P/Borrelly on September 22, 2001 (*S&T:* December 2001, page 18), when it imaged the nucleus in detail and probed Borrelly's interaction with the solar wind. Engineers will leave its radio receiver turned on indefinitely as the craft silently circles the Sun in a 218-by-183-million-kilometer orbit with a period of 568 days.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

As Yohkoh tracked the Sun during December 14th's annular eclipse, the spacecraft quite literally "lost it." Soon thereafter Yohkoh went into electronic hibernation. This series of X-ray images, taken every 96 seconds, begins at 20:52:41 Universal Time. Courtesy Hugh Hudson and ISAS.



BY JONATHAN McDOWELL

Left: From its 600-kilometer-high orbit, the High Energy Solar Spectroscopic Imager (HESSI) will monitor the Sun's powerful flares. *Right:* The business end of HESSI consists of these nine germanium detectors, which determine the energies of X- and gamma rays in solar flares. In space the detectors are being chilled to about 75° Kelvin (–324°F). Courtesy NASA/Goddard Space Flight Center.

High Energy Solar Spectroscopic Imager

It took about 22 months longer than planned, but the HESSI observatory finally reached orbit on February 6th. At an altitude of 12 kilometers (39,000 feet) over the Atlantic Ocean off the Florida coast, the 293-kilogram satellite and its Pegasus XL rocket were dropped from the belly of an L-1011 aircraft. Then the rocket's three stages fired flawlessly in turn, placing HESSI in a 600-by-585-km orbit inclined 38° to the equator. From this vantage the cylinder-shaped spacecraft will study the source of solar flares by recording high-resolution images in both X- and gamma rays (*S&T:* March 2001, page 32). The mission's long delay was due partly to a test mishap in early 2000 that left the spacecraft damaged, and partly to concerns over last September's failure of a Taurus rocket, which shares some design features with the Pegasus XL.

Full-sky Astrometric Mapping Explorer

The FAME astrometry mission has been canceled by NASA managers. As reported earlier (*S&T:* December 2001, page 30), the mission had been under review for some months after running into technical and budgetary problems. At the American Astronomical Society meeting in early January, a handwritten notice went up at the FAME exhibit booth starkly announcing the cancellation; the next day a nicely printed color replacement noted that "NASA has decided not to proceed" with the mission — but it avoided using the word "cancel," leaving open the possibility that the U.S. Naval Observatory team might pursue other sources of funding. Nevertheless, this possibility seems unlikely, meaning that the mission's scientific objectives may not be accomplished until the European Space Agency's Gaia satellite reaches orbit in 2012. FAME would have measured the positions of 40 million stars to within 0.00005 arcsecond. By comparison, the Diva astrometry satellite, proposed by German astronomers for launch later this decade, has a planned accuracy of 0.002 arcsecond — good enough to improve the stellar distance scale but well short of the capability needed to discover the extrasolar planets that FAME would have detected.

Galileo

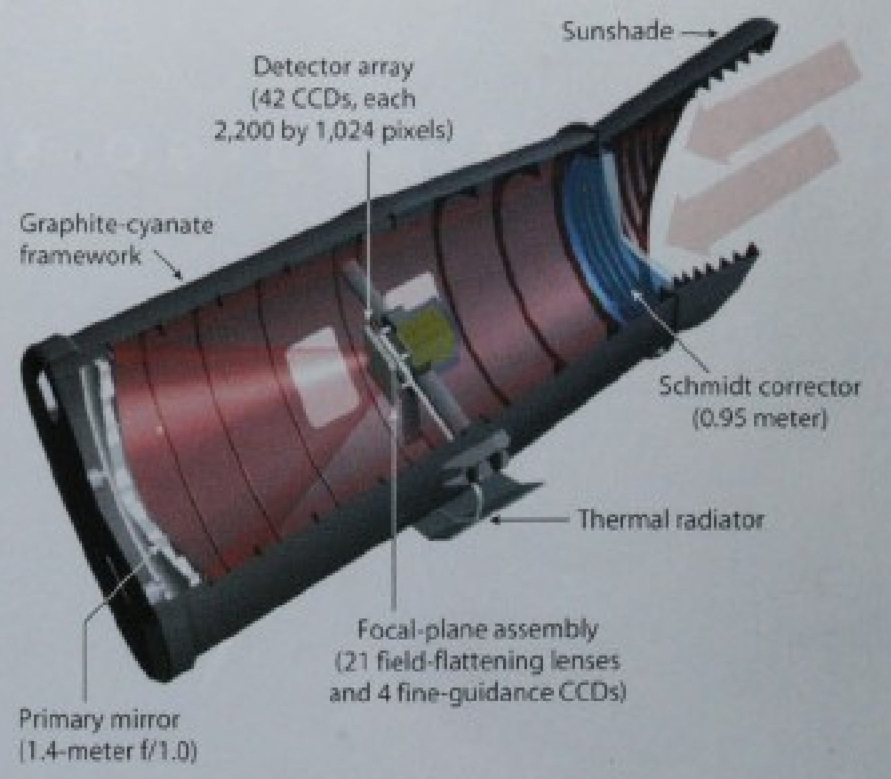
NASA's Galileo orbiter said farewell to Jupiter's Galilean moons with a final flyby of volcanic Io on January 17th. The enduring spacecraft passed just 102 km from Io's Jupiter-facing hemisphere, but the highly anticipated science observations were lost when intense radiation triggered an electronic shutdown just 30 minutes before closest approach. The harsh charged-particle environment of the inner Jovian magnetosphere has increasingly posed problems for Galileo, which has absorbed a cumulative dose of 500,000 rads — 3½ times its design limit — since arriving at Jupiter in December 1995. Since then, despite the handicap of a tangled, useless main antenna, Galileo has beamed back more than 4.8 gigabits of science data — including some 14,000 images. January's flyby was by no means a total washout: some data had already been collected when the safe mode occurred, and the spacecraft was revived in time to take close-up pictures of Jupiter's colorful cloudtops and a navigation image of the inner moon Amalthea. Galileo now loops out to a distance of 25 million km before coming back in for a 500-km pass of Amalthea on November 5th. After that, Galileo will make one more long orbit before being directed toward its demise in Jupiter's crushing atmosphere on September 21, 2003.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL

Kepler

One of two new Discovery-class missions selected by NASA managers last year, Kepler is to search for Earth-like extrasolar planets using transit photometry. Kepler's 0.95-meter-aperture Schmidt telescope will stare for four years at a single 12°-wide field in Cygnus, monitoring 100,000 stars brighter than 14th magnitude and measuring their brightness every 15 minutes to an accuracy of 0.0001 magnitude. This should reveal the faint dimming caused by any planet whose orbital plane happens to carry it in front of a star as seen from Earth. Kepler will be launched into solar orbit by a Delta rocket in 2006. The telescope's single instrument uses an array of 42 CCD cameras with a total of 100 million pixels. These detectors will be deliberately placed out of focus to improve the accuracy of the brightness measurements: spreading the light over 10 arcseconds averages out instrumental variations and improves statistics, and the image quality won't suffer as long as the star images don't overlap.



The Kepler spacecraft is essentially a Schmidt telescope with a 100-million-pixel array of detectors. Courtesy NASA/Ames Research Center.

Dawn

The second Discovery winner, Dawn, is a nine-year mission to orbit the two largest asteroids in the main belt, 1 Ceres and 4 Vesta. With launch scheduled for May 2006, this will be the first interplanetary spacecraft to take advantage of the type of ion-drive engine used by Deep Space 1 (*S&T:* December 2001, page 18). Using three of these engines, Dawn should take four years to reach Vesta. Then, in July 2010, a conventional hydrazine-fueled braking engine will place the spacecraft in a 700-kilometer-high orbit. Over the next year the spacecraft will close in to a height of only 120 km, studying the surface of the asteroid all the while. In July 2011, Dawn sets itself free of Vesta, using the ion engines again for a three-year trip to Ceres. After a year of studies there, the primary mission ends in July 2015.

Right: **Eerie blue exhaust rushes out of an ion-drive engine at more than 30 kilometers (20 miles) per second. *Above:* The Dawn spacecraft will use thrusters of this type to reach the asteroids Ceres and Vesta. Courtesy Jet Propulsion Laboratory and William K. Hartmann.**

Contour

The Applied Physics Laboratory in Maryland is fine-tuning the Contour comet probe for its upcoming mission. Engineers conducted vibration and spin-balance tests in January and February, followed by thermal-vacuum tests in March. Launch should occur this July, when a Delta 7425 rocket will place the spacecraft into an elliptical 200-by-109,000-km orbit around Earth. Contour (a contraction for Comet Nucleus Tour) will spend up to 1½ months in this parking orbit, a clever hedge against liftoff delays. Whatever the launch day, the orbit will be adjusted so that on August 15th it will be in exactly the right place for a solid-fuel rocket to put Contour in its intended solar orbit. This will range between the orbits of Venus and Mars, with a perihelion of 0.80 astronomical unit and an aphelion of 1.35 a.u. After a swingby of Earth in August 2003, Contour will zip past Comet 2P/Encke three months later. Another Earth flyby the following August will send Contour on an 18-month "backflip" across the inner solar system at an inclination of 12° (see page 14). A second series of Earth flybys, concluding in February 2006, sets up an encounter with Comet 73P/Schwassmann-Wachmann 3 in June 2006 and probably with a third comet — possibly 6P/d'Arrest — in 2008. NASA planners note that the mission design is so flexible that, given enough lead time, the spacecraft can be redirected to intercept an unexpected cometary visitor passing through the inner solar system.

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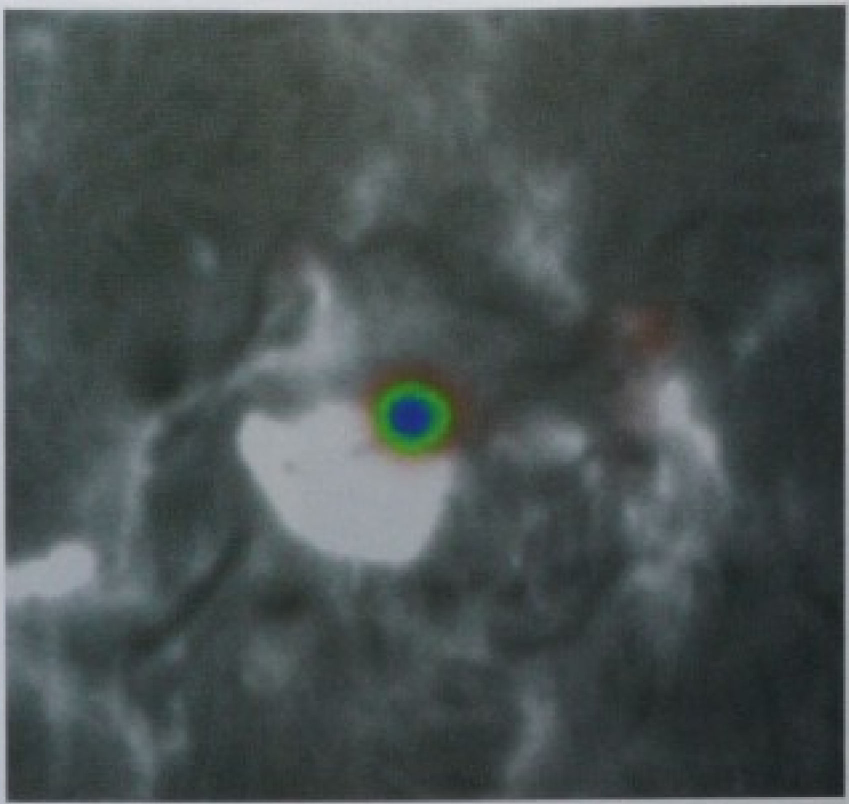
High-Energy Solar Spectroscopic Imager

To mark the inauguration of its scientific observations, NASA's newest solar observatory has been renamed the Reuven Ramaty High-Energy Solar Spectroscopic Imager, or RHESSI. Ramaty, who died last year, was a pioneering solar and high-energy physicist and a key player in the early development of this satellite. Launched on February 5th, RHESSI recorded its first solar flare on February 12th and saw several powerful M-class flares through the end of March. These images reveal, for the first time, where the energy is being released at the base of the flare: a tiny spot of 200-million-degree gas generating hard X-ray energy. Using RHESSI, solar physicists can pinpoint this source's location to better than 5 arcseconds, or about 4,000 kilometers. The source region lies at the edge of a larger plasma cloud, with a temperature of 2 million degrees, observed simultaneously by the Transition Region and Coronal Explorer (TRACE) satellite. RHESSI has also detected a burst of energy from its first extrasolar source, the soft gamma-ray repeater known as SGR1900+14.



NASA's newest solar sentinel, recently renamed to honor physicist Reuven Ramaty, recorded an Earth-size source of X-rays (colored spot) associated with a moderately powerful solar flare (white region) on February 20th. The spacecraft data have been superimposed on a hydrogen-alpha image of the Sun acquired by Big Bear Solar Observatory. Courtesy NASA/Goddard Space Flight Center.

Far Ultraviolet Spectroscopic Explorer

The FUSE spectroscopy satellite has resumed scientific operations after a hiatus of nearly three months due to reaction-wheel problems (April issue, page 30). Initially FUSE used three of these wheels to turn and point at astronomical targets, but one is no longer working. New software, loaded into the satellite's computer on January 24th, now allows FUSE to use the interaction of electromagnetic coils (called magnetorquers) with Earth's magnetic field to help swing itself around the third axis. By mid-February the flight team had regained subarcsecond pointing accuracy, and full science operations resumed on March 1st. Mission controllers are still slewing the spacecraft gingerly and with some difficulty: the strength of the magnetic field varies with position and time, and the differential gravity acting on the satellite (because one end is farther from Earth than the other) sometimes exceeds the turning force generated by the magnetorquers. However, as of late March spectroscopic observations were streaming in to the FUSE data center at Johns Hopkins University in Maryland.

Mars Global Surveyor

While 2001 Mars Odyssey has dominated the spotlight recently, it's easy to forget that another spacecraft is still operating around the red planet. Mars Global Surveyor reached its destination in 1997 and has been methodically mapping the planet from orbit since February 1999. It chronicled the development of a global dust storm last summer (*S&T:* November 2001, page 22) and began the second year of its extended mission on February 1st. In August 2001 MGS was reoriented so that its camera points 16° from the nadir, allowing more opportunities for stereo imaging. The five-year-old spacecraft is operating rather well overall, though not without problems. On June 30, 2001, the highly productive laser altimeter lost the use of its laser, and it has been used passively as an energy-sensing radiometer ever since. On February 27th Surveyor shut itself down for the fourth time in the past year; its attitude-control system occasionally has difficulty recognizing the stars its trackers are observing. The problem isn't serious, but it takes a week to resume operations each time. Recently, Malin Space Science Systems, which operates the spacecraft's camera, released the first new global map of Mars in decades, with a resolution of 230 meters. The MSSS team continues to release weekly Martian weather reports as well, which noted significant dust storms in both the northern and southern hemispheres during March.

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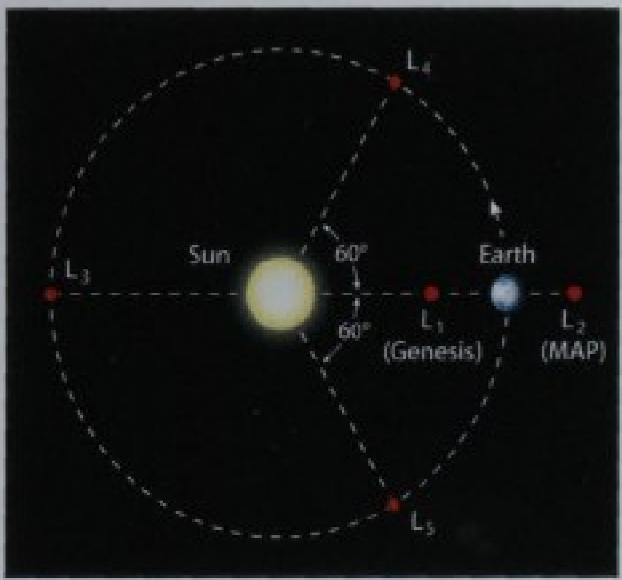
Mars Global Surveyor's camera is best known for its finely detailed images of selected surface areas. But it also takes wide-angle views, such as this one from late March showing the advance of a dust storm *(A)* spawned near the north polar cap and water-ice clouds *(C)* nearer the equator. Courtesy Malin Space Science Systems.

MISSION UPDATE

BY JONATHAN McDOWELL

Genesis

Now well into its mission to collect material from the solar wind, NASA's Genesis probe has completed its first halo orbit around the L_1 Lagrangian libration point on the Sunward side of Earth. Launched a year ago, Genesis reached its distant outpost in November 2001. It then began to loop around L_1 along a path that extends about 700,000 kilometers to either side in the ecliptic plane and about 450,000 km above and below the plane. While doing so, the spacecraft ranges between 1.2 and 1.6 million km from Earth. This "halo orbit" isn't quite stable, so Genesis made small thruster firings in December, January, March, and May to keep from drifting off course. During April an 800-km-per-second solar storm swept past the spacecraft, and a surge of proton hits confused the star-tracker camera. Fortunately, improved software prevented the craft from going into safe mode. Genesis is operated by NASA's Jet Propulsion Laboratory and will complete four more halo orbits before returning to Earth in September 2004.



At the five Lagrangian points (derived by the 18th-century mathematician Joseph Lagrange), gravitational and centrifugal forces are in equilibrium. Only the L_4 and L_5 points are truly stable, however; spacecraft must "hover" around the other three in so-called halo orbits. (Distances are not to scale.) *Sky & Telescope* illustration.

Microwave Anisotropy Probe

On the other side of Earth from Genesis, the Microwave Anisotropy Probe has also completed its first orbit around the L_2 libration point. MAP's halo orbit is much smaller, circling a mere 200,000 km above and below the ecliptic and 100,000 km to either side of the Earth-Sun line. The spacecraft's distance from Earth varies between 1.44 and 1.54 million km. On April 1st MAP completed its first survey of the entire sky, and project scientists will need until the end of the year to analyze those data. The spacecraft is measuring the cosmic microwave background, the radiant heat left over from the Big Bang. When complete, MAP's observations will show density fluctuations (represented by temperature differences of only a few parts per million) at the time when the Big Bang became transparent. Patches that are denser (cooler) than average have, by now, become clusters of galaxies. Operated by NASA's Goddard Space Flight Center, MAP is a successor to the COBE mission, which flew 10 years ago and provided stunning confirmation of the standard Big Bang cosmology.

South African entrepeneur Mark Shuttleworth enters the International Space Station on April 27th, the first of his eight days on board as a tourist astronaut. Courtesy NASA.

Human Spaceflight

Flights by private citizens into space have resumed after a 15-year hiatus in the wake of the loss of the Space Shuttle *Challenger*. Dennis Tito's tourist flight in 2001, the first to be funded out of an astronaut's own pocket, was controversial because of disagreements between NASA and Tito's Russian hosts. But the April 2002 flight of South African entrepreneur Mark Shuttleworth went much more smoothly and seems to have established the "tourist astronaut" as a new reality. Although he paid for a seat with his own money (and is also trying to buy the Soyuz ship as a souvenir), Shuttleworth wasn't joyriding the entire time: he carried out a set of experiments provided by the South African scientific community. Additional tourist accommodations are expected soon, with American musician Lance Bass and Polish banker Leszek Czarnecki among those announcing interest.

Further blurring the lines between astronaut and passenger, NASA administrator Sean O'Keefe announced in April that Barbara Morgan, the former teacher who was backup to Christa McAuliffe, will fly on the Space Shuttle in 2004. Morgan is now a fully trained astronaut and has served as spacecraft communicator ("capcom") during recent missions. She will fly as an Educator Mission Specialist.

The first nongovernment astronaut was Charles Walker, who flew as a commercial passenger on the Space Shuttle in 1984 and 1985 under the aegis of his employer, McDonnell Douglas. Then came flights by politicians Jake Garn and Bill Nelson, and by commercial passenger Bob Cenker of RCA. *Challenger*'s ill-fated 1986 mission included both Greg Jarvis of Hughes Aircraft and teacher McAuliffe. John Glenn's nostalgia trip in 1998 reopened the debate, but it was the Russian Space Agency's desperate need for money that broke the logjam. A Russian Soyuz had already carried a Japanese journalist to Mir in 1990, followed by a British promotional-contest winner who flew the next year.

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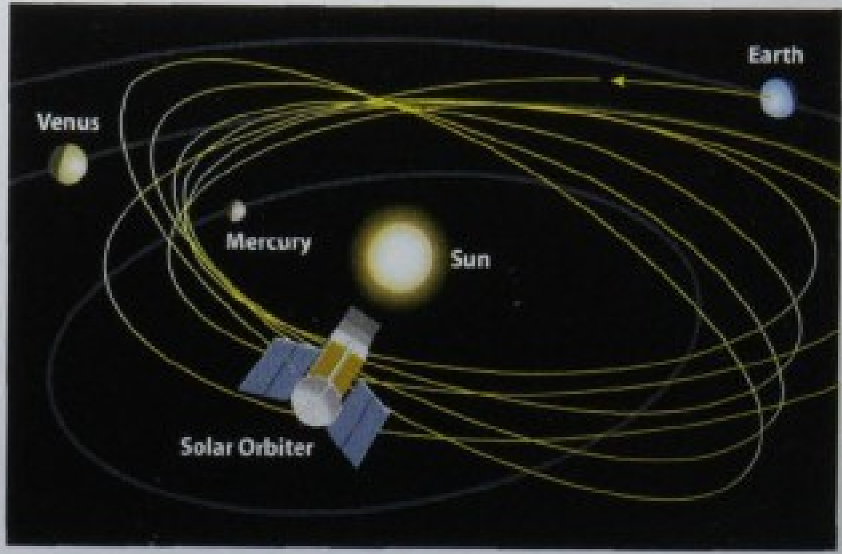
MISSION UPDATE
BY JONATHAN McDOWELL



When launched early next decade, Solar Orbiter will venture closer to the Sun (about 30 million kilometers) than any previous spacecraft. A series of close flybys of Venus will alter the inclination of its orbit plane and its perihelion distance.

Cosmic Vision 2020

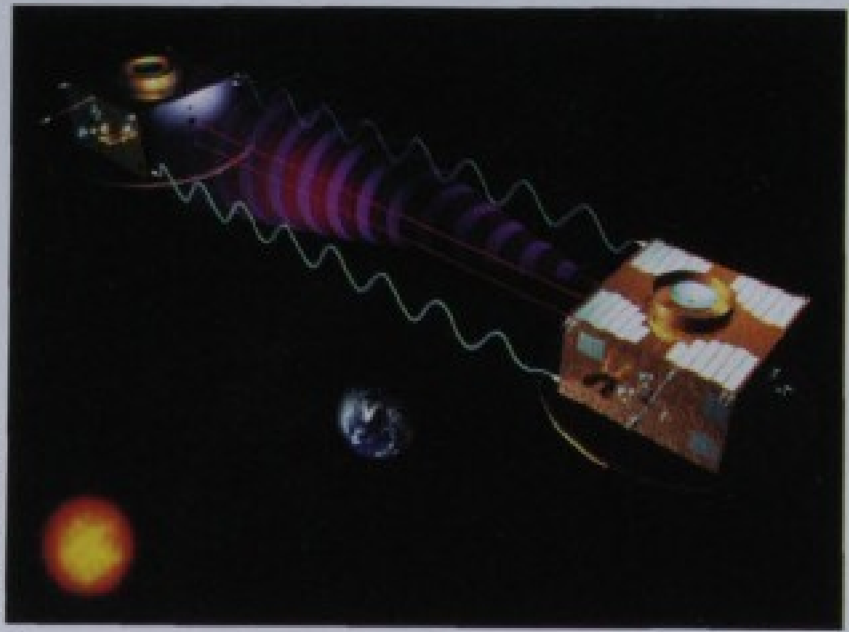
Last November, after having its long-term budget reduced, the European Space Agency's Science Programme Committee began the work of revising its slate of upcoming astrophysics, solar-system, and space-physics missions. The new plan, released in late May under the rubric "Cosmic Vision 2020," preserves the Gaia astrometry mission but shelves a proposed Venus Express initiative. Other changes are detailed below.

Solar Orbiter

ESA's Solar Orbiter project is being combined with the Bepi-Colombo mission to Mercury, with the launch of both now slipping to at least 2011. Solar Orbiter will continue the extensive European studies of the Sun pioneered by the Solar and Heliospheric Observatory (SOHO), Ulysses, and Cluster missions. Solar Orbiter will use multiple Venus flybys to assume an orbit with an inclination of up to 38° and a perihelion of as little as 0.2 astronomical unit (30 million kilometers) from the Sun, well within the orbit of Mercury. Both this spacecraft and BepiColombo will use extensive thermal shielding and solar-electric propulsion. Solar Orbiter carries a full-Sun camera and a second imager to zoom in on particular areas at 100-km resolution, as well as a magnetograph and instruments to study charged particles and electromagnetic fields. In the mid-1970s two German Helios spacecraft approached to 0.3 a.u. from the Sun, but they did not carry cameras and remained close to the ecliptic plane.

Eddington

A new mission in ESA's mix, Eddington will study stellar oscillations and search for extrasolar planets. Launch is planned around 2008, and to save money the spacecraft will use the same basic structure and components as the agency's Herschel infrared satellite and the Planck microwave-background observatory. Equipped with a 1.2-meter telescope and a wide-field camera, Eddington will perform its survey work from the L_2 Lagrangian point on the side of Earth opposite the Sun. During its first two years, Eddington will study small brightness fluctuations due to oscillations in individual stars. Then it will spend three years staring at a single star field hunting for planets. In some respects Eddington has goals similar to those of NASA's Kepler project, which is scheduled to fly in 2006. Kepler provides a larger field of view but won't target individual stars. Between them, the two missions should dramatically improve our knowledge of the population of extrasolar planets in the galaxy.



SMART 2 will test the technology needed to develop two ambitious European Space Agency missions: LISA (Laser Interferometer Space Antenna) and Darwin.

Satellite Test of the Equivalence Principle

Designed as a joint ESA-NASA project, STEP will test Einstein's equivalence principle (which posits that gravitational mass and inertial mass are the same) almost a million times more accurately than has been previously possible. Four pairs of test masses will float inside an ultrahigh-vacuum superconducting Dewar to remove external and thermal disturbances. STEP is led by the same Stanford collaboration that developed Gravity Probe B, the relativity mission awaiting launch late this year. However, NASA managers have not yet decided to participate in STEP.

Small Missions for Advanced Research in Technology

SMART 2, the second mission in a new technology-demonstration series, will be launched in 2006 to test concepts for the gravity-wave mission called LISA (Laser Interferometer Space Antenna) and the Darwin planet finder. SMART 2 represents ESA's first spaceborne interferometer. It consists of two satellites designed to travel a few hundred meters apart, maintain their separation to a few microns, and measure that distance to an accuracy of about 10 nanometers. They will accomplish all this using tiny thrusters under the control of a radio-ranging system and a laser interferometer. Their inertial sensors incorporate a 10-centimeter cube containing a freely floating test mass, whose position within the cube is determined by measuring the electrical field it induces. Thrusters will counteract the Sun's radiation pressure and keep the satellite centered on the test mass. ESA plans to launch its SMART 2 satellites into either a distant Earth orbit or a solar orbit.

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BY JONATHAN McDOWELL

Spectroscopy and Photometry of the IGM's Diffuse Radiation

NASA has selected a Boston University project, known by the acronym SPIDR, as the next mission in its Small Explorer series. The satellite will map out the diffuse matter in the intergalactic medium (IGM) by recording ultraviolet spectral lines emitted by hot oxygen and carbon ions in the IGM. Theories based on observations of the high-redshift universe predict that large amounts of gas at 10,000° to 100,000° Kelvin should remain today as a system of intertwined filaments left over from the era of galaxy formation. But this "cosmic web" has not yet been observed. Other objectives include the study of a localized hot bubble around our solar system, which is the remnant of a past supernova in our vicinity, and the Milky Way's gas halo.

In March 2005 a Pegasus rocket and Star 24 booster will place SPIDR in a highly elliptical orbit with its apogee in Earth's equatorial plane. The satellite carries six long-slit spectrometers, three of which will operate in a high-resolution mode with a 2.5° field of view, and three in a high-sensitivity mode with an 8° field of view. SPIDR will stare at each target area for a week at a time, covering about a quarter of the sky during its three-year mission.

Comet Nucleus Tour

NASA has resumed its exploration of comets with the launch of Contour from Cape Canaveral on July 3rd. Liftoff was delayed for two days because the Discovery-class space probe had gotten dusty while in the launch area. After a quick cleanup, a Delta II rocket boosted the probe into an elliptical parking orbit with an apogee of 106,000 kilometers. The orbit was to precess around Earth until August 15th, when the spacecraft would be correctly positioned for its Star 30 solid-fuel rocket to put it on course for deep space. Contour will loop around the Sun for a year and swing past Earth again before reaching its first target, Comet 2P/Encke, in November 2003. The mission is operated by the Johns Hopkins University Applied Physics Laboratory, which also had responsibility for the NEAR-Shoemaker asteroid probe.

BeppoSAX

Its mission complete, Italy's BeppoSAX orbiting observatory was switched off April 30th, the sixth anniversary of its launch. The elderly satellite, whose name combines Beppo (in honor of physicist Giuseppe Occhialini) and SAX (for "Satellite per Astronomia a raggi X"), has lost 150 km of altitude from its initial, 600-km-high orbit and is expected to reenter the atmosphere next year. The craft had operated without any stabilizing gyroscopes since October 2001, and its batteries were failing, but it still returned high-quality data to the end, with nearly 1,500 observations to its credit.

BeppoSAX is a multinational project: wide-field cameras from the Netherlands and a low-energy imager from the European Space Agency complemented the X-ray telescopes and high-energy detectors supplied by Italian space scientists. The mission's specialty was its ability to observe over a very wide X-ray energy range, taking a simultaneous spectrum from 100 to 200,000 electron volts — equivalent to observing from the far ultraviolet to the far infrared. This proved to be a powerful tool for studying the energy output of quasars and active galactic nuclei. BeppoSAX's most important contribution, though, was the first identification of the afterglows from gamma-ray bursts.

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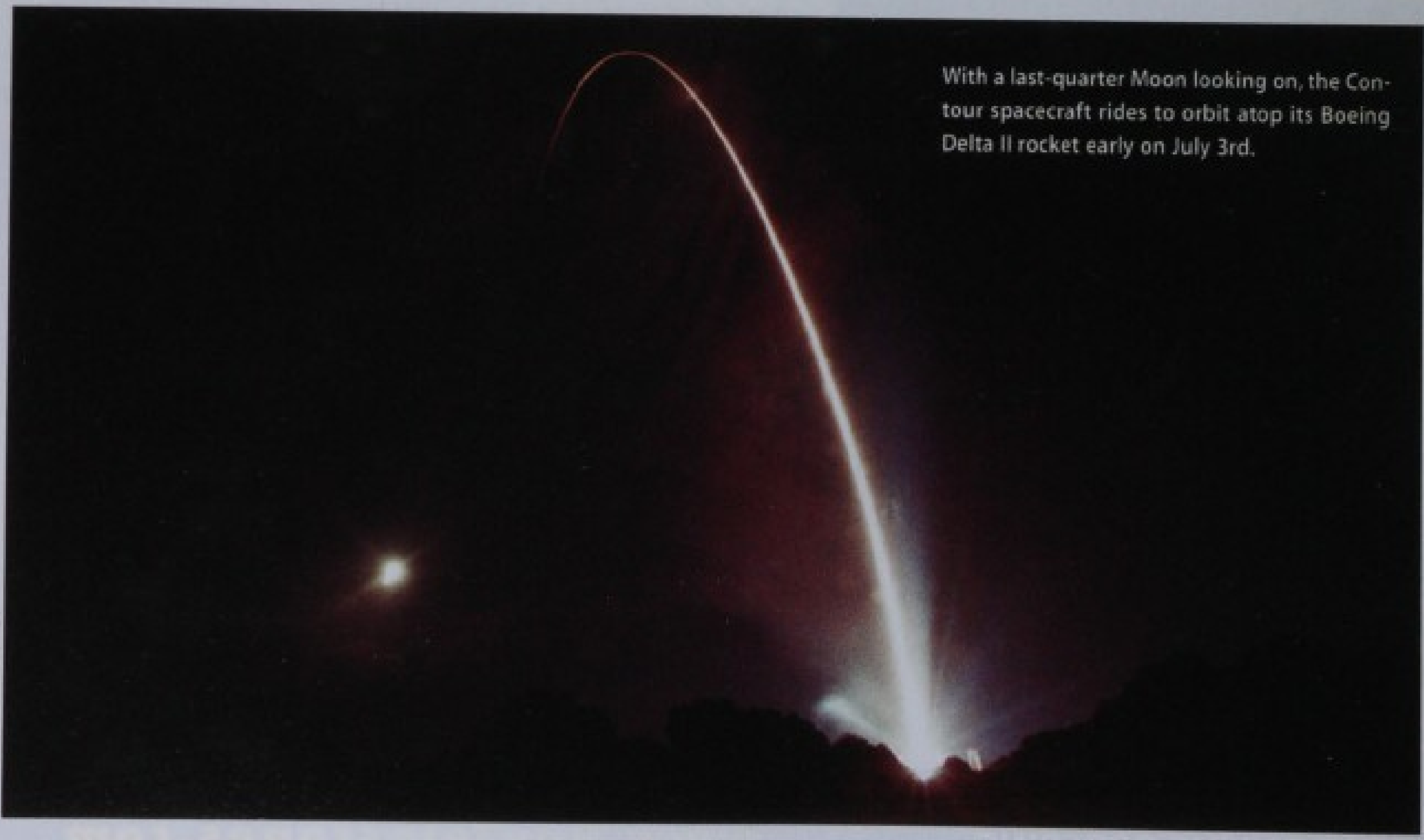
NASA/KENNEDY SPACE CENTER

With a last-quarter Moon looking on, the Contour spacecraft rides to orbit atop its Boeing Delta II rocket early on July 3rd.

MISSION UPDATE

BY JONATHAN McDOWELL

Two objects (trailed pairs of streaks within the circles) show most of what's left of the Contour spacecraft. The trails remained when the star fields in two images taken with the 1.8-meter Spacewatch telescope on August 16, 2002, were subtracted from one another. The white trails registered at 4:17 Universal Time, the black ones 21 minutes later. Copyright 2002 Spacewatch Project (LPL) University of Arizona.

Cassini

The narrow-angle camera aboard NASA's Saturn-bound Cassini orbiter has recovered from a foggy winter. In May 2001 the surface of the camera lens was contaminated during a regularly scheduled heating cycle, and during a subsequent calibration star images showed large, messy halos with only 30 percent of the light in the image core — an effect similar to that in early, uncorrected Hubble Space Telescope images, though for a different reason. A series of long heating cycles ending in early July 2002 successfully baked off the unwanted material. Now having returned to its –90°C operating temperature, the camera is again providing sharp images. The narrow-angle camera, a Ritchey-Chrétien (folded) reflector with a 2,000-millimeter focal length, will take high-resolution images of the Saturnian system when Cassini reaches the ringed planet in July 2004. For panoramic views the spacecraft also carries a 200-mm-focal-length camera, which is working normally. By August 2002, Cassini was 1.2 billion kilometers from Earth and 300 million km from Saturn. After a year of relative inactivity, the science team is now performing instrument calibrations in preparation for the approach to the planet.

Venus Express

The European Space Agency's Venus Express mission has been saved from cancellation. Although this mission was initially excluded from the agency's Cosmic Vision 2020 blueprint due to budget limitations (September issue, page 26), advocates managed to restore it to the schedule in July. Venus Express stands to be the first dedicated mission to Earth's cloud-enshrouded neighbor since Magellan ended its radar mapping in 1994. It will utilize the design of the already-funded Mars Express and seven backup instruments from both that spacecraft and Rosetta. Venus Express will be launched by a Russian Soyuz-Fregat rocket in November 2005 and, upon reaching the planet, will enter a 250-by-45,000-km polar orbit (similar to those used by Magellan and the earlier Pioneer Venus Orbiter). The main objectives are studying the composition of the lower atmosphere, mapping the surface and atmospheric temperatures globally, and studying the energetic particles and fields in the planet's vicinity.

The planned Venus Express mission will draw heavily from the design and instruments of the European Space Agency's Mars Express spacecraft, depicted here with the upper stage (spheres) of its Russian-built Fregat booster. Courtesy ESA.

Comet Nucleus Tour

The ambitious $159 million Contour comet probe was lost on August 15th during the firing of its solid-fuel rocket motor. The maneuver was meant to propel the spacecraft out of the Earth-Moon system and toward flybys of periodic comet 2P/Encke in November 2003 and Comet 73P/Schwassmann-Wachmann 3 in June 2006. Launched on July 3rd, the probe had already spent more than a month in a highly elliptical parking orbit around Earth. As Contour dropped to its 230-km perigee over the Indian Ocean, it speeded up to an impressive 10.7 km per second — 17 times faster than at apogee. At that moment, the rocket motor began a 50-second-long burn to increase the probe's speed by another 2 km per second, pushing it to escape velocity.

However, it appears that something went badly wrong near the end of the maneuver, as tracking stations in NASA's Deep Space Network were unable to pick up any signals from Contour thereafter. Over the next two days ground-based telescopes recorded two and possibly three objects following a trajectory close to Contour's planned track, instead of just one, leading observers to suspect that the rocket motor may have broken up or exploded. If the objects discovered in those telescopic images are indeed the remains of Contour, its Star 30 motor provided only about 3 percent less impulse than planned before failing. The mission team at the Johns Hopkins University's Applied Physics Laboratory will attempt to reestablish contact with Contour through December, when the spacecraft will be favorably aligned to receive transmissions from Earth.

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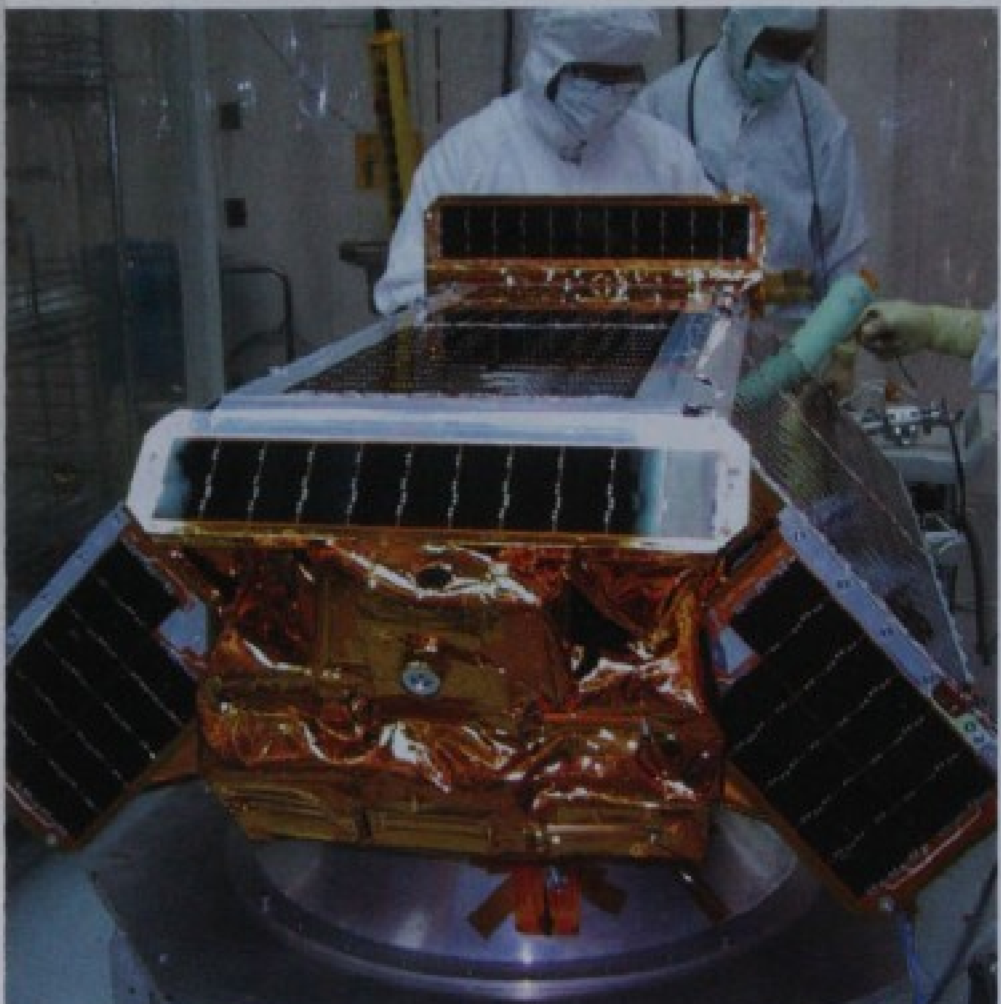
MISSION UPDATE
BY JONATHAN McDOWELL

A hangar crew in Waco, Texas, extracts the telescope assembly for SOFIA from the Airbus Beluga cargo plane that ferried it from Bonn, Germany, in early September. Courtesy Universities Space Research Association.

Cosmic Hot Interstellar Plasma Spectrometer

The CHIPS spacecraft is set for launch in mid-December from Vandenberg Air Force Base in California. It will fly as a secondary payload aboard the Delta 2 rocket carrying ICESat, a NASA spacecraft for studying Earth's climate. CHIPS is a small, 60-kilogram "University Explorer," a class of U.S. space-science missions costing less than $13 million, and it carries a single instrument: an extreme-ultraviolet spectrograph developed by the University of California, Berkeley (*S&T:* April 2000, page 26). The spectrograph's six slits project their diffracted light onto a microchannel plate detector — the same technology used in the Chandra X-ray Observatory's main camera.

After reaching its 600-kilometer-high polar orbit, CHIPS will record spectral lines in the 90- to 260-angstrom range, where million-degree gas in the local hot bubble around the solar neighborhood emits most of its radiation. More-distant gas at this temperature can't be studied because the galaxy is opaque in the extreme ultraviolet, so it's not clear which atomic transitions are responsible for cooling interstellar gas in various astrophysical settings. Therefore, the CHIPS data will allow astronomers to refine the models used for simulating conditions in both local and extragalactic hot gas.



The CHIPS spacecraft sits atop the adapter for the Delta rocket that will launch it into orbit. Six aperture slits for the craft's spectrometer are visible below the small silvery disk in the middle of the gold-colored foil. The black rectangles are solar cells, and the light-blue tube in back, near a hand, is the craft's magnetometer. Courtesy Michael Sholl (Space Sciences Lab, University of California, Berkeley).

Stratospheric Observatory for Infrared Astronomy

Progress on SOFIA, the world's largest airborne observatory, reached another milestone in early September when the all-important telescope assembly arrived in the U.S. from Bonn, Germany. It has taken the German Aerospace Center and its subcontractors 5½ years to build and test the telescope, which has a 2.5-meter (98-inch) primary mirror. Over the next nine months, engineers from L-3 Communications Integrated Systems will install the telescope in its permanent home: a Boeing 747SP aircraft. When SOFIA becomes operational, it will fly at altitudes near 12½ km (41,000 feet), where the telescope will observe a host of infrared sources through a 5½-by-4-meter opening in the plane's fuselage. First light is scheduled to occur in October 2004, with general observations commencing the following January.

International Gamma-Ray Astrophysics Laboratory

When launched late this year, the Integral observatory will begin one of Europe's most ambitious astronomy missions. The spacecraft carries a battery of four X- and gamma-ray telescopes, as well as a small optical monitor with a 5-centimeter aperture. Gamma-ray photons are too energetic to focus by conventional optics, so instead astronomers use coded-mask telescopes. These employ a pattern of holes to cast gamma-ray shadows, which computer software then transforms into images.

The spacecraft's largest coded-mask telescope is IBIS, which has a 1.1-meter aperture and two imagers covering 20,000 to 10 million electron volts in photon energy. This range is comparable to those monitored by the low-energy spectrometers on NASA's now-defunct Compton Gamma Ray Observatory but with much improved spatial resolution (12 arcminutes). France's Sigma telescope, which flew on the Soviet Union's Granat satellite in 1989, had a similar imaging capability but was a factor of 10 less sensitive. Integral also carries SPI, a high-resolution spectrometer with a 0.7-meter aperture, and JEM-X, a pair of 0.53-meter imaging telescopes to detect X-rays with energies of 3,000 to 35,000 electron volts. To save money, the European Space Agency built Integral around the same spacecraft bus used for its XMM-Newton satellite. A Russian Proton launcher was scheduled to boost Integral into space in mid-October and place it in a highly elliptical orbit much like those of Chandra and XMM.

Jonathan McDowell, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly online newsletter about the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

BY JONATHAN McDOWELL


FASTLIGHT AND INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE

A portrayal by artist James Garry shows the MUSES C spacecraft just prior to its touchdown on minor planet 25143.

Nozomi

Japan's first-ever Mars probe headed into space 4½ years ago but has yet to reach its destination. A rocket malfunction caused Nozomi's initial injection into solar orbit to fall short. Now the craft is getting a second chance. It makes a flyby of Earth on December 21st, using our planet's gravity to swing into a transfer orbit that will set up a second pass of Earth next June. This second flyby will finally put Nozomi on course for Mars, with a planned arrival in January 2004.

It's been a difficult mission in other ways as well. Last April solar activity damaged the onboard communications system. A heater unit failed as well, which led to a hydrazine-fuel freeze as the spacecraft neared its aphelion of 1.4 astronomical units, just inside Mars's orbit. By September Nozomi had closed to 1.25 a.u. from the Sun, and enough of the fuel had melted to allow critical course-correction burns. The spacecraft should be able to operate until late 2003, when its outbound travel will once again cause the fuel's temperature to drop. If the heater problem cannot be fixed by then, the probe may not be able to fire its braking rocket and slip into orbit around the planet.

Mu Space Engineering Satellite C

Another Japanese interplanetary probe has run into continuing delays. MUSES C, third in the Mu Space Engineering Satellite series, originally had a launch date in early 2002, but that slipped to December and recently to May 2003. First an Earth-orbiting test capsule failed to separate from its launch vehicle, then engineers at Japan's Institute of Space and Astronautical Science became concerned about the attitude-control system, which has since been cleared for flight. MUSES C will be the first mission to return rock samples from an asteroid. Its target is the unnamed minor planet 25143, also known as 1998 SF_{36}. This 400-meter-wide body ranges from just inside the orbit of Earth to just beyond that of Mars, from 0.95 to 1.69 a.u., with an orbital inclination of 1.7°. MUSES C will lift off from Kagoshima Space Center in Japan and use ion propulsion to rendezvous with the asteroid near its perihelion in 2004. Plans call for the vehicle to land, scoop up a sample, and take off to begin the return voyage. In 2007 MUSES C's reentry capsule will scream through Earth's atmosphere at 12 kilometers per second and land in Utah.

Beagle 2

The small Mars lander Beagle 2 is being built by a team at the Open University, Britain's pioneer in distance learning. In traditional British fashion, the project has state-of-the-art objectives and a shoestring budget. Now the development team is faced with airbag problems. Beagle 2's planned landing speed exceeds 100 km per hour, much faster than Mars Pathfinder's cushioned arrival in 1997, and in early tests the airbags burst open. (Similar problems have arisen with the landing system for NASA's forthcoming Mars Exploration Rovers.) Although the design has now been improved, the Beagle 2 effort is running short of money and time. In fact, there's concern that the craft might miss its ride aboard the European Space Agency's Mars Express mission, whose launch on a Soyuz-Fregat rocket from Kazakhstan is set for May. However, if the schedule is met, Beagle 2 will bounce to a stop on the surface of Isidis Planitia in December 2003. Its instrument package includes a mass spectrometer, a gas analyzer, and both stereo and microscope cameras.

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Although it weighs just 30 kilograms, the clamshell-like Beagle 2 is well equipped to study the rocks and dust it will find on Mars. Its planned landing site is Isidis Planitia, an ancient impact basin.

MISSION UPDATE

BY JONATHAN McDOWELL

Minor planet 5535 Annefrank, as recorded by the Stardust spacecraft on November 2, 2002. About 8 kilometers long, the asteroid is darker than expected and roughly twice the size predicted by ground-based observations. The straight edge at right is a processing artifact. Courtesy NASA/JPL.

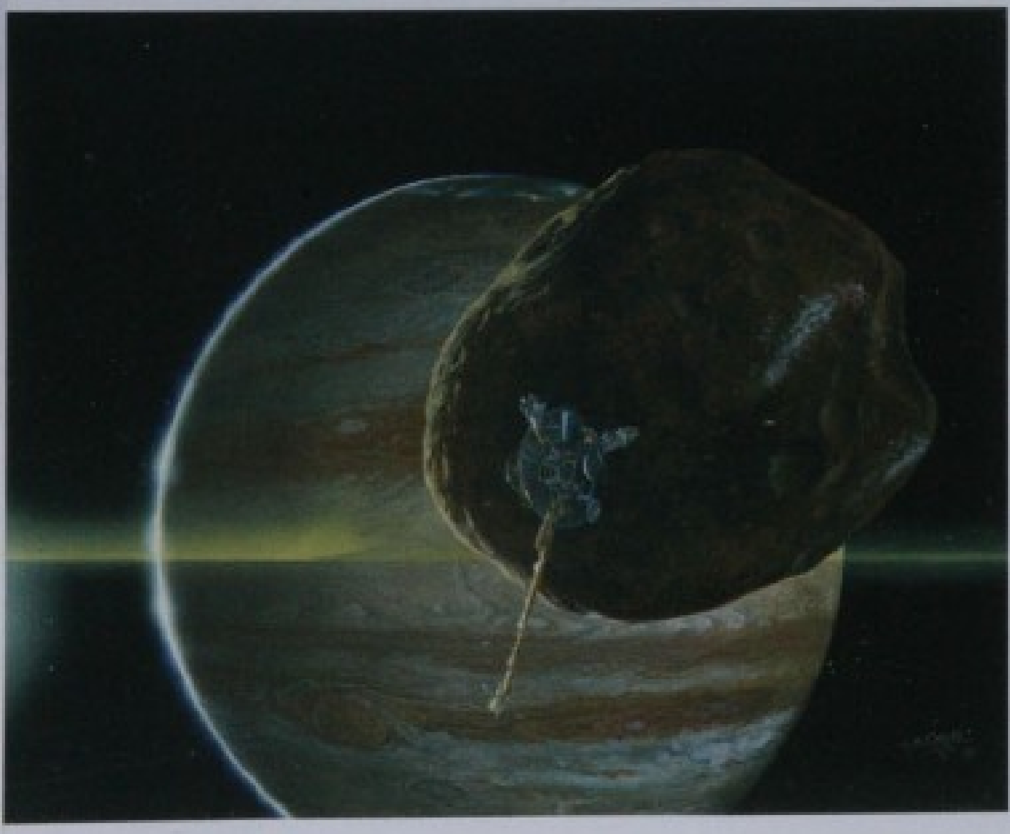
International Gamma-Ray Astrophysics Laboratory

On October 17, 2002, the European Space Agency's gamma-ray observatory, Integral, headed into orbit atop Russia's mighty Proton launch vehicle. The explosion of another Russian rocket two days earlier had heightened the tension on launch day, but Integral's liftoff went perfectly, and the satellite achieved its planned, highly elliptical orbit with an apogee of 153,000 kilometers. Over the next two weeks the onboard propulsion system raised the perigee from 700 km to 9,000 km, ensuring a long orbital life for the spacecraft. By early November Integral's JEM-X and SPI telescopes (*S&T:* December 2002, page 30) had detected their first astronomical sources.

Galileo

The veteran Galileo orbiter made its last flyby of a Jovian moon on November 5th with the first-ever close pass of Amalthea. Even though the craft passed just 160 km from the irregularly shaped body, to save money its camera was not used. Instead, mission scientists will use the slight trajectory shift imparted by Amalthea's gravity to determine the moon's mass. Galileo then dipped to a point just 71,400 km above the giant planet's cloudtops, during which onboard instruments studied particles and fields in the planet's inner magnetosphere and ring. However, shortly before closest approach (7:23 Universal Time), the intense radiation field sent Galileo into a "safe" (standby) mode, so part of the flyby data was not collected. The craft's final orbit has a periapsis below the cloudtops; Galileo will arc up to 26 million km from the planet in April, then fall into Jupiter in September. This deliberate destruction will prevent any chance of Galileo contaminating Europa, considered a possible abode of life.

The final science task in Galileo's seven-year-long Jupiter odyssey was an imageless flyby of the inner moon Amalthea last November 5th. Courtesy Michael Carroll and NASA/JPL.



Stardust

To ready Stardust for its January 2004 encounter with Comet 81P/Wild 2, mission managers at the Jet Propulsion Laboratory used a distant (3,300-km) flyby of minor planet 5535 Annefrank on November 2nd to test the spacecraft's systems and instruments. Prior to the pass the mission team had downplayed the potential for obtaining useful science, but the resulting images clearly show the asteroid's irregular shape. Annefrank turned out to be bigger (8 km long) and darker (10 percent reflective) than expected. Stardust's camera successfully locked on to the asteroid using autoguiding software derived from that used by the Deep Space 1 mission. The craft's dust detector and mass spectrometer also got a checkout.

Rosetta

Europe's next scientific mission is the Rosetta comet probe. In September its builder, Astrium (formerly Dornier), delivered the spacecraft to the launch site in Kourou, French Guiana, and in the weeks thereafter an extensive simulation allowed engineers at the European Space Operations Center in Darmstadt, Germany, to communicate directly with the spacecraft. After launch in January on an Ariane 5 rocket, ESOC will use the 34-meter dish at Perth in Western Australia to contact Rosetta once it leaves Earth's vicinity. In August 2005 Rosetta will pass just 200 km from Mars, making its first gravity-assist flyby. Close passes by Earth the following November and in November 2007 will redirect Rosetta out into the asteroid belt. Finally reaching Comet 46P/Wirtanen in late November 2011, Rosetta will drop an instrumented package onto the nucleus. Meanwhile, the main craft will be snapping images and studying cometary dust and gas over a two-year period. Rosetta is Europe's first comet probe since the pioneering Giotto mission returned spectacular data on Comet 1P/Halley in 1986. Together with the forthcoming launch of Mars Express, it marks the start of a significantly more ambitious solar-system exploration program for the European Space Agency.

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BY JONATHAN McDOWELL

A key component of NASA's Earth Observing Program, the Solar Radiation and Climate Experiment (SORCE) will help scientists understand how the Sun's energy output affects long-term climatic changes on Earth. Courtesy Orbital Sciences.

Solar Radiation and Climate Experiment

SORCE is a small solar observatory designed to study minuscule variations in the Sun's energy output. Scheduled for launch in early 2003 on an aircraft-borne Pegasus rocket, the 290-kilogram satellite carries four instruments and will be operated by the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. The Spectral Irradiance Monitor measures the Sun's energy output at visual and near- to mid-infrared wavelengths, while the Total Irradiance Monitor evaluates the ultraviolet-to-infrared range to an accuracy of 0.01 percent. These two instruments are descendants of payloads flown on a series of past spacecraft. The Solar-Stellar Intercomparison Experiment (Solstice), originally planned to fly on a separate satellite, has two spectrometers to study variations in the Sun's ultraviolet spectrum from 115 to 320 nanometers. An earlier version flew on the Upper Atmosphere Research Satellite, launched in 1991. Finally, the XPS extreme-ultraviolet photometer covers the high-energy end of the solar spectrum, looking for variations at wavelengths between 1 and 34 nanometers (10 and 340 angstroms).

New Horizons

The fortunes of the proposed New Horizons mission to the outer solar system have improved, thanks to strong support from Congress and the scientific community and NASA's proposal to inaugurate the New Frontiers series of outer-planet missions. Fortified by $115 million in funds for fiscal 2003, New Horizons is now on track for launch around January 2006 aboard either a Delta 4 or an Atlas 5, large next-generation vehicles that have now completed one launch each. The probe is to fly past Jupiter in early 2007, using the planet's gravity to boost it to the icy worlds in the outermost solar system. New Horizons should reach its primary targets in 2015, passing 10,000 kilometers from Pluto and 27,000 km from its moon, Charon. Several months of observations are planned before and after these flybys, but the most crucial data will be acquired during a day-long close encounter. The probe will carry cameras, infrared and ultraviolet spectrometers, and instruments to study charged particles and plasma. After leaving Pluto and Charon, New Horizons will coast outward through the Kuiper Belt, making close flybys of one or two objects during the ensuing decade.

Spectrum-X-Gamma

Russia's long-suffering Spectrum-X-Gamma mission may not be completely dead yet. Although construction of the current design is mostly complete, it requires a large Proton launch vehicle to reach orbit, and these are in demand for profit-making launches of commercial communications satellites. So the Russians are investigating the possibility of flying some of the instruments on a smaller satellite that could be lofted into orbit by a cheaper rocket like the Soyuz-Fregat. However, the savings gained by using a smaller launcher may not fully offset the cost of developing a new spacecraft. Moreover, prospects for getting more international funding for this decade-late mission continue to dim, as new missions like Integral (*S&T:* December 2002, page 30) chip away at the science that Spectrum-X-Gamma would have carried out. While the Russians ponder their options, the ready-to-fly JET-X telescope for SXG's original payload remains in storage in a plastic bag in Leicester, England; other international contributions are also being maintained by their respective instrument teams.

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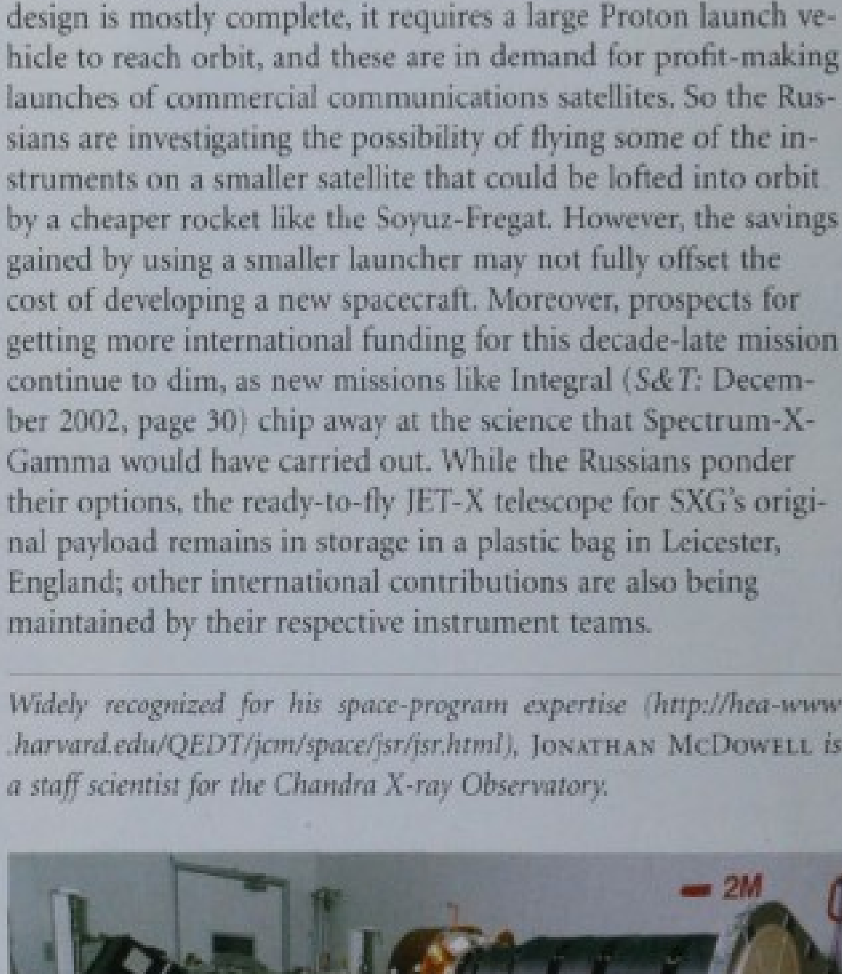

With a length of 4.5 meters and a mass of 550 kilograms, the Joint European Telescope for X-ray astronomy (JET-X) remains in storage as Russian space planners decide how to proceed with the Spectrum-X-Gamma spacecraft. Courtesy Alan Wells (University of Leicester).

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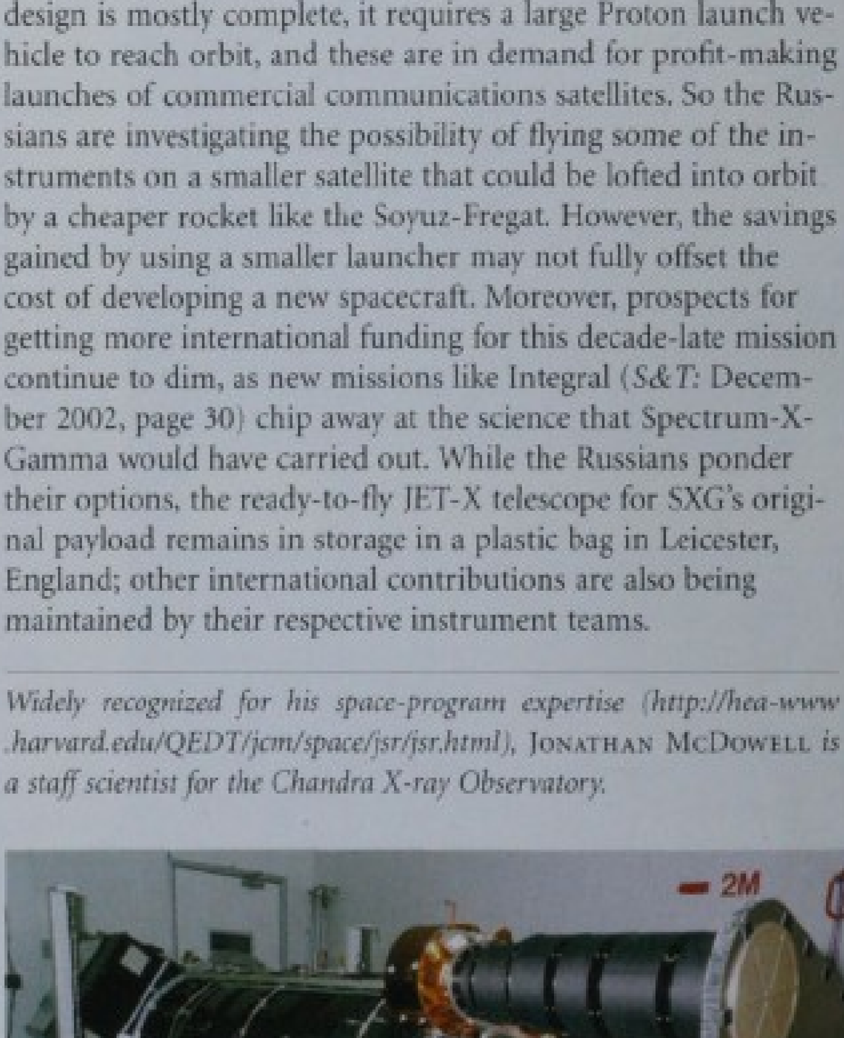

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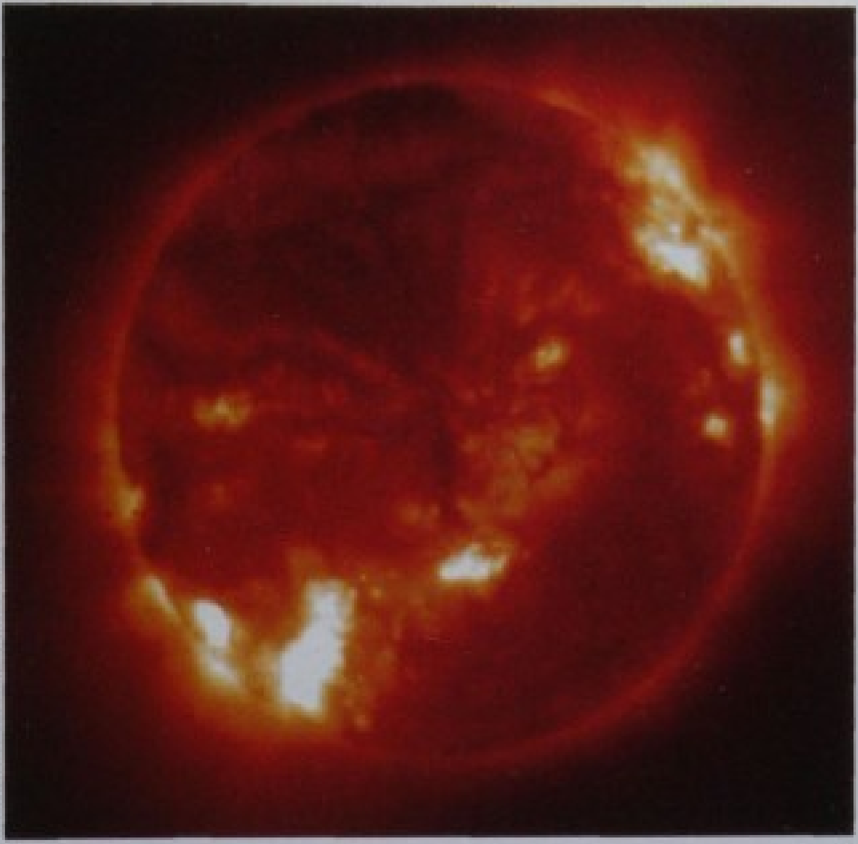

NOAA SPACE ENVIRONMENT CENTER

An imager aboard the GOES 12 weather satellite recorded its first X-ray view of the Sun on September 7, 2002.

Geostationary Operational Environmental Satellite 12

The National Oceanic and Atmospheric Administration has announced that its GOES 12 satellite will enter service in April. The spacecraft was launched on July 23, 2001, and placed in a geostationary storage orbit. A maneuver in late January repositioned the craft to its operational location over the Atlantic Ocean at 75° west longitude. Meanwhile, the satellite's soft X-ray imager, which began regular observations of the Sun on January 22nd, is generating daily movies of solar activity. The imager has a broad X-ray response, from 0.6 to 6.0 nanometers (6 to 60 angstroms), and it records the full solar disk once per minute. This marks the first operational solar imaging by the weather agency and culminates decades of planning with the U.S. Air Force, which funded the instrument's construction.

National Aeronautics and Space Administration

The Bush administration's proposed NASA budget for fiscal 2004 was released on February 2nd, during the first week after the *Columbia* tragedy that is likely to reshape it considerably. Sean O'Keefe, the space agency's administrator, has changed NASA's declared strategy to emphasize "flexible building blocks" that will support a range of missions rather than picking a particular target like Mars. Of the three new mantras now coming from headquarters, the NASA vision and mission statements have generalized goals — for example, "to explore the universe and search for life."

However, it is the New Exploration Strategy that offers the first real clue for the agency's future. The Integrated Space Transportation Plan envisages operations of the shuttle until at least 2015 and possibly beyond 2020. Shuttle flights to and from the International Space Station are to be augmented with a small Orbital Space Plane launched on a Delta 4-class expendable rocket starting around 2010. This schedule may well be accelerated as a result of the loss of *Columbia*. O'Keefe also hopes to transform NASA's human-exploration "enterprise" into an operation that supports the mission-driven activities of space and Earth science, biological and biophysical research, and aeronautics.

The fiscal 2004 budget request is $15.5 billion, up slightly from last year's request, of which $4 billion is allocated for space science and planetary exploration. Under a new initiative called Beyond Einstein, the LISA gravitational-wave observatory and Constellation-X high-energy spectroscopy mission get real funding for the first time. The New Horizons mission to Pluto and the Kuiper Belt finally has NASA's backing and seems secure at last. Funding for an advanced 2009 Mars rover mission has been added as well.

A major and controversial new initiative is Project Prometheus, which foresees the use of fission-based propulsion and power systems to send missions to the planets. A reconnaissance orbiter for Jupiter's icy moons may demonstrate its first use. Another proposed innovation would use laser-based communication systems to increase the data rate from scientific spacecraft and may eventually supplant the aging Deep Space Network.

Solar Radiation and Climate Experiment

NASA's newest Sun-monitoring satellite was successfully launched on January 25th. Its carrier aircraft left Cape Canaveral, Florida, then headed out over the Atlantic Ocean to drop the Pegasus rocket that sent the spacecraft on its 10-minute trip into orbit. Initial checkout of all the instruments was complete by February 7th. Designed to operate for at least five years, SORCE will measure the total energy output from the Sun to an accuracy of one part in 10,000 and detect changes down to 0.001 percent per year. The Sun's output is known to vary by as much as 0.1 percent, so careful monitoring of the energy reaching Earth's atmosphere will provide a crucial parameter for climate studies. SORCE will also record the Sun's production at ultraviolet wavelengths and compare it with absolute calibrations made each day using a set of standard stars. The output of visible-wavelength sunlight will be measured daily as well. Another instrument will measure the solar X-ray flux, which can vary by a factor of 2 despite being a small contribution to the Sun's total energy. The satellite will be operated by the University of Colorado at Boulder, while its data will be routed to NASA's Goddard Space Flight Center in Greenbelt, Maryland.

NASA/KENNEDY SPACE CENTER

An L-1011 cruises off the Florida coast prior to launching a Pegasus rocket (nestled under the fuselage) and its payload: the SORCE solar-monitoring satellite.

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BY JONATHAN McDOWELL

Galaxy Evolution Explorer

The Galex spacecraft is shown during its construction *(left)* and as it will appear once in orbit around Earth *(right)*.

ORBITAL SCIENCES CORP.; KARL FORSTER / CALTECH

The next Pegasus rocket will carry the Small Explorer mission Galex, which is to make the first sensitive all-sky survey of the ultraviolet universe. The satellite's launch had been scheduled for late March, but a wiring problem delayed that until at least April 26th. Galex will operate in a low-altitude equatorial orbit and observe only when on the night side of Earth. Besides its all-sky assignment, the spacecraft will carry out even more sensitive surveys of smaller regions. These will assess star formation and element production in galaxies by tracing the ultraviolet light coming from short-lived, massive, luminous stars. The mission's principal investigator is Christopher Martin (Caltech), who has flown ultraviolet payloads on numerous sounding rockets. His group will lead science operations, while satellite manufacturer Orbital Sciences will operate the spacecraft. Galex's sky map and source catalogs should be ready by 2004 or 2005, in time for the Hubble Space Telescope to follow up interesting objects in detail. Hubble has a narrow field of view suitable for zeroing in on specific targets, but the only wide-area ultraviolet survey to date was carried out by the European Space Research Organization's TD-1A satellite in 1972–73. Moreover, it cataloged only the brightest ultraviolet stars and could not record faint extragalactic sources.

Pioneer 10

NASA scientists have received their final transmission from Pioneer 10. When last heard from, on January 22nd, the venerable spacecraft was 12.2 billion kilometers from Earth and its signal was very weak. Project officials fear that the plutonium power sources onboard have decayed too much to provide adequate electricity. Attempts to contact the craft again on February 7th were unsuccessful, and the space agency has no plans for additional tries.

Launched on March 2, 1972, Pioneer 10 was the first spacecraft to reach Jupiter. During a dramatic flyby on December 3, 1973, the craft relayed images of the giant planet and data on the charged particles trapped in its magnetosphere. Since then Pioneer 10 has been heading out of the solar system, and it crossed the orbit of Pluto in 1983. Although designed to last only 21 months, the spacecraft continued to collect scientific data for more than 30 years. Its twin, Pioneer 11, was last heard from in 1995. Earlier inner-solar-system probes in the Pioneer series were equally robust: although it is no longer tracked, Pioneer 6 appeared healthy when contacted on its 35th anniversary in December 2000, and Pioneers 7 and 8 were still functioning on their last contacts in 1995 and 1996 (Pioneer 9 has been silent since 1983).

Meanwhile, the two Voyager probes continue their push into the outer solar system in search of the heliopause, the boundary at which the solar wind meets the interstellar medium.

Right: **Artist Don Davis's rendition of Pioneer 10 looking back at the Sun from Neptune's orbit. The hardy spacecraft was the first to travel beyond Pluto. Courtesy NASA/Ames Research Center.**

Mu Space Experiment System C

Three years after the Japanese space-science community was shaken by the loss of the Astro E X-ray observatory during liftoff (*S&T:* May 2000, page 26), a Mu V rocket is back on the pad to launch MUSES C, Japan's most ambitious interplanetary probe, in May. The probes in the Mu series are principally intended for technology development but have included increasingly complex science payloads. In 1990 MUSES A (later named Hiten) pioneered the use of aerobraking and of weak stability regions to explore the Earth's outer magnetosphere, while MUSES B (also called HALCA) made radio-astronomy observations. MUSES C is to return samples of the unnamed asteroid 25143 to Earth. The probe will use ion propulsion to rendezvous with the asteroid and to go into orbit. During a five-month stay it will eject a small marker onto the surface; this target will provide scale for a navigation camera as the spacecraft hovers close by before touching down. A small projectile fired into the surface should kick up material into a collector, after which MUSES C will take off for the trip home — but not before leaving behind a tiny instrumented lander called Minerva. In 2007 a capsule containing the asteroid sample will reenter Earth's atmosphere and be recovered in Australia.

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MISSION UPDATE

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Space Infrared Telescope Facility

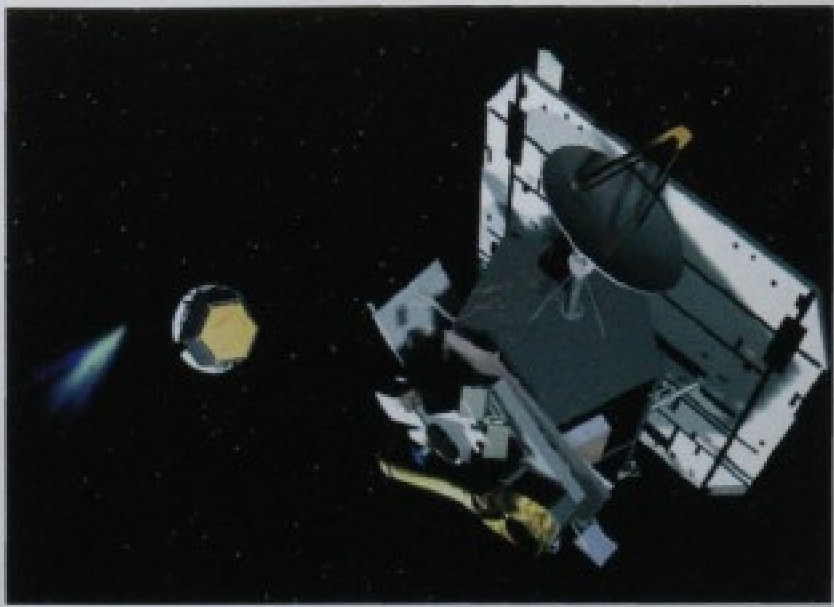
The long-awaited debut of the last of NASA's Great Observatories was called off a week before launch in April and will now be delayed until at least mid-August. The problem is not with the spacecraft itself but with the new Delta II Heavy rocket that will propel it into space. One of the Delta's nine strap-on solid-fuel rockets needs to be replaced because the composite material used in its exhaust nozzle has deteriorated. There is not enough time to remove and replace the rocket motor before the Mars Exploration Rover B, which uses the same launch pad, must depart during June (when Mars is well placed for receiving visitors). SIRTF, on the other hand, can be launched into its Earth-trailing orbit around the Sun at any time of year, though its observing program will have to be replanned. For details about the mission and its scientific objectives, see page 42 of the February issue.

Rosetta

The European Space Agency's Rosetta comet probe is still stuck on Earth following the failure of an Ariane 5 rocket last year (April issue, page 30). And while the launcher returned to flight status in April, Rosetta's fate is to remain grounded until February 2004, when the Ariane 5G+ rocket originally planned for the mission will propel the 1,700-kilogram craft to a new target, Comet 67P/Churyumov-Gerasimenko. This comet has a 6.5-year orbit and will be 1.3 astronomical units from the Sun when Rosetta finally arrives in March 2009. Its properties are not as well known as those of Comet 46P/Wirtanen, the original target, but it's thought to be much larger (5 kilometers versus 1.6 km); an intensive observing program is under way to find out if Rosetta's lander can touch down safely. Earlier this year mission managers had considered a trio of options for the spacecraft, including going to Wirtanen using a Proton rocket (since the standard Ariane 5 is not powerful enough to achieve the trajectory now needed). But the deciding factor was that the tanks storing nitrogen tetroxide propellant could not be safely drained from the spacecraft, thus forcing it to remain paired with its Ariane booster.

INSTITUTE OF SPACE AND ASTRONAUTICAL SCIENCE

Launched in 1998 by a faulty rocket, Japan's Nozomi spacecraft should reach Mars in December 2004 — about four years late.



If managers for NASA's Deep Impact mission surmount their fiscal and technical problems, the spacecraft will blast a crater in the nucleus of Comet 9P/Tempel 1 in mid-2005. Courtesy NASA/JPL.

Deep Impact

Meanwhile, NASA's next comet mission has narrowly escaped the ax. Deep Impact is behind schedule and over budget, with a propulsion system plagued by contamination. So its launch has been delayed from January to December 2004, giving the team time to make sure the probe is ready. Originally the spacecraft was to orbit the Sun for a year and swing past Earth to speed it toward Comet 9P/Tempel 1. The new strategy sends the probe directly to the comet, trading an earlier launch date that afforded lots of test time in space for extra test time on the ground. This plan preserves the original arrival date of July 4, 2005, when the comet is its closest to the Sun and crossing the ecliptic plane just outside Earth's orbit. The spacecraft will smash a 370-kg copper "bullet" into Tempel 1's nucleus at 10.2 km per second and then analyze the resulting crater and spray of debris. The collision will release the equivalent of almost 5 tons of TNT and, depending on the comet's surface composition, could make a crater anywhere from a few meters to a few hundred meters across.

Nozomi

Japan's Nozomi probe continues its struggle to reach Mars. Early on December 21st the probe passed 30,000 km from Earth, just within geostationary-orbit distance, which flung the spacecraft out of the ecliptic into an orbit with an inclination of 6°. Exactly six months later, when Nozomi crossed the ecliptic again, Earth was positioned right there. This second flyby, closer at only 15,000 km, placed Nozomi into an elliptical orbit whose aphelion will intersect Mars in December. However, just being on the right track is not enough for the Japanese spacecraft — its ability to tell mission managers on Earth what it's doing has been lost. During the two recent flybys of Earth, engineers at Japan's Institute of Space and Astronautical Science tricked Nozomi into switching its radio beacon on and off to confirm that commands had been received correctly. However, a solution to the lost telemetry must be found if Nozomi is to return any science data once it reaches Mars.

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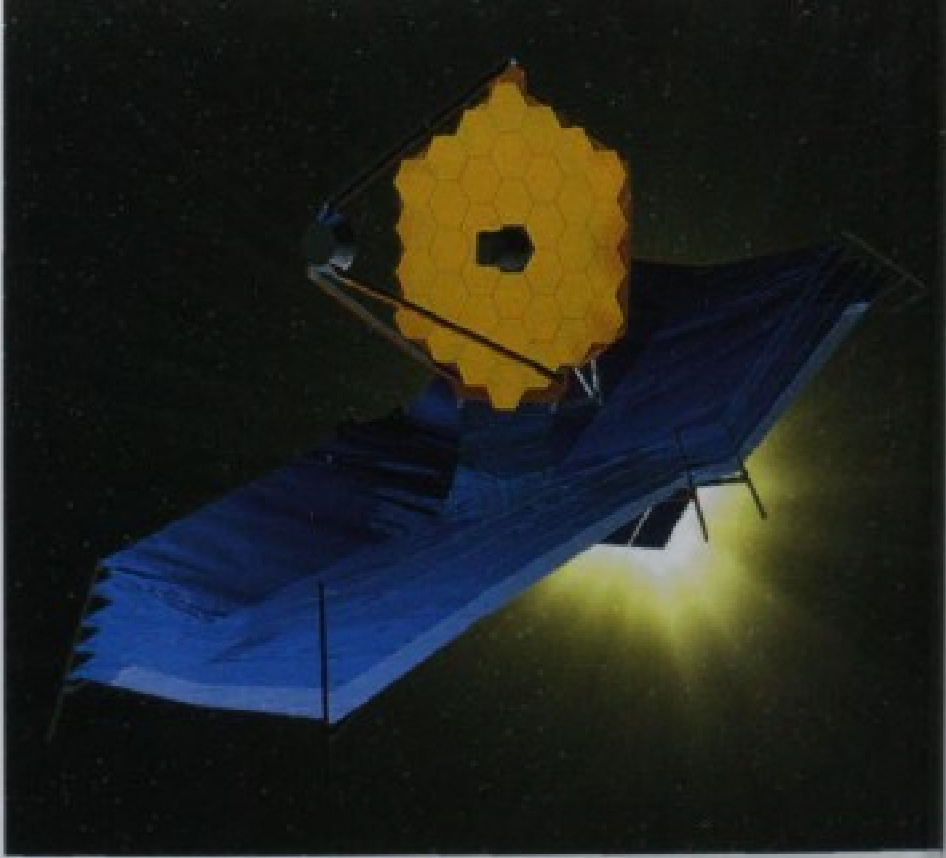


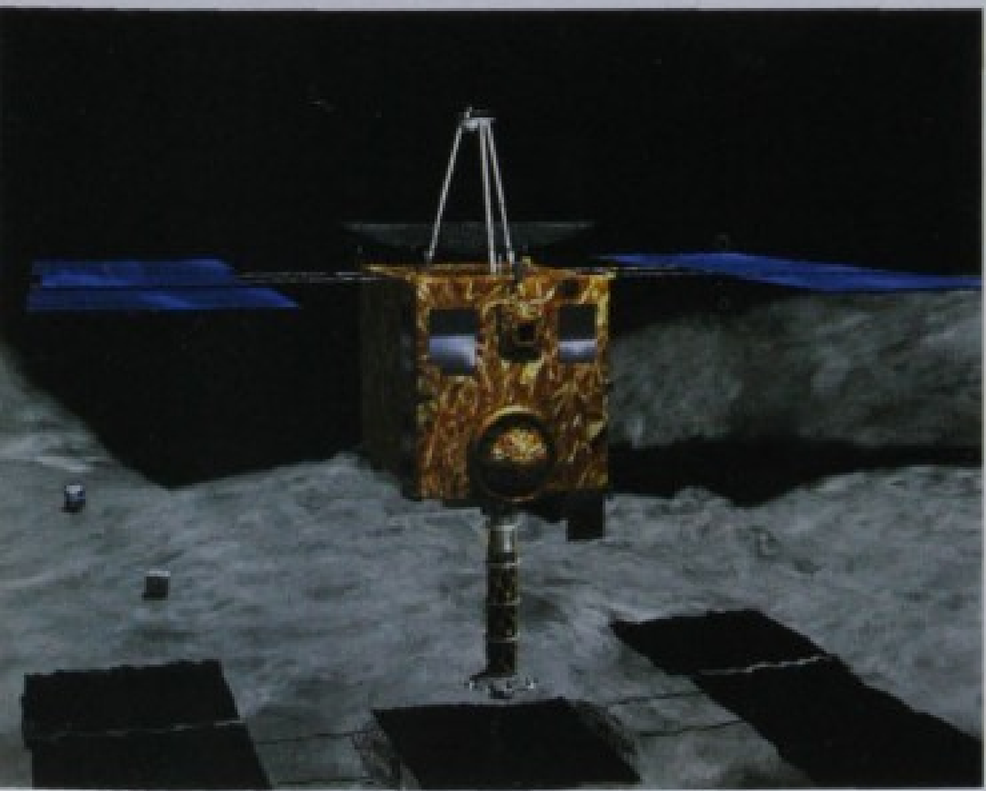
Last September TRW (now part of Northrup Grumman) won the contract to build NASA's James Webb Space Telescope. But technical challenges have threatened cost overruns in the $1.6 billion project. Copyright 2000 Northrup Grumman.

Hubble Space Telescope

A gyroscope on the Hubble Space Telescope failed on April 28th, stopping astronomical observations and sending the spacecraft into standby mode for a day. Of six gyros aboard the satellite, two are now out of action — and since three are needed for full science operations, only one spare now remains. Flight engineers are trying to develop software that might let Hubble perform some observations if only two of the units are left functioning. The gyroscopes are the most failure-prone components on the 13-year-old observatory and are less reliable than modern designs. All six were replaced in late 1999 during Space Shuttle mission STS 103. The next servicing mission will replace any failed gyros and install new science instruments, but with the grounding of the shuttle fleet this work will likely slip to at least 2005. Early discussions are under way to develop new instruments that would allow the observatory to remain productive until the James Webb Space Telescope (JWST) is launched in 2010 or thereafter; one concept is a very wide-area imaging array to take the place of one of HST's three Fine Guidance Sensors. Meanwhile, JWST project managers have taken steps to head off a potential $300 million overrun of NASA's $1.6 billion budget for the mission. The telescope's primary mirror will be reduced in diameter from 6.5 meters to 6, and the European Space Agency will launch the spacecraft on an Ariane 5 rocket at its own expense, not NASA's.

Hayabusa (MUSES C)

Japan's first-ever asteroid probe was launched on May 9th from the Kagoshima Space Center at the southern tip of Kyushu Island. The Mu V rocket, in its first trial since the disastrous loss of the Astro E X-ray observatory in 2000, placed the spacecraft into orbit around Earth; a smaller motor then boosted it to escape velocity and into orbit around the Sun. Soon after the launch, officials of Japan's Institute of Space and Astronautical Science renamed the spacecraft Hayabusa ("Falcon"). Over a 22-month period its xenon-fueled ion engine will match the orbit of the unnamed Earth-crossing minor planet 25143, whose heliocentric distance ranges from 0.95 to 1.69 astronomical units. After arrival in March 2005, Hayabusa will swing into action for five months of scientific studies. The 364-kilogram spacecraft carries a multiband imaging camera, an infrared spectrometer, an X-ray fluorescence spectrometer, and a laser altimeter. Moreover, Hayabusa will return a small sample of the asteroid to Earth in mid-2007.



Formerly known as MUSES C, the recently launched Hayabusa spacecraft will land on an asteroid in 2005 and return a sample of it to Earth two years later. Courtesy James Garry and ISAS.

Galaxy Evolution Explorer

On April 28th a Pegasus rocket, borne by a jumbo jet out over the Atlantic Ocean east of Cape Canaveral, Florida, boosted the newest Small Explorer satellite into space. GALEX reached a 700-kilometer-high orbit minutes later and deployed its two solar panels, then began a month-long checkout in anticipation of its ultraviolet all-sky survey. The observatory's half-meter-wide telescope and detectors are sensitive in the near ultraviolet from 135 to 300 nanometers (1350 to 3000 angstroms), similar to the range studied by the durable International Ultraviolet Explorer (1978–96) and by the ultraviolet spectrographs on the Hubble Space Telescope. Shorter wavelengths were surveyed by the Extreme Ultraviolet Explorer in 1992 and were followed up more recently by the Far Ultraviolet Spectroscopic Explorer. However, there hasn't been an all-sky survey in the GALEX wavelength range since 1972, when the European Space Research Organization's TD 1A satellite generated a catalog of about 30,000 sources. The GALEX survey will be at least 3,000 times more sensitive and will employ long exposures of smaller areas to detect even fainter sources.

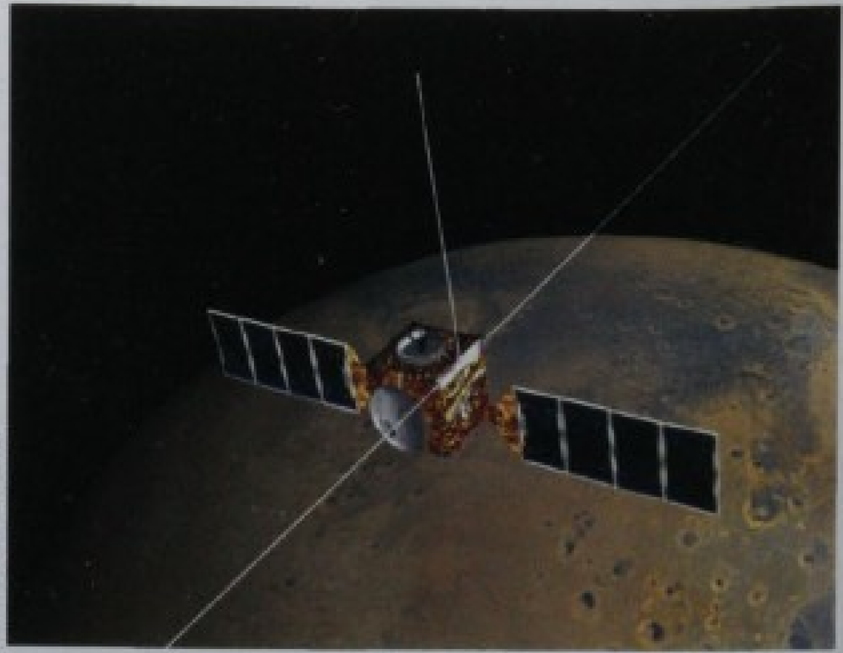
JONATHAN McDOWELL *has been an obsessive-compulsive gatherer of space-flight trivia since he was in high school. In his spare time, he does research in astrophysics and writes software for astronomy.*

MISSION UPDATE

BY JONATHAN McDOWELL

Mars Express and Beagle 2

The European Space Agency marked the opening of the biennial Earth-to-Mars travel window with the launch of its Mars Express probe. Boosted into solar orbit by a Russian Soyuz-Fregat rocket on June 2nd, Mars Express will arrive at the red planet in December. This is the most ambitious European planetary probe to date, and it carries an extensive suite of instruments to study the surface and atmosphere of the planet from orbit. One of these, called MARSIS, is designed to detect concentrations of underground water. It uses a 40-meter-long antenna to generate long-wavelength radio waves that will penetrate to perhaps 5 kilometers below the surface and then reflect back to the spacecraft. Mars Express also carries the British-built Beagle 2 lander — the first *Beagle* was Charles Darwin's expeditionary ship — which will drop onto the surface to search for tracers of life such as unusual ratios of carbon isotopes and traces of atmospheric methane.



Mars Express carries an extensive suite of instruments, including a ground-penetrating radar system that will employ a 40-meter-long antenna to map buried reservoirs of water.

Spirit and Opportunity

NASA's two Mars Exploration Rovers, christened Spirit and Opportunity in late May, will join the search for water on the planet's surface. Spirit was launched by a Delta II rocket on June 10th, while Opportunity was to follow no earlier than July 5th atop a more powerful Delta II-H (to make up for a less favorable planetary alignment). Firings from a small engine will adjust each rover's route to its Martian landing target, with Spirit set to arrive next January 4th and Opportunity on January 25th. Each craft is surrounded by enormous airbags, which will be inflated just before landing, and in turn this entire package is encapsulated in a heat shield for protection during its passage through the thin Martian atmosphere. The identical payloads consist of a camera, a robot arm to reach rock and soil samples, and a quartet of instruments to assess their composition and character.

With a mass of 174 kilograms, these rovers are much more capable than Mars Pathfinder's 11-kg Sojourner, which arrived in 1997. The realities of space travel are such that to get a 174-kg rover to the Martian surface required a 1,062-kg spacecraft, which in turn had to be heaved into space by a 230-ton rocket. Thus, even given this year's favorable alignment, less than 0.01 percent of the launch mass will end up rolling around Mars. The MER spacecraft represent a big test for NASA, as they are the first developed under a Mars-exploration program that was revamped after the embarrassing loss of two craft in 1999. A successful holdover from that older program is 2001 Mars Odyssey, which remains in operation around the planet together with the elderly Mars Global Surveyor. The latter craft has been dependably returning high-resolution images and other data for nearly six years.

Nine-year-old Sofi Collis poses with a model of NASA's Mars Exploration Rover. She bested nearly 10,000 other applicants in a "Name the Rovers" contest by proposing that the twin spacecraft be called Spirit and Opportunity.

Spectroscopy and Photometry of the IGM's Diffuse Radiation

Boston University's SPIDR cosmology satellite was canceled in May only a year after being selected for development as a Small Explorer mission. The cancellation follows NASA's termination of the FAME astrometry spacecraft (*S&T:* August 2002, page 28) as part of a new, tougher policy toward missions that run into management trouble. However, it is unusual and perhaps unprecedented for the agency to ax a mission so early in its implementation. SPIDR was meant to map diffuse ultraviolet emission from the intergalactic medium. But suspicions arose that the detector's signal-to-noise estimates were overly optimistic, and a special review concluded that SPIDR wouldn't be able to perform the mission as designed. A revised version of the SPIDR mission is being resubmitted to compete with other proposals — including another ultraviolet-background mission — in this year's Small Explorer selection.

Widely recognized for his space-program expertise (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html), JONATHAN McDOWELL *is a staff scientist for the Chandra X-ray Observatory.*

BY JONATHAN McDOWELL

Microvariability and Oscillations of Stars

Canada's first astronomical satellite began its observing program within days of reaching orbit on June 30th. Launched by a converted Russian missile, the satellite is being operated from a Toronto control center using dishes in Canada and Austria. MOST consists of a small (15-centimeter-aperture) visible-light telescope and a CCD camera in a dedicated 60-kilogram package. Teams from the University of Toronto and the University of British Columbia are using the telescope to observe bright stars. Lenses smear the light out over many camera pixels so that each star's brightness can be determined to a few parts per million. A second CCD measures the positions of guide stars to keep MOST fixated on its target for weeks at a time. MOST is the first microsatellite to be able to point with 10-arcsecond precision, accomplished using small reaction wheels and electromagnets. It will study the internal structure of stars by detecting small seismic oscillations, which drive slight changes in light output, and search for tiny changes in the light reflected from distant planets as they orbit other stars.

Mission scientist Jaymie Matthews (University of Toronto) checks out the MOST telescope assembly (left foreground) and spacecraft prior to its launch. Courtesy Canadian Space Agency.

Gravity Probe B

The saga of the ambitious Gravity Probe B mission has moved into a new phase with the spacecraft's shipment to its launch site at Vandenberg Air Force Base in California. After years of delays and setbacks, including a final threat of outright cancellation in April, the satellite is now considered ready to fly on its yearlong mission to search for the gravitomagnetic effects predicted by Einstein's general theory of relativity. GP-B carries a 14-centimeter telescope with a quartz primary mirror (for thermal stability). This telescope will repeatedly observe the position of IM Pegasi, a 5th-magnitude binary star, and compare its apparent position to the spin axis of its onboard gyroscopes to search for a yearly shift of 0.042 arcsecond predicted by relativistic effects. To restrict their drift to less than 1 microarcsecond per day, the gyroscopes are kept at 1.8° Kelvin by liquid helium and protected from Earth's magnetic field by superconducting lead foil. Thermal-vacuum tests completed in May confirmed that the rate of boil-off from GP-B's storage Dewar was low enough for the mission to be completed before the liquid helium runs out. Launch is now scheduled for November aboard a Delta rocket.

Technical difficulties have plagued the ambitious Gravity Probe B spacecraft, which finally has been completed and cleared for launch.

RUSS UNDERWOOD/LOCKHEED MARTIN SPACE SYSTEMS

Solar and Heliospheric Observatory

SOHO, an 8-year-old European solar observatory, has survived yet another scrape. In June ground controllers were alarmed to discover a malfunction on the spacecraft's main antenna. SOHO makes a roughly circular orbit around the L_1 Lagrangian point on the Earth-Sun line, so the antenna must move to remain centered on Earth. A mechanical problem in one axis of the antenna's pointing system threatened to cut off data from the spacecraft for a few weeks every three months. As expected, on June 27th SOHO lost contact with the 26-meter NASA ground station assigned to it, as the antenna pointing drifted away from our planet. However, NASA provided access to a larger 34-meter dish in its Deep Space Network, allowing full data access to continue for an extra few days. Then, for two weeks, SOHO had to use its omnidirectional low-gain antenna to transmit at a lower rate to even bigger dishes. Solar scientists are alarmed at the signs of aging on this observatory, which has become a key source of information on solar activity and space weather. SOHO will not be replaced until the launch of the Solar Dynamics Observatory in 2007 or 2008.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html).*

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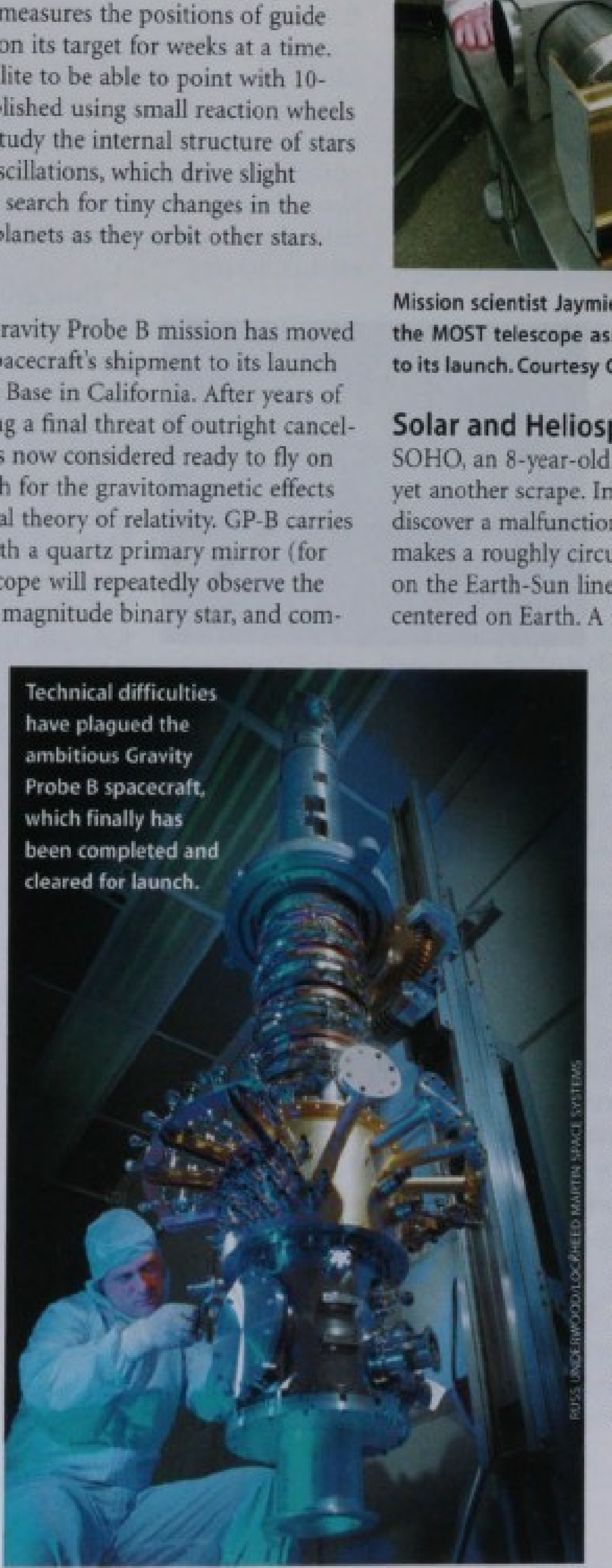

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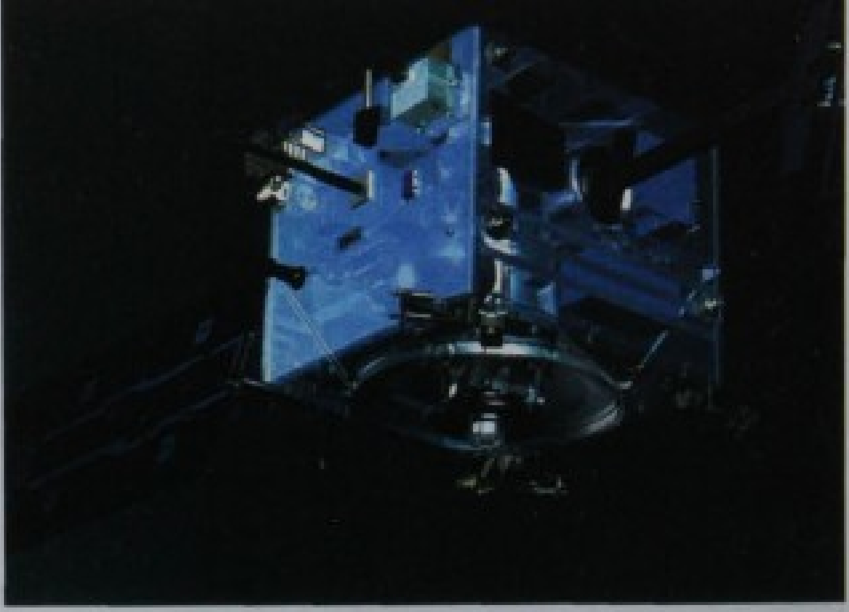
MISSION UPDATE
BY JONATHAN McDOWELL



The European Space Agency's SMART 1 spacecraft measures 1 meter (3.3 feet) on a side, but it will span 14 meters once its large solar-cell arrays are extended in space. Courtesy European Space Agency.

Galileo Orbiter

NASA's resilient Galileo orbiter ended its mission on September 21st with a fatal plunge into the Jovian atmosphere at 48 kilometers (30 miles) per second. Space-agency officials decided to destroy the spacecraft rather than leave it orbiting Jupiter; they feared that if by tiny chance it someday crashed into the moon Europa, the resulting biological contamination would compromise future searches for life there. Galileo's farewell encounter was a 500-km brush past Amalthea in November 2002. A looping orbit then carried the spacecraft 26.4 million km from the planet last April, after which it picked up speed as it fell back toward Jupiter. The plasma and energetic-particle instruments returned data throughout this final orbit, their data transmitted to Earth in real time because the spacecraft's tape recorder had been shut off.

Originally Galileo was to be carried into space in mid-1986 by the Space Shuttle and propelled directly to Jupiter by a Centaur booster. But the loss of *Challenger* just a few months beforehand heightened concern about stowing the liquid-fueled Centaur in the shuttle's cargo bay. *Atlantis* finally deployed Galileo and a safer but less powerful solid-fuel booster on October 18, 1989. To reach Jupiter, Galileo first had to carom around the inner solar system, picking up speed from flybys of Venus and Earth. It encountered asteroids 951 Gaspra and 243 Ida during its cruise toward Jupiter, and upon arrival in December 1995 the orbiter dispatched the separately instrumented Galileo Probe into the Jovian atmosphere and fired its engine to begin circling the planet. Despite the failure of its main antenna to deploy correctly, Galileo returned seven years of spectacular images and data, completing 34 close passes of the planet and its Galilean satellites.

After 14 years of coursing through the solar system and circling Jupiter, NASA's Galileo orbiter ended its mission as a dazzling meteor in the Jovian atmosphere. Artwork by David A. Hardy.

SMART 1

The European Space Agency's first lunar probe was launched on September 27th aboard an Ariane V vehicle from Kourou, French Guiana. Developed as part of ESA's Small Missions for Advanced Research and Technology program, SMART 1 will use an ion-drive engine to escape Earth's gravitational grasp and head for the Moon. The French-built engine uses 1.3 kilowatts of electricity to ionize xenon fuel and expel it at high velocity. This generates an acceleration of only 20 millionths that of Earth's gravity, so the craft will take more than a year to reach its target and make several close flybys of the Moon before final capture into lunar orbit. Interplanetary ion propulsion was pioneered by NASA's Deep Space 1 probe, and ESA engineers also gained extensive experience with the Artemis satellite. However, this is the first time ion propulsion has been used in combination with gravity assists. SMART 1 will eventually pass through the Earth-Moon L_1 Lagrangian point and take up an initial 300-by-10,000-km loop over the lunar poles. The ion engine will continue firing to lower the orbit and get the craft skimming closer to the surface. Built by the Swedish Space Corp., SMART 1 has a mass of 370 kilograms (815 pounds). It carries cameras, infrared and X-ray spectrometers, and detectors for particles and fields.

Messenger

NASA's seventh Discovery interplanetary mission is nearing its planned launch in May 2004. The Mercury Surface, Space Environment, Geochemistry, and Ranging mission, known as Messenger, is to make the first visit to the innermost planet since Mariner 10 in 1975. Built by Johns Hopkins University's Applied Physics Laboratory, Messenger will fly past Venus three times before reaching Mercury in October 2007. Images taken during that arrival flyby and during a second pass in July 2008 should reveal the half of Mercury's surface that Mariner 10 never saw clearly. During a third encounter in July 2009, Messenger will fire its engine and slip into orbit for a year of intensive observations. The spacecraft carries a camera, magnetometer, charged-particle detectors, X- and gamma-ray spectrometers (to determine surface composition), and a laser altimeter (to measure the heights of topographic features).

Widely known for his space-program expertise (www.planet4589.org/space/jsr/jsr.html), contributing editor Jonathan McDowell *is a staff scientist for the Chandra X-ray Observatory.*

MISSION UPDATE

BY JONATHAN McDOWELL

The Shenzhou 5 spacecraft lifts off from the Jiuquan Space Center in the Gobi Desert on October 15th, carrying the People's Republic of China's first astronaut, 38-year-old Yang Liwei. He orbited Earth 14 times and landed safely in northern China.

Shenzhou 5

On October 15, 2003, the People's Republic of China became just the third nation to send a human into space. China's first astronaut, Yang Liwei, spent 21 hours orbiting the Earth in the Shenzhou 5 spacecraft, launched aboard a Chang Zheng 2F ("Long March") rocket. The name Shenzhou has been translated as "Divine Vessel," but "Spaceship" may be equally accurate. The Shenzhou has three sections — engine, descent, and orbital modules — and is similar to the Russian Soyuz in overall appearance. Indeed, the descent module was developed after China bought several used Soyuzes from Russia. The orbital module, however, is an advanced, all-Chinese design with its own solar-cell panels; it will remain in orbit and continue to carry out experiments for several months. Liwei emerged from the capsule after the descent module landed in northern China, less than 5 kilometers from its intended target. Xie Mingbao, director of China's piloted space effort, explains that the next Shenzhou will be launched in a year or two.

South Korea's Space and Technology Satellite 1 (STSat 1), which carries a US-built astronomy experiment, was launched on September 27, 2003, aboard a Russian rocket.

STSat 1

The Korea Advanced Institute of Science and Technology (KAIST) launched the first satellite in a new series, the Space and Technology Satellite 1 (STSat 1, also known as KAISTSAT 4), on September 27, 2003. The spacecraft is now undergoing orbital checkout following its launch aboard a Russian Kosmos 3M rocket. The satellite carries several scientific experiments, including one from the United States. SPEAR (Spectroscopy of Plasma Evolution from Astrophysical Radiation), a far-ultraviolet telescope from the University of California, Berkeley, has two spectrographs that will carry out the first all-sky survey of diffuse radiation at a resolution of 5 arcminutes. The survey will include the important emission lines of ionized oxygen and carbon (centered on wavelengths of 104 and 155 nanometers, respectively) that will allow SPEAR to study the heating, cooling, and composition of hot interstellar plasma at upward of 100,000° Kelvin (180,000°F). This will allow astronomers to examine gas that is hotter than the visible-light nebulae seen in Hubble Space Telescope pictures and cooler than the plasma recorded by satellites like the Chandra X-ray Observatory.

Stardust

The Stardust space probe's big moment will come on January 2nd when it flies through Comet 81P/Wild 2, coming only 100 kilometers from its icy nucleus. The spacecraft was launched in February 1999, made a gravity-assist flyby of Earth in January 2001, and flew past asteroid 5535 Annefrank in November 2002 (*S&T:* February 2003, page 30). While out in the asteroid belt for months, the probe has been collecting interplanetary dust by exposing one of its aerogel panels to space. In contrast, gathering cometary material onto a separate aerogel panel will take just a few hours, as Stardust streaks through the comet at more than 6 km per second. After imaging the nucleus and coma, then stowing its collectors, the probe will continue on an orbit that intersects Earth in January 2006. A capsule carrying the scientific treasure will be picked up in Utah.

Target: Mars

Mars Global Surveyor and 2001 Mars Odyssey continue to function in orbit around the red planet. Five more spacecraft are due to arrive very soon (see page 44):

Upcoming Encounters with Mars

Mission	Arrival date
Nozomi (orbiter)	December 13, 2003
Beagle 2 (lander)	December 25, 2003
Mars Express (orbiter)	December 26, 2003
Spirit (surface rover)	January 4, 2004
Opportunity (surface rover)	January 25, 2004

JONATHAN McDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of astronomy and space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

BY JONATHAN McDOWELL

Swift

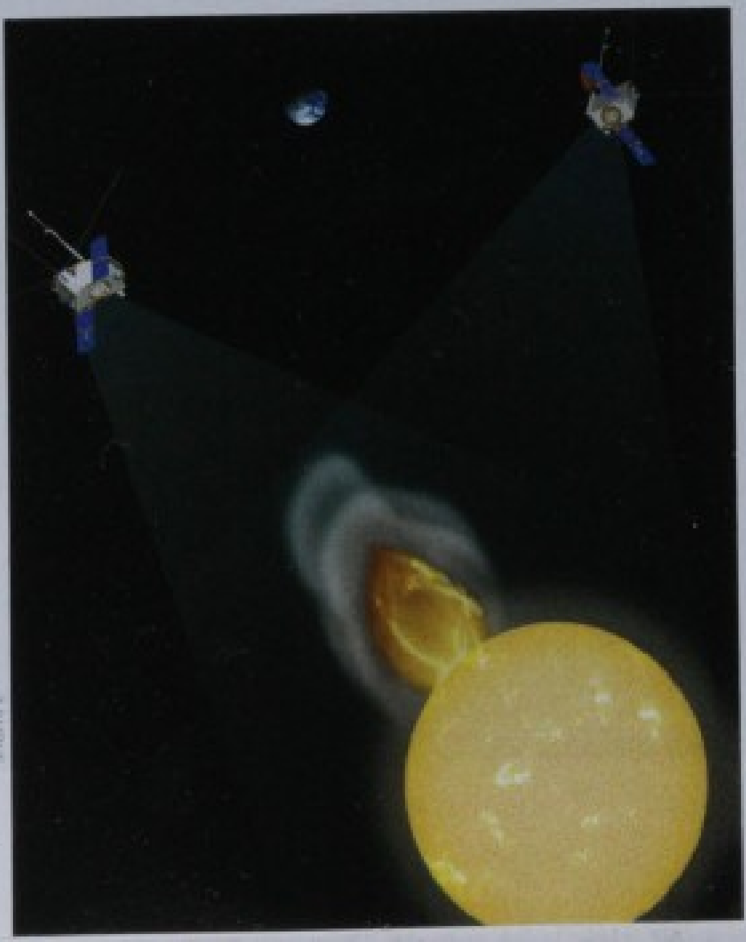
Launch of NASA's Swift gamma-ray observatory is now scheduled for May 2004 aboard a Delta rocket from Cape Canaveral, Florida. According to principal investigator Neil A. Gehrels (NASA/Goddard Space Flight Center), the two instruments that will study the X-ray and ultraviolet/visible-light afterglows of gamma-ray bursts (GRBs) have been tested and installed in the spacecraft. However, two rounds of electronics problems have plagued Swift's Burst Alert Telescope (BAT) — the wide-angle detector that will register GRBs in the first place. BAT was to have been installed in early December, in time to support the new launch date. Gehrels expects the satellite to spot several bursts per week and use the X-ray and ultraviolet cameras to pinpoint their locations. The BAT detectors will also perform a sensitive all-sky survey in "hard" X-rays (having energies of more than 10,000 electron volts). Swift is the fourth NASA medium-class Explorer (MIDEX) mission, following the IMAGE magnetospheric observatory, the FUSE ultraviolet telescope, and the WMAP cosmology probe; each continues to operate successfully in space.


NASA/GSFC

NASA's Swift spacecraft, scheduled for launch in May 2004, will target enigmatic gamma-ray bursts using X-ray and ultraviolet cameras.

STEREO

The massive solar storms of late 2003 brought renewed attention to the physics of eruptions on the Sun. NASA is planning to launch a pair of spacecraft in November 2005 to study these coronal mass ejections (CMEs), which can have major effects on Earth's environment. The Solar Terrestrial Relations Observatory (STEREO) consists of twin probes launched on a single Delta rocket into an orbit extending out to lunar distance. In January 2006, after four trips around Earth, the two craft will make flybys of the Moon at heights of about 10,000 kilometers. STEREO B will be swung into a solar orbit that will trail Earth. STEREO A will loop back to the Moon a month later and make a second flyby to fling it such that it leads Earth. The craft will return to Earth's vicinity after 16 years, long after completing their mission. With one STEREO probe trailing Earth in its orbit and the second one preceding it by the same amount, astronomers will be able to get a true three-dimensional view of the eruptions for the first time. Johns Hopkins University's Applied Physics Laboratory is now building the spacecraft, which will carry coronagraphs, radio-burst detectors, and particle detectors.


JHU/APL

The aptly named STEREO mission will use two spacecraft that will gradually drift away from Earth in opposite directions to obtain a three-dimensional view of eruptions from the Sun.

Small Explorers

NASA has announced five candidates for the next two Small Explorer missions, which are scheduled for launch in 2007–8; a final decision will be made in late 2004. NEXUS (Normal-incidence Extreme Ultraviolet Spectrometer), led by Joseph M. Davila (NASA/Goddard), would study the solar corona. The Dark Universe Observatory (DUO), proposed by Richard E. Griffiths (Carnegie Mellon University), carries an array of seven X-ray telescopes to give a wide field of view to search for clusters of galaxies and to study associated "dark matter" and "dark energy." Nicholas M. Schneider (University of Colorado) proposed JMEX, the Jupiter Magnetospheric Explorer, which is an ultraviolet observatory in Earth orbit that would stay pointed at Jupiter to study the Jovian aurora and the Io plasma torus. NuSTAR (Nuclear Spectroscopic Telescope Array) has been proposed by Fiona A. Harrison (Caltech); it would be the first X-ray observatory to use focusing optics to image in hard X-rays. David J. McComas (Southwest Research Institute) leads IBEX, the Interstellar Boundary Explorer, to study the global interaction between the interstellar medium and the solar wind. Launched into a highly elongated Earth orbit, IBEX would use two detectors to map particles reaching Earth's vicinity from the outer solar system.

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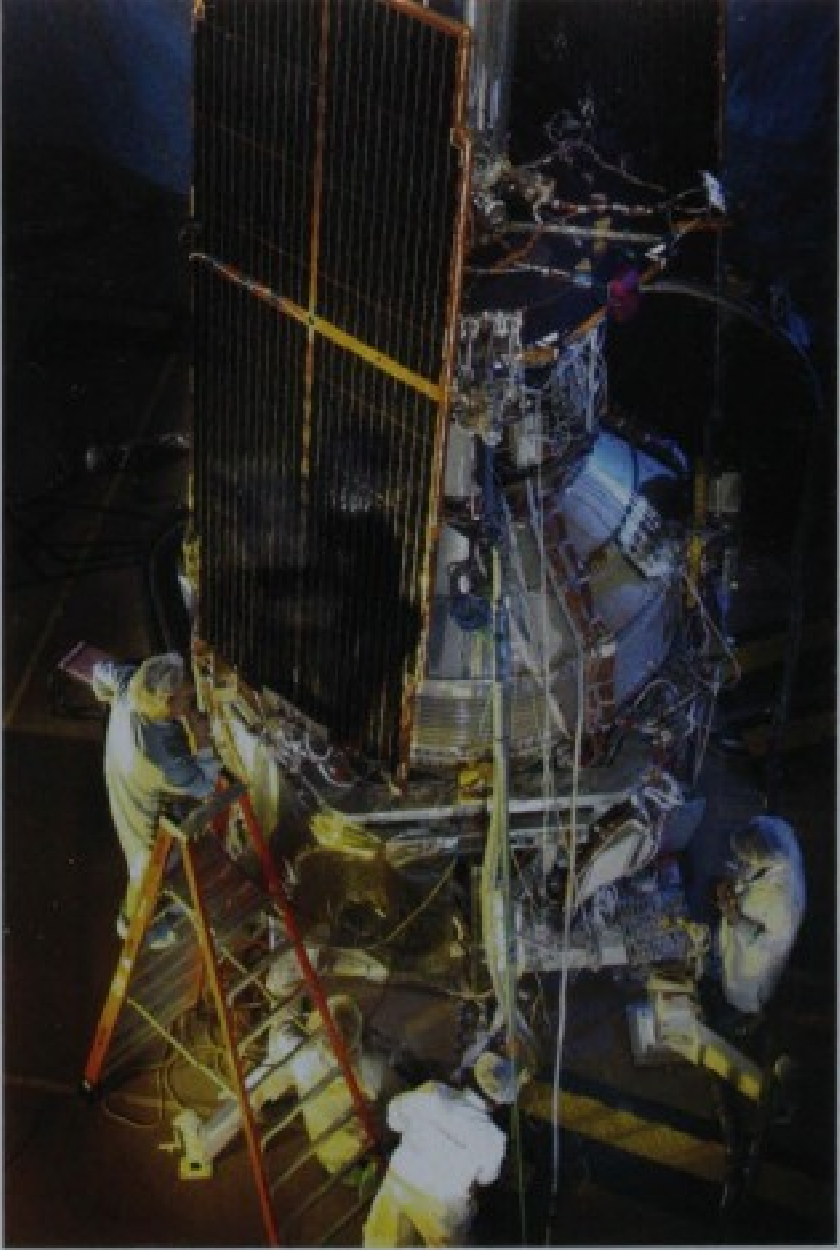
BY JONATHAN McDOWELL

Gravity Probe B

The start of the Gravity Probe B mission has been delayed again, despite being only weeks from launch at Vandenberg Air Force Base in California. In mid-November the relativity-testing satellite was ready to be attached to its Delta rocket when engineers discovered an electrical problem in the vehicle's experiment control unit. Even with this new delay, the craft's supercooled Dewar — filled with liquid helium so that a super-sensitive gyroscope made of quartz will stay at only 1.8° Kelvin above absolute zero — will still remain cold enough to last through the life of the mission. The goal of the GP-B project was first proposed to NASA in 1961, but the needed technological advances came much later: in 1972 the US Navy's Triad satellite successfully isolated spacecraft instruments from outside disturbances by using a free-floating outer shell, and in 1983 the Infrared Astronomical Satellite (IRAS) tested a supercold Dewar in orbit. Construction of GP-B began in 1992, but repeated delays and repairs have postponed this challenging experiment. The launch date has been rescheduled for April 20, 2004.



The Gravity Probe B spacecraft has been under development for more than four decades. An electrical problem discovered in November has forced another launch delay. Courtesy Russ Underwood and Lockheed Martin Space Systems.

Cancellation and Cutback

The European Space Agency's science budget continues to sink deeper into trouble. At a recent meeting ESA decided to cancel one major astronomy mission and cut back another. Any unplanned expenses — such as all-too-common launch delays — could trigger further crises. The panel axed the Eddington mission, which would have studied stellar oscillations and searched for extrasolar planets. Eddington's 1.2-meter optical telescope would have been placed near the L_2 Lagrangian libration point on the outward side of Earth from the Sun. It would have monitored a variety of stars to study their oscillations (asteroseismology) and also would have stared at single fields to spot the dimming of stars as their planets crossed in front of them. Although the small Canadian MOST satellite is pioneering stellar-oscillation measurements from orbit (*S&T:* October 2003, page 28), Eddington was the only major mission planned to focus on asteroseismology. Its planet-hunting goal was similar to NASA's Kepler project. ESA trimmed back some of the BepiColombo mission by eliminating the first lander to be sent to Mercury. The action leaves intact the two orbiters, which will reach the planet at the end of the decade. An American mission to Mercury, Messenger, is due for launch in early 2004.

Financial concerns forced the European Space Agency to reduce the scope of its BepiColombo mission to explore Mercury. Courtesy ESA; illustration by Medialab.

XMM-Newton

The European Space Agency's XMM-Newton high-energy astrophysics observatory has completed its fourth year in orbit, with more than 750 revolutions in its long, looping path around the Earth. In November ESA approved extending support to the mission until March 2008, well beyond its planned operation. Indeed, the spacecraft could operate even longer; its instruments have had only minor problems so far. As with several other deep-space satellites, the dramatic solar flares last October and November put the observatory into a standby mode for almost two weeks, delaying some observations but causing no permanent damage. During 2004 all XMM observations will be reprocessed to generate an improved archive for the astronomical community. This revision is a common procedure for space-science missions, because it typically takes several years for astronomers to understand the details of how a spacecraft and its instruments perform in space and to develop fixes for unexpected quirks such as malfunctioning chips or drifting calibrations. The reevaluation shouldn't invalidate the major scientific conclusions obtained during the first few months of observation, but it will allow significant improvement in the accuracy of brightnesses, positions, and spectral properties, letting scientists dig deeper in the data.

JONATHAN McDOWELL *has been an obsessive-compulsive gatherer of space-flight trivia since he was in high school. In his spare time he does research in astrophysics and writes software for astronomy.*

MISSION UPDATE

BY JONATHAN McDOWELL

Astro E2

Engineers at the Japan Aerospace Exploration Agency (JAXA) are well into assembling their new X-ray astronomy observatory in preparation for launch in February 2005. Astro E2 is a copy of the first Astro E, which was lost when its rocket went off course during launch four years ago (*S&T:* May 2000, page 26). Despite the delay, the mission will still break new ground. One of its five X-ray telescopes will carry the XRS, the first solid-state microcalorimeter to fly in orbit. This spectrometer will have a spectral resolution of only 6 electron volts (eV), far higher than the imaging chips on the Chandra and XMM-Newton observatories, and will beat their spectroscopic gratings at high energies. The XRS has two drawbacks, however. First, the low spatial resolution of its simple telescope — about 120 arcseconds, compared to the 0.5 arcsecond of Chandra's exquisite mirrors — will prevent it from studying faint sources. Second, XRS has only 31 active pixels, compared to Chandra's 6-megapixel ACIS camera. The XRS detector works by sensing the tiny increases in a pixel's temperature caused by the arrival of individual X-rays. XRS will be kept at 0.06° Kelvin above absolute zero using a four-stage refrigerator that uses liquid helium and solid neon. The four other X-ray telescopes on Astro E2 will have conventional CCD imagers covering the same energy range of 400 to 10,000 eV. All five telescopes are mounted on booms that must extend after launch to reach 4.8-meter (16-foot) focal lengths. Two additional detectors will directly measure high-energy X-rays of 10,000 to 700,000 eV. This broad coverage gives Astro E2 a further advantage over other X-ray observatories in the detailed study of bright sources.

JAXA

The Japanese space agency JAXA is readying its second Astro E spacecraft for launch next year to replace the first one, which was lost after liftoff four years ago.

SOURCE: JAXA

To follow up on Astro E2, JAXA is studying the proposed New X-ray Telescope, which will image the sky using advanced mirrors.

NeXT

With Astro E2 under way, JAXA is considering proposals for new science missions. One candidate is NeXT, Japan's New X-ray Telescope, which would use new mirror technology to allow images in high-energy X-rays with energies above 10,000 eV, corresponding to wavelengths smaller than 1.2 angstroms. It's difficult to persuade such high-energy or "hard" X-rays to change their direction of travel, and until now the hard X-ray sky has been studied either with simple collimator detectors, which block out all but a small part of the sky but don't make an image, or with "coded-mask" pinhole cameras like those used on Europe's Integral satellite that indirectly produce low-resolution images. NeXT's "super mirrors" would take advantage of a process known as Bragg reflection, which will actually focus the hard X-rays using optics with multiple layers of metal coatings.

Space Interferometry Mission

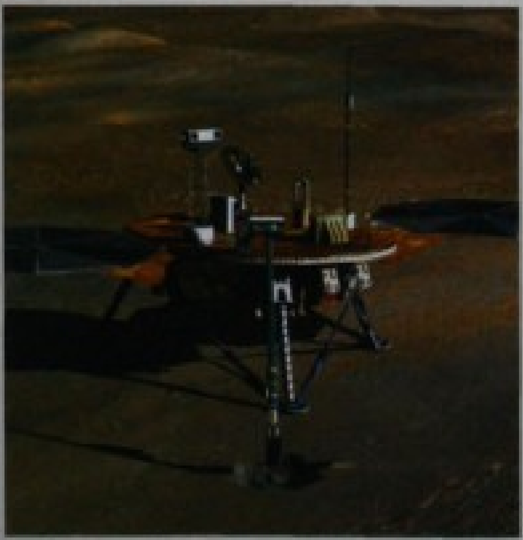
Design of NASA's Space Interferometry Mission (SIM) to search for extrasolar planets is advancing, with launch now expected in 2009. The SIM spacecraft is an unusual box-shaped telescope with four pairs of 33-centimeter *siderostats* — flat tracking mirrors — separated by 10 meters on a very stable optical bench. The light from each pair of mirrors will be combined in the center of the spacecraft to make interferometric fringes, allowing structure only 0.01 arcsecond across to be detected — about five times finer than the best Hubble Space Telescope data. To make this work, the light path within the telescope must be kept stable to a nanometer (a millionth of a millimeter), and the mirrors must be pointed more accurately than standard spacecraft star trackers can handle. The SIM telescopes will work in visible light and will detect extrasolar planets indirectly by the change in position of their parent stars as the orbiting planets' gravity tugs on them.

JONATHAN McDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

NASA/JPL/CALTECH

The Space Interferometry Mission — to be launched in 2009 — aims to find planets around other stars by watching for stellar wobbles. Project manager Renaud Goullioud stands in front of the Microarcsecond Metrology Testbed, being used to develop SIM's technology.

mission update *by jonathan mcdowell*



NASA

Mars 2009

Following the high-resolution Mars Reconnaissance Orbiter (to be launched in 2005) and the Phoenix north-pole lander (2007), two NASA missions are expected to leave for the red planet in 2009. The Mars Science Laboratory will use a new precision landing system and incorporate a large (450- to 600-kilogram) rover — three times heavier than Spirit and Opportunity — that will operate for more than a year and may travel up to 10 kilometers from the landing site. The lander's communications will be supplemented by the Mars Telesat Orbiter (MTO), whose equipment will include an experimental laser-based relay system. MTO would be the harbinger of a network of communications and space-weather outposts throughout the inner solar system — the kind of deep-space "infrastructure" that interplanetary astronauts would require.

NASA Budget for Fiscal 2005

Following President Bush's dramatic announcement of a restructured NASA (April issue, page 24), his administration announced its budget request for fiscal year 2005 in February, laying out the space agency's new priorities. The new initiatives foresee a crew exploration vehicle — Project Constellation — that will replace the Space Shuttle and will ferry astronauts to the Moon by 2020 and eventually to Mars. To support this effort, new robotic lunar probes will start flying in 2008, and the Mars exploration program will incorporate plans for robotic "human precursor" missions starting in 2011 to develop technology for piloted voyages to the planet.

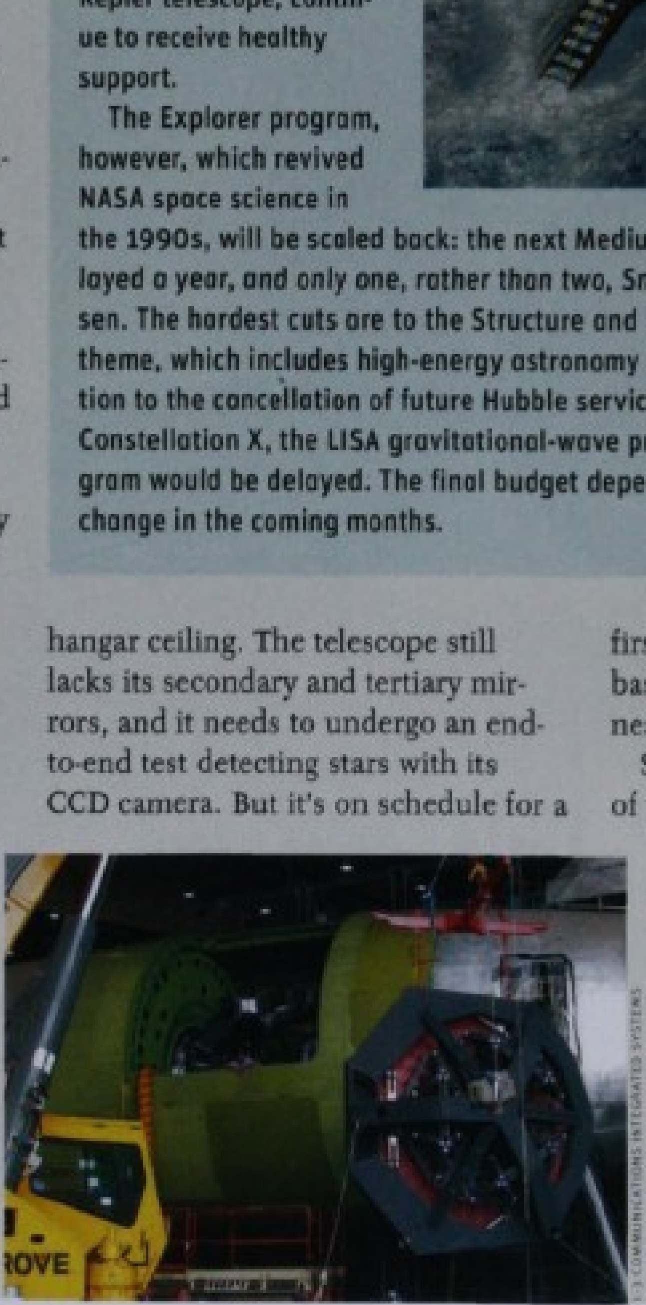
Relatively little new funding is being requested; most of the money will come out of NASA's existing budget, and long-term plans show a decline in science funding relative to inflation. Projects in NASA's Origins program that will search for extrasolar planets, such as the James Webb Space Telescope, the Space Interferometry Mission, and the Kepler telescope, continue to receive healthy support.

NASA

The Explorer program, however, which revived NASA space science in the 1990s, will be scaled back: the next Medium-class Explorer selection will be delayed a year, and only one, rather than two, Small Explorer candidates will be chosen. The hardest cuts are to the Structure and Evolution of the Universe (SEU) theme, which includes high-energy astronomy and early-universe studies. In addition to the cancellation of future Hubble servicing missions, the X-ray observatory Constellation X, the LISA gravitational-wave project, and the Einstein Probes program would be delayed. The final budget depends on Congress, so the picture may change in the coming months.

SOFIA

The telescope for the Stratospheric Observatory for Infrared Astronomy (SOFIA) has now been installed in its Boeing 747SP carrier aircraft. The 1,820-kilogram (2-ton) primary mirror and support structure were hoisted into the aircraft last July (see the photo at right). Since then, the bearing has successfully turned the 2.5-meter telescope, and engineers have tested its three tracking cameras. The wide-field camera has already imaged simulated stars produced by lasers illuminating the hangar ceiling. The telescope still lacks its secondary and tertiary mirrors, and it needs to undergo an end-to-end test detecting stars with its CCD camera. But it's on schedule for a first science flight in 2005 from its base at NASA's Ames Research Center near San Francisco.



L-3 COMMUNICATIONS INTEGRATED SYSTEMS

SOFIA's initial instruments consist of three infrared cameras covering wavelengths from 1 to 240 microns, five spectrometers covering 5 to 655 microns, and a high-speed imaging photometer for recording occultations in visible light.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (www.planet4589.org/space/jsr/jsr.html).*

mission update *by jonathan mcdowell*

Ulysses

The European Space Agency's Ulysses probe has completed a distant encounter with Jupiter, the latest event in its 14-year odyssey. The spacecraft came no closer than 120 million kilometers to Jupiter — more than the distance between Venus and the Sun, but close enough to allow detailed studies of the enormous Jovian magnetosphere.

As 2003 drew to a close the spacecraft was high above Jupiter's north pole, a region that the Galileo orbiter did not reach. From its distant vantage Ulysses detected high-velocity dust streams from Io of a type originally discovered during its first and much closer Jupiter encounter in 1992. Its instruments continue to monitor the interplanetary medium as well, and though Ulysses is more than 5 astronomical units from the Sun, it sensed a coronal mass ejection from the massive solar flare last November.

Despite fading power levels on the spacecraft as the plutonium in its radioisotope generators slowly decays, ESA managers have extended the mission until 2008, keeping the probe alive through a third pass over the Sun's poles in 2007–08 during the solar activity minimum. The previous pass, in 2000–01, took place at solar maximum, while the first one, in 1994–95, also occurred at solar minimum.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

Genesis


NASA / JPL

After three years at the Earth-Sun L_1 Lagrangian point 1½ million km from home, the Genesis probe is concluding its mission to gather material cast off from the Sun in the solar wind. Flight controllers closed its set of collectors in early April, after which an engine firing was to send it back to Earth. On September 8th the probe will plunge into Earth's atmosphere at 10.7 km per second, marking the first return to Earth by a spacecraft that has been beyond the Moon's orbit. The descent capsule will hang-glide into the Utah Test and Training Range, where a helicopter will snatch it in midair and ferry it to recovery-team members on the ground. Several types of collector material, expected to have about 0.4 milligram of captured solar-wind matter, will then be sent to laboratories. There scientists expect to learn more about the composition of the Sun's atmosphere.

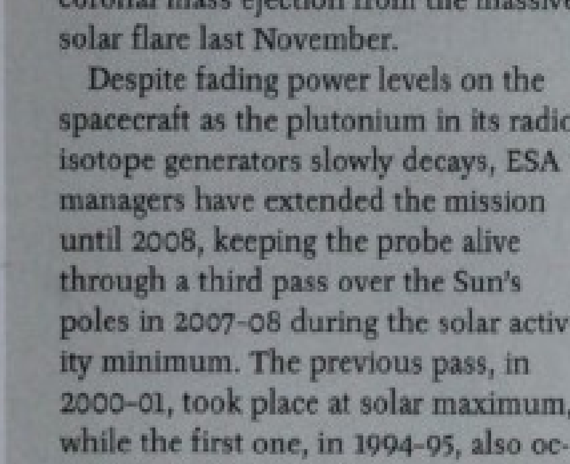
Cassini

NASA's Cassini orbiter is on final approach to Saturn. On February 9th the spacecraft snapped a color portrait (below) as it entered Saturn's sphere of influence, the 48-million-km-radius region where the gravitational effect of the planet exceeds that of the Sun. Rather than being in an elliptical orbit around the Sun, Cassini's trajectory is now better described as a hyperbolic path around Saturn. When Cassini comes closest to the planet on July 1st, it will fire a rocket engine to cut its speed and collapse the orbit to a long, Saturn-centered ellipse.

Well before that, however, Cassini will fly past the moon Phoebe. This 220-km-wide world goes around the ringed planet in a distant, backward orbit. Relatively little has been learned about Phoebe since its discovery in 1898. Our best view to date came in 1981, when Voyager 2 captured a crude image from more than 2 million km away. Cassini will come within just 2,000 km of Phoebe on June 11th, so expect exciting data from its complement of instruments.


NASA / JPL / SPACE SCIENCE INSTITUTE

Janet Mattei, 1943–2004


S&T: EDWIN L. AGUIRRE

Astronomy lost one of its brightest stars when Janet Akyüz Mattei passed away on March 22nd after a six-month battle with acute leukemia. She was 61.

Born in Bodrum, Turkey, Mattei directed the American Association of Variable Star Observers through its many stages of growth and modernization since 1973. The AAVSO, founded in 1911, is one of the oldest and largest amateur organizations in the world, with members in more than 40 countries and more than 10 million variable-star observations in its database. Mattei's accomplishments include fostering professional-amateur collaboration in the study of cataclysmic variables and establishing educational programs such as the Hands-On Astrophysics and High-Energy Astrophysics Workshops for Amateur Astronomers. In 2001 the International Astronomical Union named asteroid 1998 FA_{74} as 11695 Mattei. — EDWIN L. AGUIRRE

mission update *by jonathan mcdowell*

WIRE

Although the Wide Field Infrared Explorer (WIRE) failed in its intended mission, it's observing again.

The satellite was to perform an infrared sky survey, but its main 30-centimeter (12-inch) supercooled telescope was rendered useless a few hours after its 1999 launch when a malfunction boiled off the solid-hydrogen coolant.

DAVID SHUPE (IPAC / CALTECH)

Derek L. Buzasi of the US Air Force Academy persuaded NASA to let him make astronomical observations using the diminutive 5-cm optical star-tracker, which served as the satellite's finderscope (arrowed in photo at left). The star-tracker can take high-accuracy brightness measurements in a fraction of a second and has been used to study variable stars and the internal structure of stars by noting the tiny brightness changes as a star quivers — a technique called asteroseismology. The frequencies of these vibrations tell the interior properties of the star. Buzasi's observations stopped in September 2000 because of funding problems, and the satellite then became an engineering training tool.

However, the telescope returned to service on November 26, 2003. After several weeks of checkout, high-quality data started rolling in again on December 16th at the rate of two measurements per second. "So far, the camera seems essentially unaffected by its long hibernation," Buzasi reports. "Probably our most interesting target to date is a month-long observation of Polaris." The period and amplitude of this Cepheid variable have been changing for decades (S&T: January 1999, page 18).

MOST

Following WIRE's serendipitous success in asteroseismology, Canada launched the first mission dedicated to this technique in late 2003. The Microvariability and Oscillations of Stars (MOST) satellite began its science-observing program in January. Its 15-cm telescope concentrated on Procyon in Canis Minor during the first month of observation. Although MOST has 1/28,000 the collecting area of the Hubble Space Telescope and looks only at bright stars, its detectors can spend an entire month aimed at one star. Procyon's brightness over time is now known better than that of any other star except the Sun. MOST will concentrate on naked-eye stars, though the target list includes a few 11th-magnitude Wolf-Rayet stars.

D. BUZASI, N. EVANS, AND D. SASSELOV

©2000 CNES / DAVID DUCROS

COROT

A French project will carry on the asteroseismology endeavor. COROT (a contraction of "convection, rotation, and planetary transits") will be launched in mid-2006 to study stellar oscillations and search for transits by extrasolar planets. The 670-kilogram (1,475-pound) satellite is one of a new series of small missions that began with the Jason oceanography satellite in 2001. It's the first dedicated French astronomy mission since the Signe 3 gamma-ray satellite in 1977, though other European countries are collaborating to reduce costs. Like Signe 3, COROT will ride to orbit on a Russian rocket and will be controlled from the space center in Toulouse, France. Its main instrument is a 30-cm telescope with four large CCD detectors providing a 2.8°-square field of view. These detectors will measure the brightnesses of all stars in preselected regions of the sky. Mission scientists want COROT to stare for five months at a time at two fields along the plane of the Milky Way: one in Aquila not far from the galactic center and the other on the opposite side of the sky in Monoceros. This should yield a survey of some 60,000 faint stars for planetary transits and oscillation measurements for about 50 bright stars.

JONATHAN McDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

mission update *by jonathan mcdowell*

Gravity Probe B

NASA's Gravity Probe B satellite finally reached space on April 20th after almost 40 years of development (July issue, page 22). This challenging physics experiment, developed by a Stanford University team and built by Lockheed Martin, will stare at the 5th-magnitude star IM Pegasi for more than a year, attempting to measure the tiny shifts in the orientations of ultra-precise gyroscopes caused by the "frame dragging" of space-time imparted by Earth's rotation. This phenomenon, predicted by general relativity, should alter the spacecraft's orbital plane by 0.0409 arcsecond per year. GP-B will also make an accurate measurement of the well-established warping of space-time due to Earth's mass, which should have a much larger effect of 6.6144 arcseconds per year in a different direction. To measure such ultrafine quantities, the 3,145-kilogram spacecraft carries four gyroscopes (kept at 1.8° Kelvin by liquid helium), laser retroreflectors, two Global Positioning System receivers, and a 14-centimeter quartz-mirror telescope.

Engineers confirm that the gyros are operating well. One malfunctioning thruster has been deactivated, but the remaining ones are working fine. The thruster system is critical to counteract atmospheric drag, isolating the interior of the satellite from all perturbing effects. By the third week of the mission the satellite successfully located its target star.

Jonathan McDowell, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program at www.planet4589.org/space/jsr/jsr.html.*

2001 Mars Odyssey


NASA / JPL / ARIZONA STATE UNIVERSITY

The Mars Odyssey spacecraft will complete its primary mission in August. Launched in April 2001 as the first element in NASA's renewed Mars-exploration effort following a pair of failures, Odyssey reached the red planet in October of that year, performed aerobraking maneuvers to lower its orbit, and started regular operations in February 2002. The craft finished a full Martian year orbiting the planet in January 2004, and it's been used as a crucial communications relay for the Spirit and Opportunity rovers.

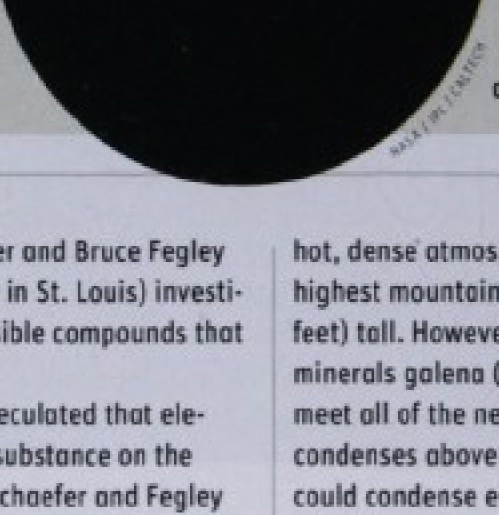
The low-resolution (100-meter) infrared images from the Thermal Emission Imaging System (THEMIS) camera now cover the whole planet. THEMIS's spectacular high-resolution (20-meter) visible-band imaging has recently concentrated on the southern polar regions. Odyssey completes one polar orbit every two hours, and its ground track repeats every two days. The spacecraft's other working instrument, a gamma-ray spectrometer, continues to study surface composition. A third experiment intended to assess radiation failed during a powerful solar flare in October 2003.

NASA's next orbital mission, Mars Reconnaissance Orbiter, will be launched in August 2005 but will not begin science operations until November 2006.

Galaxy Evolution Explorer

The GALEX satellite completed its first year in orbit in April, and the complete data from those 12 months will become available to the astronomical community in October. GALEX's primary mission of scanning the sky at ultraviolet wavelengths will continue for another year. The project's Nearby Galaxy Survey is nearly completed (see page 32), and its Medium Imaging Survey, which covers the regions of the deep Sloan Digital Sky and 2dF Galaxy Redshift surveys, is more than 60 percent finished. Future observing time will concentrate on completing the all-sky and specialized spectroscopic surveys.

GALEX's sensitive ultraviolet telescope operates when the satellite is in Earth's shadow. While observing passes typically last about 30 minutes, the windows on some orbits are slashed to as little as 4 minutes when magnetospheric charged particles concentrated over the South Atlantic Ocean interfere with the instrument. GALEX transmits 6 gigabytes of information daily, which exceeds the combined data rate of the Hubble and Spitzer space telescopes. The surveys will catalog several tens of millions of sources, including galaxies (such as NGC 55, at left), quasars, and white-dwarf stars.

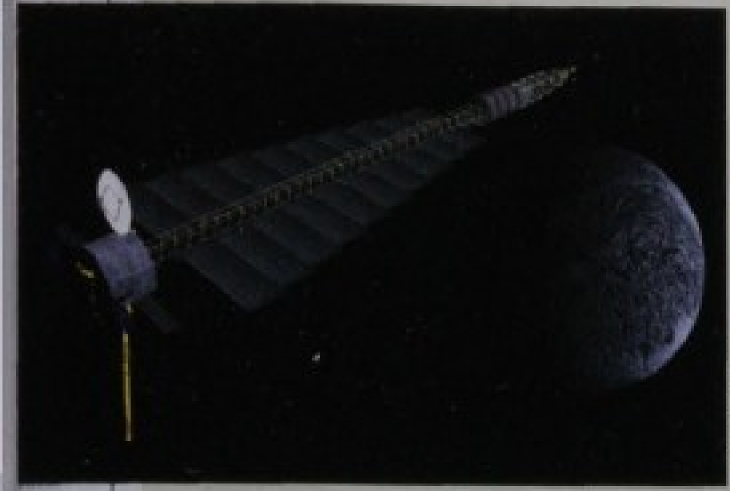

NASA / JPL / CALTECH

Heavy-Metal Frost on Venus

High atop Venusian mountain peaks is something strange: a deposit that is highly reflective to radio waves. Radar pings from Earth strongly suggest the presence of a semiconducting, likely semimetallic material coating the heights. Laura Schaefer and Bruce Fegley Jr. (Washington University in St. Louis) investigated more than 650 possible compounds that it might be.

Previous groups had speculated that elemental tellurium was the substance on the mountaintops. However, Schaefer and Fegley found that solid Te won't condense below an altitude of 47 kilometers (29 miles) in Venus's hot, dense atmosphere, while the planet's highest mountains are only 10 km (33,000 feet) tall. However, the team found that the minerals galena (PbS) and bismuthite (Bi_2S_3) meet all of the necessary criteria. Bismuthite condenses above a mere 1.6 km, while galena could condense everywhere. Both agree with the dielectric constants that have been measured from orbit as well. — David Tytell

mission update *by jonathan mcdowell*



NASA / JPL / CALTECH

Jupiter Icy Moons Orbiter

Planning is picking up for NASA's Jupiter Icy Moons Orbiter (JIMO), slated to embark around 2015. JIMO will demonstrate the use of a nuclear reactor to provide power for outer-planet missions. The proposed spacecraft will be 20 meters (65 feet) long and will weigh 20 tons — three times the size and four times the mass of Cassini, the largest deep-space probe to date. The reactor will power an electric-propulsion system to reach Jupiter and allow a multiyear mission with ample capability for trajectory changes. JIMO will orbit several of the Galilean moons to study their likely subsurface oceans. It will carry a larger and more power-hungry science payload than possible on current interplanetary spacecraft, as well as communicate at a much higher data rate.

The mission is part of the multibillion-dollar Project Prometheus, dedicated to perfecting nuclear power systems for space use. NASA argues that nuclear-fission-reactor technology is crucial for future exploration of the solar system. The only previous US space reactor was the SNAP-10A experiment in 1965. The Soviet Union launched 34 reactors between 1970 and 1988 to power radars aboard naval reconnaissance satellites and suffered several notorious failures, including the scattering of radioactive material across Canada in 1978. Simpler and safer radioisotope thermoelectric generators, which use noncritical amounts of plutonium and generate electricity from the heat of its decay, have been flown on the Apollo, Pioneer 10 and 11, Viking, Voyager, Galileo, and Cassini missions.

Hayabusa

© 2004 JAXA

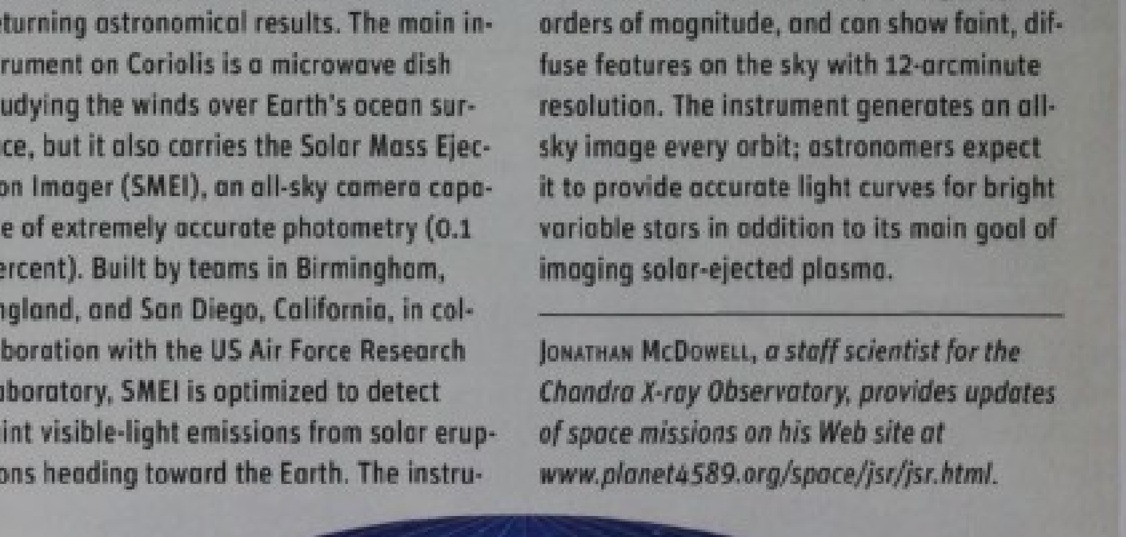
Japan's Hayabusa (formerly MUSES C) asteroid mission has completed its first orbit of the Sun following launch in May 2003. Two or three of its four ion engines have been operating more than 50 percent of the time, increasing the probe's velocity by 4 meters per second per day — an acceleration of only five-millionths of an Earth *g*, but enough to increase its aphelion by 13 percent. Flight controllers shut down the engines temporarily on December 22nd, after 120 total days of use; another 40 days of operation put Hayabusa on course for an Earth flyby on May 19th (see the image above). As the spacecraft swooped only 3,725 kilometers (2,315 miles) above the surface, gravity altered its orbit to carry it out to near-Earth asteroid 25143 Itokawa, named after Hideo Itokawa, a pioneer of the Japanese space program.

Hayabusa's ion engines will slowly match the probe's orbit with that of the asteroid, which ranges from 0.95 to 1.69 astronomical units from the Sun. In June 2005, Hayabusa will rendezvous with the half-kilometer rock and spend several months looking for a good spot to touch down. After collecting some dust from Itokawa's surface, the probe will set off back toward Earth and land in Australia in mid-2007.

Coriolis

The US Air Force Coriolis satellite, launched into a polar orbit in January 2003, is now returning astronomical results. The main instrument on Coriolis is a microwave dish studying the winds over Earth's ocean surface, but it also carries the Solar Mass Ejection Imager (SMEI), an all-sky camera capable of extremely accurate photometry (0.1 percent). Built by teams in Birmingham, England, and San Diego, California, in collaboration with the US Air Force Research Laboratory, SMEI is optimized to detect faint visible-light emissions from solar eruptions heading toward the Earth. The instrument's three cameras operate at visible and near-infrared wavelengths (450 to 950 nanometers), suppress stray sunlight by 15 orders of magnitude, and can show faint, diffuse features on the sky with 12-arcminute resolution. The instrument generates an all-sky image every orbit; astronomers expect it to provide accurate light curves for bright variable stars in addition to its main goal of imaging solar-ejected plasma.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*



S. JAMES TAPPIN, UNIVERSITY OF BIRMINGHAM

mission update *by jonathan mcdowell*

EUROPEAN SPACE AGENCY

Mars Express

Europe's Mars Express orbiter completed its formal scientific commissioning on June 3rd, but the mission has run into a problem with one of its main science instruments. The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) will use long radio waves to penetrate the Martian surface to search for deeply buried water or ice. The deployment of its 40-meter-long (130-foot) antenna has been put on hold, however, because of a possible design flaw. Although prelaunch studies indicated that its two spring-loaded antennas would lock into place smoothly, in March engineers raised new concerns that the flexible rods might whip back with enough force to damage other parts of the spacecraft. Simulations have failed to resolve the issue, and for now the deployment is on hold. MARSIS will be the first active radar sounder on a deep-space mission since Apollo 17 probed the lunar surface.

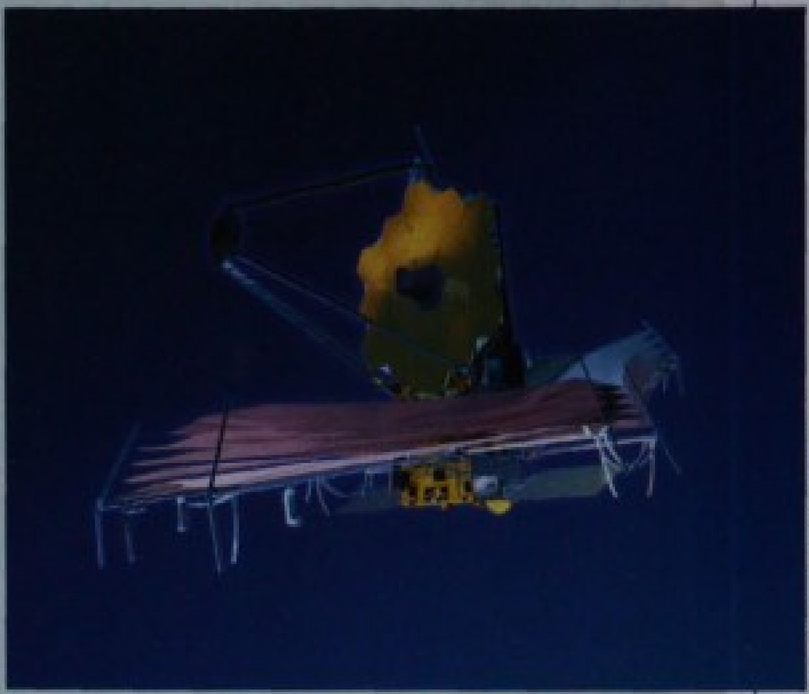
The spacecraft arrived in Martian orbit last December 25th. After an initial period of science operations, flight controllers adjusted its orbit on May 6th, lowering the highest point to 10,000 kilometers (6,000 miles). For several months the high-resolution stereo camera charted spectacular volcanoes and canyons, as well as complemented the continuing operations of the US rovers. Mars Express now has its closest approach (260 km) on the night side of the planet, and scientific activity has shifted to its atmospheric spectrometers.

James Webb Space Telescope

Development of the James Webb Space Telescope (JWST) took a step forward in June with the announcement that the European Space Agency (ESA) will fund its share of the construction of the Mid Infrared Instrument (MIRI). This camera and spectrograph are critical for studying the structure of the earliest, most distant galaxies, whose visible starlight is redshifted far into the infrared. MIRI will operate in the 5- to 28-micron range, and its imaging component will make pictures with 0.1-arcsecond-wide pixels across a 1-arcminute field of view. The Jet Propulsion Laboratory will build the instrument in collaboration with the European team.

ESA is also providing NIRSpec, a near-infrared multi-object spectrograph sensitive from 0.6 to 5 microns, and probably an Ariane 5 launcher to get JWST to its solar orbit in 2011. NASA will be responsible for the spacecraft, the telescope, and the near-infrared imaging camera (NIRCam). Developed by a University of Arizona team, the 0.6- to 5-micron NIRCam will be the main imaging instrument on JWST. With a pixel size of 0.03 arcsecond and a several-arcminute field of view, it will not only have red-light capability similar to the Hubble Space Telescope's Advanced Camera for Surveys, but also will supersede the capability of the Spitzer Space Telescope's Infrared Array Camera. MIRI will fill in the spectral gap between Spitzer's instruments and will have much better resolution.

On the other hand, JWST covers a much narrower spectral range than Hubble and Spitzer together can, as it lacks coverage in the far infrared and in the yellow-to-ultraviolet realm.



NORTHROP GRUMMAN SPACE TECHNOLOGY

FUSE

The Far Ultraviolet Spectroscopic Explorer (FUSE) satellite celebrated its fifth anniversary in June, having acquired more than 29,000 spectra of 2,000 targets with a total exposure time of 1½ years. Despite a crisis with the attitude-control system in 2001 and later gyroscope problems — both overcome with software fixes — FUSE continues to operate well with no near-term technical limits on its future health. The sensitivity of its ultraviolet instrument has declined by only 20 percent, which is rather good considering that UV coatings are notoriously difficult to keep free of contamination. FUSE has confirmed the existence of a halo of hot, ionized gas around the Milky Way Galaxy, thus helping astronomers understand the importance of halo and intergalactic material in the evolution of galaxies. It has also made strides in the cosmologically important measurement of deuterium abundance in our galaxy. University of Colorado researchers recently used FUSE to estimate that this hydrogen isotope exists at 23 parts per million in our galaxy. The ratio for the entire universe is only slightly higher, suggesting that less deuterium has been destroyed by stellar processes than expected.

JONATHAN McDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (www.planet4589.org/space/jsr/jsr.html).*

mission update *by jonathan mcdowell*

Hubble Space Telescope

One of the Hubble Space Telescope's premier science instruments failed on August 3rd. A power converter blew in the main electronics box for the Space Telescope Imaging Spectrograph (STIS), the only detector on Hubble that can record spectra in visible and ultraviolet light, leaving it unusable — most likely permanently — and the telescope without a crucial capability.

This is a huge blow to astronomers, since spectra are needed to study the chemical composition and physical state of the objects Hubble examines, and to measure redshifts of galaxies and gas velocities around black holes — all science goals that the remaining instruments cannot help with. Furthermore, STIS's ultraviolet capability is unique, because ultraviolet light from space doesn't reach ground-based telescopes. This leaves astronomers without any way to record the important ultraviolet spectral fingerprints of ionized hydrogen and carbon considered crucial to studies of quasars and of the atmospheres of hot stars. Hubble's keen sight also allowed STIS to take spectra of very small regions within larger sources, a key factor in revealing the prevalence of supermassive black holes in the cores of galaxies.


NASA

STIS was added to Hubble in February 1997 during the second Space Shuttle servicing mission, replacing two earlier instruments: the Faint Object Spectrograph and the Goddard High Resolution Spectrograph. Its successor, the Cosmic Origins Spectrograph (COS), is ready for launch but has been grounded indefinitely because of the ban, currently under review, on post-*Columbia* shuttle missions to service the Hubble telescope (last month's issue, page 26).

Submillimeter Wave Astronomy Satellite

On July 23rd the groundbreaking Submillimeter Wave Astronomy Satellite (SWAS) took its last scientific data and entered a standby mode. Although the science instrument remains fully usable, two laser diodes in the spectrograph are nearing the end of their lives. In its retirement, SWAS will be used to test new software for satellite subsystems.

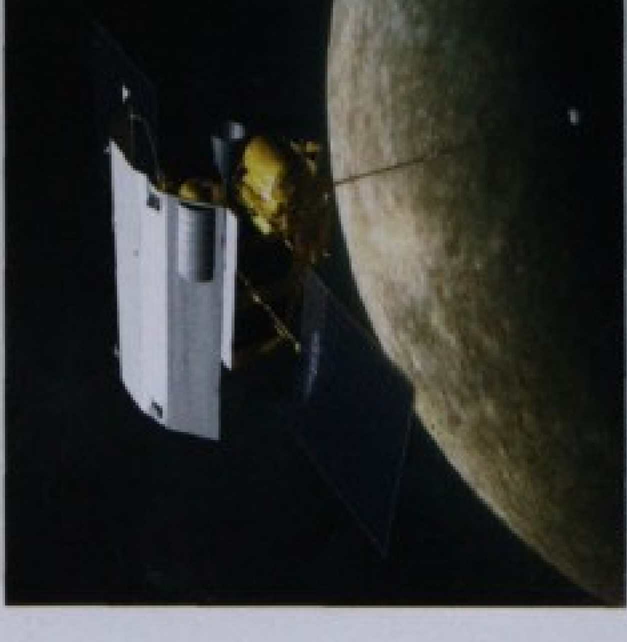
Launched in December 1998, SWAS studied emission from water molecules in our galaxy to map the chemistry of star-formation regions. Its original two-year mission stretched to five, with main operations concluding in September 2003. Its earlier studies probed the structure of the upper atmosphere of Mars and caught the onset of a localized dust storm, providing critical new information on how the Martian atmosphere can redistribute itself when a storm hits. Taking advantage of the improved sensitivity afforded by the close opposition of Mars, NASA approved a special observation campaign for the still-healthy satellite in the fourth quarter of 2003.

SWAS lay idle for a few months until a pair of two-week campaigns for a similar study of water in the atmosphere of Venus took place in March and July 2004. This had never been attempted because it violated a mission rule that SWAS shouldn't point near the Sun.

Messenger

After a one-day delay because of clouds from Hurricane Alex, NASA's seventh Discovery planetary mission is now on its way to the solar system's innermost world. The Mercury Surface, Space Environment, Geochemistry, and Ranging mission — known as Messenger — lifted off from Cape Canaveral on August 3rd. Operated by Johns Hopkins University's Applied Physics Laboratory, the probe passed the orbit of the Moon a day later. The Delta rocket's final stage left Messenger escaping from Earth about 54 kilometers per hour slower than planned, an amount that flight controllers can easily make up with the first course correction.

Messenger's first solar orbit is a 365-day circuit inclined 6° to Earth's orbital plane. After one year the craft will make a close Earth flyby to redirect it into an orbit that swings inward past Venus. After two close brushes with that planet, Messenger will end up with a perihelion near Mercury, allowing flybys of the innermost planet starting in 2008. Getting into orbit around Mercury is much tougher, however, as Messenger must lose a lot of speed to match the planet's orbital velocity. Three Mercury gravity assists will slow the probe enough to drop into an elliptical polar orbit on the fourth encounter in 2011. Messenger's expected arrival at Mercury is several years later than originally planned, but it will still get there ahead of the rival European mission, BepiColombo, whose launch has slipped from 2010 to 2012.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JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

mission update *by jonathan mcdowell*

Beagle 2

Following a scathing internal inquiry in May by the European Space Agency (ESA) and the British National Space Centre that criticized the Beagle 2 Mars lander project for inadequate management and testing, the Beagle team has released its own assessment of the mission. That review defends the lander's design and concludes that incorrect models of the Martian atmosphere may have caused the probe to crash.

Atmospheric density is used as a guide during landing preparations; thinner air means both a faster descent and later activation times. After riding piggyback to Mars on ESA's Mars Express orbiter, Beagle 2 was last seen a few minutes after it separated from that spacecraft on December 19, 2003. Five days later it entered the Martian atmosphere at a speed of 5.5 kilometers per second, and it should have landed on the surface 4 minutes later. NASA's Spirit and Opportunity rovers both experienced thinner atmospheres than expected during their landings in January, squeaking by to safety with parachute openings that were later than originally planned. It's possible that Beagle 2 failed to deploy its airbags or parachutes at all before it slammed into the surface.

The team does acknowledge that the mission was incorrectly treated as if it were just another science instrument attached to the orbiter, rather than as a much more complex enterprise requiring additional resources and funding.


BEAGLE 2 PROJECT. ALL RIGHTS RESERVED

Genesis


NASA

When its sample-return capsule slammed into the Utah desert on September 8th, Genesis's three-year flight to collect solar wind samples came to a catastrophic end. But much of the mission may be salvaged.

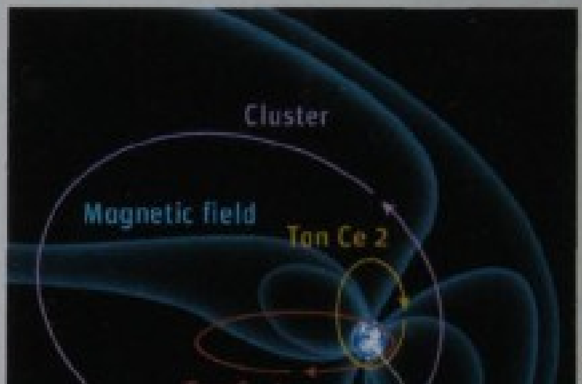
The capsule separated from the main spacecraft 60,000 kilometers above Earth and made a successful atmospheric entry at 11 km per second. But the mortar used to deploy the capsule's parachute did not fire, and the tumbling vehicle streaked past the waiting capture helicopters and hit the ground at around 85 meters per second (190 miles per hour). Rescuers found the capsule cracked open and partly embedded in the desert floor, in the middle of its target area in the Great Salt Lake Desert.

The Genesis space probe was launched in August 2001 to orbit the L_1 Lagrangian point, 1.5 million km sunward from Earth, where it collected atoms of the solar wind. It became the first spacecraft to return to the Earth's surface from beyond the distance of the Moon. Its payload consisted of 275 wafers of silicon, sapphire, gold, and diamond that were exposed to space for 29 months.

Scientists hope that the largely intact wafers picked out of the wreckage are sufficiently uncontaminated to reveal the isotopic makeup of the gas streaming through interplanetary space, and thus the exact composition of the Sun. The ratio of oxygen's three isotopes is particularly crucial, since it seems to vary from planet to planet and cosmochemists are not sure why.

Double Star

The People's Republic of China launched Tan Ce 2, the second and last Double Star satellite, into polar orbit on July 25th, a half year after its equatorial-orbit twin. The Double Star program combines Chinese satellite and rocket technology with European space-science instrumentation left over from the Cluster magnetospheric research project. The two Tan Ce ("Explorer") satellites will probe Earth's inner magnetosphere from relatively low-altitude, elongated orbits in collaboration with the four European Cluster satellites — Tango, Rumba, Samba, and Salsa — which are in higher polar orbits.



S&T: GREGG DINDERMAN; SOURCE: ESA

Launched southward from China's Taiyuan spaceport, Tan Ce 2 reached an orbit that carries it 39,000 km above the Arctic Circle; Tan Ce 1 has an apogee of 79,000 km over the equator, like that of the Cluster armada. The new satellite carries a complement of proton and electron detectors, magnetometers, and long antennas to measure plasma-wave phenomena, as well as an advanced neutral-atom imager that takes "pictures" of the magnetosphere by detecting atoms rather than light.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly electronic newsletter on the space program (www.planet4589.org/space/jsr/jsr.html).*

mission update *by jonathan mcdowell*

Genesis

Thousands of broken shards from the sample collectors of the Genesis spacecraft have been sent for analysis to NASA's Johnson Space Center (see last month's issue, page 26). Preliminary investigation indicates that the parachute failed to deploy during reentry due to a design error in the switches that should have detected the capsule's deceleration.

The Genesis sample-return canister was ejected from its parent spacecraft at 11:53 Universal Time on September 8, 2004, and entered the atmosphere four hours later. Meanwhile, the rest of the spacecraft made a course change at 12:08 UT so that it missed Earth and headed back out into deep space. By November, the spacecraft should be at the edge of Earth's gravitational influence. The Genesis team has proposed an "Exodus" follow-on mission to enter solar orbit and monitor the solar wind, but funding for this is not yet secured.

New Horizons

Success of the New Horizons mission to Pluto and the Kuiper Belt has been threatened by the shutdown of work at Los Alamos National Laboratory after a security breach. This has delayed production of the plutonium-238 fuel for the spacecraft's thermoelectric power source. NASA now plans to go ahead with the January 2006 launch with as little as 80 percent of the planned plutonium load, which should permit the Pluto flyby in 2015 but may leave the probe with insufficient power to return data from encounters with Kuiper Belt asteroids.

The 465-kilogram (1,020-pound) craft will carry six main science instruments. The primary cameras are the Long Range Reconnaissance Imager (LORRI) and the two-part Pluto Exploration Remote Sensing Investigation (PERSI). The latter has an ultraviolet detector called Alice and a visible-infrared camera system called Ralph (which is behind schedule and over budget). Two plasma instruments will study low- and high-energy particles. A dust counter will sample trans-Neptunian space, and the X-band radio system will also be used for scientific measurements.

An Atlas 5 rocket will boost New Horizons toward a gravity-assist flyby of Jupiter one year after launch. After passing just outside the orbit of Callisto, the craft will be on course for an eight-year coast to Pluto and its moon Charon. The probe will explore the distant Kuiper Belt if it has any energy left. New Horizons principal investigator Alan Stern (Southwest Research Institute) is arguing for an extra mission as a backup. New Horizons 2 would target 1999 TC_{36}, a binary Kuiper Belt object, as well as other minor planets — if plutonium production is restored.

Astrosat

The Indian Space Research Organisation (ISRO) is developing Astrosat, its first dedicated astronomy satellite. The spacecraft will be launched in 2007 and will carry ultraviolet and X-ray instruments for observations of variability in active galactic nuclei, cyclotron emission lines in X-ray binaries, and a six-month UV survey of the galactic polar regions.

Two 40-centimeter (16-inch) telescopes make up the UV imaging instrument — one for far-UV (120–180 nanometers) and the other for near-UV (180–280 nm). The largest X-ray instrument will have sensitivity similar to the Rossi XTE detector but with a much broader energy window. Scanning sky monitors will continue the legacy of XTE's all-sky detectors and identify transient sources, while four coded-mask telescopes will provide better spectral resolution than a similar telescope on the Swift satellite. A soft X-ray telescope fills out Astrosat's capabilities.

Scientists from the Raman Research Institute, the Indian Institute of Astrophysics, the ISRO Satellite Centre, the Inter-University Centre for Astronomy and Astrophysics, and the Tata Institute of Fundamental Research are involved in the project. India has a significant heritage of space astronomy, but this is the first Indian science mission competitive with contemporary satellites from the United States and Europe.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

mission update *by jonathan mcdowell*

SOFIA


LOWELL OBSERVATORY

The airplane-based Stratospheric Observatory for Infrared Astronomy (SOFIA) – a joint venture between NASA and the German space agency, DLR – passed several important milestones in recent months. In August engineers interrupted their preparation of the Boeing 747SP aircraft to attach the first science instrument to the telescope temporarily (see the photograph at right), then rolled the plane out from its hangar to sit under the Waco, Texas, sky. The High-speed Imaging Photometer for Occultations (HIPO) made its first astronomical observations from the taxiway.

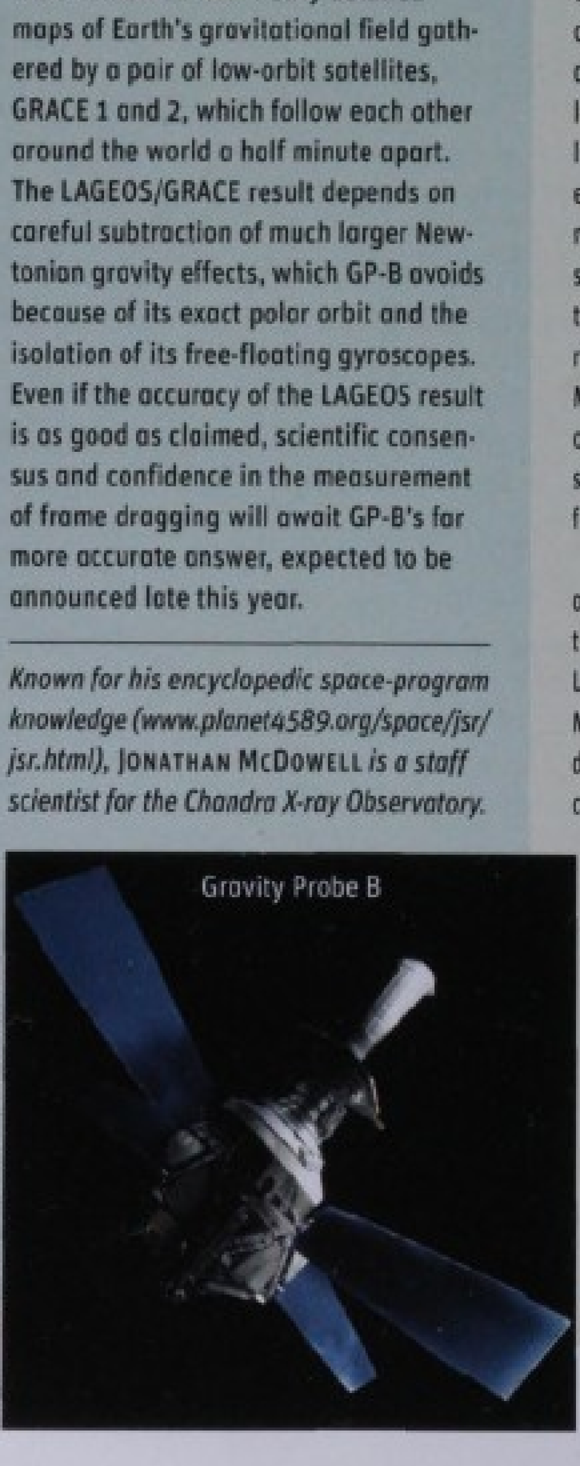
After this shakeout of the telescope and successful capture of light from Polaris, work shifted back to the 747. During a comprehensive maintenance check in October, two engines and the upper half of the aperture door arrived for installation. The aircraft will perform test flights at Waco in early 2005, then will fly to NASA's Ames Research Center in California. Once the science instruments are completed and installed, test flights will resume in late 2005 – when the science team will open the plane's huge fuselage aperture for the first time and make airborne observations.

Gravity Probe B

GP-B continues its quest to prove the existence of the relativistic "frame dragging" of space-time, more formally known as the Lense-Thirring effect (*S&T:* July 2004, page 22). Early troubles delayed the start of full science operations (with all four gyroscopes aligned on target star IM Pegasi) until September 16th, more than five months after launch. And that milestone was followed by further glitches. In October the forces applied to the spinning gyros resonated with the sloshing of liquid helium in the spacecraft's dewar, causing problems for the control system. Two gyros repeatedly switched operating modes until flight controllers made adjustments. On November 10th a solar event intensified the lower portion of Earth's radiation belt and forced GP-B into a safe mode, interrupting observations for a couple of days. However, these difficulties have reduced only slightly the data to be collected during the satellite's 13-month mission, which will provide precise measurements of gravitational subtleties predicted by the general theory of relativity.

Meanwhile, physicists are intrigued by last October's controversial claim that researchers have measured the frame-dragging effect in orbital shifts of the two LAGEOS satellites (January issue, page 26). Measurements of this pair of high-orbit laser-ranging targets were combined with newly detailed maps of Earth's gravitational field gathered by a pair of low-orbit satellites, GRACE 1 and 2, which follow each other around the world a half minute apart. The LAGEOS/GRACE result depends on careful subtraction of much larger Newtonian gravity effects, which GP-B avoids because of its exact polar orbit and the isolation of its free-floating gyroscopes. Even if the accuracy of the LAGEOS result is as good as claimed, scientific consensus and confidence in the measurement of frame dragging will await GP-B's far more accurate answer, expected to be announced late this year.

Known for his encyclopedic space-program knowledge (www.planet4589.org/space/jsr/jsr.html), JONATHAN MCDOWELL *is a staff scientist for the Chandra X-ray Observatory.*


Gravity Probe B
KATHERINE STEPHENSON / STANFORD UNIV. / LOCKHEED MARTIN

SMART-1

The European Space Agency's first Small Missions for Advanced Research in Technology spacecraft (SMART-1) has reached lunar orbit after a year in space. It was carried as a piggyback payload on an Ariane rocket launching commercial communications satellites in September 2003 and put into an elongated orbit reaching to 36,000 kilometers. The satellite's ion-powered propulsion system – which gives a very weak thrust for very long durations – gradually raised the altitude to edge it toward the Moon. In an innovative technique, SMART-1's orbit was synchronized with the Moon in such a way that it received repeated boosts from lunar gravity.

On November 11th, after 322 loops around Earth, the spacecraft finally crossed the weak gravitational boundary at the L_1 Lagrangian point between Earth and the Moon. Thereafter, its orbit was better described as Moon-centered than Earth-centered. SMART-1's first lunar orbit, inclined 81° to the Moon's equator, brought it to within 5,000 km of the surface four days later and then back out to 51,400 km, the most loosely bound lunar orbit ever achieved. Since then SMART-1's xenon-ion engine has shrunk the orbit and bound the craft more tightly to the Moon. By January the spacecraft was to be looping between 300 and 3,000 km from the surface, and instruments were to begin hunting for ice hidden in shadow at the lunar poles.

Swift

Swift – an innovative satellite designed to locate and study gamma-ray bursts (GRBs) – was launched on November 20, 2004, into a 600-kilometer equatorial orbit. By early December, all its instruments had been activated and were observing the sky. Full operation of Swift was not expected until January.

Swift is the next step in a long effort to understand GRBs – intense seconds-long bursts of radiation coming from deep space (*S&T:* March 2004, page 32). Previous missions, such as Italy's BeppoSAX and the international High Energy Transient Explorer 2, made steps toward pinpointing them, but Swift takes a different approach – it's optimized to detect GRB afterglows with a trio of specialized instruments.

Its wide-area search system is the Burst Alert Telescope (BAT), a coded-mask telescope with a cadmium-mercury-telluride detector sensitive to "hard" X-rays with energies between 15,000 and 150,000 electron volts (eV). BAT made its first sky image on December 3, 2004. BAT can see 10 percent of the sky at once. When a GRB occurs, it will immediately trigger the satellite to point roughly at the site of the burst so that the X-ray Telescope (XRT), working in the softer 300- to 1,000-eV energy range, and the 30-centimeter Ultraviolet/Optical Telescope (UVOT), will catch the resulting light and zero in on the burst's location.

The accurate position obtained by XRT and UVOT will also be flashed to astronomers worldwide, who will then rush to use ground-based telescopes and other satellites to catch the afterglow before it fades. XRT and UVOT will also take spectra to measure the glow's redshift and physical properties.

Soon after launch, engineers discovered that XRT has a faulty power supply

NASA

in its cooler. The telescope can still operate, but it may have to run its CCDs hotter than planned, which will lower their sensitivity.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

ESA

Rosetta

After a year orbiting the Sun, Europe's comet-bound Rosetta spacecraft will fly by Earth in March. Last November 25th a rocket burn changed Rosetta's speed by a mere 9 centimeters per second, precisely targeting its approach. Rosetta will pass within 4,500 km of Earth's surface and will pick up enough speed to throw it on course for a Martian gravity-assist flyby in early 2007. More Earth flybys are necessary before Rosetta can match position and speed with the comet 67P/Churyumov-Gerasimenko in 2014. Engineers completed Rosetta's commissioning phase in October, with a thorough workout of the probe's spectrometers and imagers as well as a checkout of the lander systems.

Constellation-X

Despite budget cuts to Constellation-X, the planned successor to the Chandra X-ray Observatory, technology development for the next generation of X-ray telescopes continues. A major challenge is to make images at higher X-ray energies than is possible with optics like those on Chandra or Swift while providing more spatial resolution than current high-energy instruments have.

Last September a US-Japanese team flew a balloon payload over Texas to test one of the first high-energy X-ray focusing telescopes. The InFOCuS instrument consists of conical aluminum-foil mirrors – similar to the ones on Japan's Astro E satellite (*S&T:* April 2004, page 28) – with alternating super-thin layers ("multilayers") of platinum and carbon. The coatings allow InFOCuS to reflect the high-energy photons that would pass through older telescope designs. Lofted to a height of 39 km (24 miles), the telescope imaged an X-ray pulsar with two-arcminute resolution – an order of magnitude better than coded-mask imagers in the same energy range.

In 2001, NASA's Marshall Space Flight Center flew a balloon payload called High Energy Replicated Optics (HERO), which made the first images with focused hard X-rays. An improved version of HERO with more than 15 times as much collecting area will get its chance to fly in early 2005.

TAKASHI OKAJIMA (NASA / GSFC)

mission update *by jonathan mcdowell*

Mars Science Laboratory

NASA's Mars Science Laboratory (MSL) represents a giant leap in capability over the Mars Exploration Rovers (MERs). It is designed to study its landing site as a potential habitat for life, has a planned lifetime of two years, and has a minimum range of several kilometers. Scheduled for launch in December 2009, it will follow two non-rover missions: the 2005 Mars Reconnaissance Orbiter, which will look for a good MSL landing site, and the 2007 Phoenix Mars Lander, which will study ice near the Martian north pole.


NASA / JPL

Including its interplanetary cruise stage, MSL will weigh 3 metric tons compared to the 1-ton MERs, and it needs a bigger Delta 4 or Atlas 5 rocket instead of the cheaper Delta 2 used by recent Mars missions. MSL is too heavy for an airbag landing system, so it will use a new technique in which the lander first jettisons its parachute at an altitude of 500 meters, then uses rockets to slow down and hover only 5 meters above the surface, and finally lowers the rover slowly to the ground on a rope.

The ambitious MSL is more like a modern version of the 1970s Viking landers than the small, lightweight 1990s Mars orbiters and landers. The MERs use a rotating drill to strip off and study rock surfaces. MSL will carry a laser to do the same thing by zapping the rocks from up to 10 meters away and then analyzing the materials underneath. Let's hope the Martians won't be alarmed.

MSL will carry a microscope with 2.4 times more resolution than the one on the 2004 rovers, and it will perform two key analysis experiments known as CheMin and SAM. CheMin will use X-ray diffraction and fluorescence to determine the mineral makeup of rock and soil. SAM, the Sample Analysis at Mars suite, will have a gas chromatograph mass spectrometer and a laser spectrometer capable of detecting organic compounds in both atmospheric and surface samples.

Mars Science Laboratory Instruments

Name	Measurement
MSL Mast Camera	High-resolution stereo images
Laser Induced Remote Sensing for Chemistry and Micro-Imaging	Laser ablation, remote sensing of rocks
Mars Hand Lens Imager	Microscopic imager
Alpha Particle X-ray Spectrometer	Elemental composition of rocks
X-ray Diffraction/ Fluorescence instrument	Sample analysis
Radiation Assessment Detector	Radiation environment
Mars Descent Imager	Pictures during landing
Sample Analysis at Mars	Mineral and gas analysis suite
Pulsed Neutron Source and Detector	Hydrogen measurements
Meteorology Package	Atmospheric conditions
Ultraviolet Sensor	Ultraviolet flux

Lunar Reconnaissance Orbiter

Although the human-exploration component of NASA's "New Vision for the Nation's Space Exploration" remains cloudy, the shift in priorities for robotic missions is gaining momentum. The first venture resulting from President George W. Bush's initiative is the Lunar Reconnaissance Orbiter, or LRO, due for launch in October 2008. In December 2004, NASA announced LRO's experiments.

The mission will measure the radiation environment in lunar orbit, the detailed topography of the Moon's surface, the distribution of hydrogen in the extremely thin atmosphere, the temperature distributions in the permanently shadowed areas, and the reserves of water ice near the poles.

Researchers building Boston University's Cosmic Ray Telescope for the Effects of Radiation (Crater) will use "tissue-equivalent plastics" to simulate the human body and measure the radiation dose that astronauts would receive if they spent prolonged periods in lunar orbit. The Southwest Research Institute's far-ultraviolet Lyman-Alpha Mapping Project (LAMP) will search for lunar resources, particularly polar water ice, by taking pictures of permanently shadowed polar crater areas using faint reflected ultraviolet starlight.

Northwestern University's LRO Camera consists of two narrow-angle cameras with half-meter resolution for landing-site imaging and one wide-angle camera with 100-meter resolution, which will complement the Clementine spacecraft's old green-to-infrared lunar maps with new blue and near-ultraviolet ones. The shorter-wavelength mapping will help astronomers survey minerals that could be later mined for iron and oxygen.

The 500-kilogram craft, plus its onboard propellant for lunar-orbit insertion (also about 500 kg), will lift off via a three-stage Delta rocket. LRO will operate in a polar orbit only 50 kilometers above the lunar surface — one-tenth as high as Clementine orbited and half as high as the Apollo and Lunar Prospector missions. Its nominal life span is one year, after which it might be placed into a higher orbit, where it can act as a communications relay.

Lunar Reconnaissance Orbiter Instruments

Name	Measurement
Lunar Orbiter Laser Altimeter	Global surface topography
LRO Camera	Landing-site imaging
Lunar Exploration Neutron Detector	Water ice via neutron flux
Diviner Lunar Radiometer Experiment	Temperature map
Lyman-Alpha Mapping Project	Frost in shadowed craters
Cosmic Ray Telescope for the Effects of Radiation	Radiation environment

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

mission update *by jonathan mcdowell*

Mars Express/Beagle-2

After a year's delay, European Space Agency officials will finally deploy the two long antenna booms of the Mars Express MARSIS radar sounder this May. In April 2004 the booms' US manufacturer, Astro Aerospace, became worried that the antennas might spring out so violently during deployment that the appendages could wrap around and hit the spacecraft, causing a premature end to Mars Express's science mission (*S&T:* October 2004, page 27). After months of review, ESA decided that though there is a small risk that the booms might get stuck in the deployment, there's no danger of damaging the spacecraft. Therefore officials gave the MARSIS team the go-ahead for deployment. Spacecraft radars have studied the Moon, Earth, and Venus, but this will be the first close-up radar study of Mars.

A less successful aspect of the Mars Express mission was the loss of the United Kingdom's Beagle-2 lander. Last year, mission scientists led by the Open University's Colin Pillinger suggested that bad luck in the form of an unexpectedly thin Martian atmosphere may have fooled Beagle-2 into crashing (December 2004, page 26). In January, though, a scathing report from the official independent review board was made public. Dismissing the thin-atmosphere excuse, the report enumerates a laundry list of design problems, any of which could have compromised the landing attempt. The group concludes that Beagle-2 should never have been launched.


NASA / GSFC

Swift

Scientists are continuing diagnostic tests of NASA's Swift gamma-ray-burst (GRB) observatory. In a departure from its main mission, Swift used its 30-cm Ultraviolet/Optical Telescope (UVOT) to snap a six-filter (three in visible light, three in ultraviolet) calibration image of the nearby face-on spiral galaxy M101 in Ursa Major.

As of mid-February, UVOT hadn't imaged any burst afterglows — a good candidate on January 26 was out of bounds because it was only a few degrees from Vega, which is so bright that it might have damaged the instruments. The X-Ray Telescope (XRT) has had better luck. On January 17th Swift fully demonstrated its unique capability when its onboard computer automatically whirled the satellite around in response to a GRB in Cassiopeia, allowing XRT to image the burst and determine its position only three minutes after the event had begun.

During January Swift also took test images with XRT to improve the craft's ability to locate the positions of sources — expected to reach about 5 arcseconds when calibration is complete. The more precisely Swift can locate a burst, the easier it is for other telescopes to pick out the optical fireball for follow-up studies. By mid-February ground-based telescopes had analyzed several Swift detections, but the telescope had yet to relay GRB finds directly to observatories on Earth.

Deep Impact

The Deep Impact space probe successfully lifted off from Cape Canaveral, Florida, on January 12th. In July the 1-metric-ton vehicle will release a 372-kilogram "impactor spacecraft." On July 4th this craft will slam into the surface of Comet 9P/Tempel 1 at a speed of 10.2 kilometers per second (22,800 miles per hour), gouging a crater in the nucleus and sending a plume of material into space.

The main spacecraft will fly past the impact site at a safe, 500-km distance and will train its instruments on the plume and crater, giving astronomers an unprecedented close-up view of a cometary nucleus's interior makeup. The flyby spacecraft carries a 30-centimeter high-resolution telescope as well as a mercury-cadmium-telluride near-infrared imaging spectrometer array and a wider-angle multiband camera.


NASA

Jonathan McDowell, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

follow that story

SUPERNOVAE ARE NOT ROUND, CONTINUED

Now that many pulsars have been observed racing across interstellar space at several hundred kilometers per second, astronomers realize that the core-collapse supernovae giving birth to these objects are often aspherical. This observation and others have led to theoretical research by J. Craig Wheeler and Lifan Wang (University of Texas, Austin) suggesting that jets play a major role in supernovae formation, just as they do in gamma-ray bursts (*S&T:* January 2002, page 40).

Supernova 2004dj, which flared last July in the galaxy NGC 2403 in Camelopardalis, gives credence to these ideas. Using the 3-meter telescope at Lick Observatory, Douglas C. Leonard (now at Caltech) and his colleagues measured significant polarization in the supernova's ejecta at a critical moment: just when the opaque, expanding gaseous envelope surrounding the ejecta cooled and thinned enough to expose the hot inner core of the explosion. The degree of polarization suggests an elongated inner core, just as the Wheeler/Wang model predicts. "These observations point to asphericity in the explosion mechanism," says observing team member Alexei V. Filippenko (University of California, Berkeley). "Jets may be important in the explosion, but our data don't necessarily require jets." — R. N.

Big Bang Material Brewed?

ACCORDING TO A PAPER in the March 18th *Physical Review Letters*, experiments at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven, New York, may have succeeded in creating a quark-gluon plasma over the past few years by slamming together gold nuclei at high velocities. This soup of free quarks (particles that make up protons and neutrons) and gluons (particles that transmit the strong nuclear force) existed in nature for only a few millionths of a second after the Big Bang.

The paper, by University of Washington physicists John G. Cramer and Gerald A. Miller, explains why the gold collisions produce fireballs that appear smaller and shorter-lived than predicted, which had led to skepticism that the plasma had been created. "We have converted a piece of evidence that seemed to contradict the quark-gluon plasma scenario into evidence in support of the scenario," says Cramer. "A microsecond after the Big Bang, there was a state of matter that no one was able to investigate until very recently. Our understanding is growing." — R. N.

mission update *by jonathan mcdowell*

Rosetta

The European Space Agency's Rosetta comet probe completed its first lap around the Sun on March 4th and used Earth's gravity to sling it toward its next encounter: Mars in 2007.

The flyby took place only 1,955 kilometers (1,215 miles) above Baja California, Mexico, and allowed amateur astronomers the rare opportunity to image an interplanetary spacecraft in midflight (see the image above). As backyard telescopes pointed at Rosetta, the craft looked back at them, using the flyby as an opportunity to test the comet orbiter's science instruments.

Scientists took the opportunity to test Rosetta's asteroid flyby mode. When probes fly past small targets — such as asteroids — whose orbits aren't perfectly known, it's often a challenge to make sure the camera is pointed correctly. Past probes used a scattershot approach with the hope of capturing the target in at least *some* of the pictures. Rosetta uses an onboard guider camera to detect and track the asteroid with its camera. In this test, the "asteroid" was Earth's Moon, and it stayed centered in the camera's field as Rosetta zipped by.

Rosetta's first real asteroid encounter will be with 2867 Steins in 2008, on the way to its final destination in 2014, Comet 67P/Churyumov-Gerasimenko. Once there, it will observe the comet and release a lander dubbed Philae.

New Horizons

Construction of the New Horizons spacecraft is nearing completion at the Applied Physics Laboratory in Maryland. Last year mission planners were concerned about a lack of plutonium fuel for the craft's radioisotope thermoelectric generators because of a work shutdown at Los Alamos National Laboratory. It now appears that the mission's fuel tanks won't be full, but there should be enough energy to keep the probe alive until it reaches the Kuiper Belt.

New Horizons will use the new Atlas V rocket. To date the launch vehicle has flown five times — all successfully. The Atlas V will carry many future NASA science missions, starting with the Mars Reconnaissance Orbiter set to launch in August of this year. However, the version used by the Pluto probe will be the most powerful ever launched. It will sport a record five solid boosters strapped onto the rocket's first stage and an extra solid-fuel "kick stage" that will give the probe its final boost toward the outer solar system. New Horizons will lift off in January 2006. It has a Jupiter gravity-assist flyby in 2007 and a flyby of Pluto and Charon in 2015. It will observe other Kuiper Belt objects after that.

New Horizons has had a rocky road to the launch pad. The Bush administration tried to cancel it several times, but congressional and public support has forced the agency to keep it alive.

JIMO

The ambitious Jupiter Icy Moons Orbiter was axed in the Bush administration's latest budget request. This move isn't terribly surprising — JIMO's projected cost was more than $10 billion and the mission's specific scientific goals were still unclear. The 20-metric-ton spacecraft would have launched in 2015 and orbited Ganymede, Callisto, and Europa in turn.

JIMO was announced in 2003 as a replacement mission for a smaller-scale ($1 billion) Europa orbiter that had been abandoned a few months earlier. At the time many planetary scientists expressed fear that JIMO was an unrealistic proposal and would eventually be canceled.

Their concern was justified. The death of JIMO further delays the "high-priority" search for a putative Europa subsurface ocean. Moreover, the prospects for future outer-planet exploration missions appear bleak as NASA focuses on the Moon and Mars.

JIMO was part of NASA's Project Prometheus nuclear-technology program and was to feature a Navy-built fission reactor that would provide 100 kilowatts of energy to the craft's electric-propulsion system as well as to a large battery of instruments.

NASA will continue efforts to develop nuclear-powered spacecraft but with a less aggressive flight program.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

mission update *by jonathan mcdowell*

Hard Times for Space Science

AS A NEW LEADER takes the helm at NASA, the future of the United States space-science program is in doubt. Although spectacular results continue to pour in from NASA's interplanetary spacecraft and robotic telescopes, the long-term funding prospects for space astronomy are looking bleak. Back in 2001 former NASA administrator Sean O'Keefe was appointed to solve NASA's budget problems and put the International Space Station back on track. But his tenure was dominated by the 2003 *Columbia* accident. When he announced his resignation on December 13, 2004, the budget problems still remained and the future of the station was even more in doubt.

On January 14, 2004, President George W. Bush announced his administration's new Vision for Space Exploration, which focuses on human space flight to the Moon and Mars. It's an ambitious and exciting plan that is projected to cost more than $50 billion over the next 15 years. Unfortunately that doesn't leave room for many of NASA's existing programs. To put these numbers in perspective, NASA's total budget was bumped from $15.4 billion to $16.2 billion in 2005. It is projected to be $18 billion by 2009. The increases don't make up the difference in costs, and thus many things will hit the cutting-room floor. The current plan is to phase out the Space Shuttle at the end of the decade and abandon significant US funding for the space station soon after it's completed.

Michael Griffin succeeds Sean O'Keefe as NASA administrator.

And all the while, funding for science won't keep up with inflation. For the early part of this year, with acting administrator and former astronaut Fred Gregory holding the reins, cutbacks hit science hard thanks to the costs of "Return to Flight" for the shuttle.

NASA's new boss, Michael D. Griffin, rose to prominence in the 1980s as the head technologist for the Strategic Defense Initiative Organization, where his work included three pioneering low-cost, quick-turnaround Delta space missions that led to the "faster, better, cheaper" approach of the 1990s. Griffin later went to NASA to lead George H. W. Bush's late-1980s Moon-Mars initiative, which foundered because of its over-ambitious scope and lack of political support.

After the "reign of the bean counters," I'm encouraged to see a new leader who has six engineering and physics degrees. My impression is that O'Keefe's admittedly difficult decision to decommission the Hubble Space Telescope might have been different had it been made by someone with technical expertise. On a more hopeful note, Griffin's April 12th testimony to Congress suggests that he may reverse O'Keefe's Hubble death sentence. Before the Senate panel, he declared, "The decision not to execute the planned shuttle servicing mission was made in the immediate aftermath of the loss of *Columbia*. . . . In light of what we learn after we return to flight, we should revisit the earlier decision."

On Capitol Hill, Griffin was quite clear: "Those who claim that NASA cannot afford robust programs in both robotic science and manned space flight are mistaken." He added, "NASA can do more than one thing at a time."

Griffin has long been a cheerleader for human space exploration and is expected to enthusiastically support President Bush's Moon-Mars initiative. On the other hand, he has previously expressed a marked lack of enthusiasm for the shuttle program.

In today's NASA, lunar and Martian probes are expected to continue receiving preferred funding; future exoplanet missions like the Terrestrial Planet Finder have strong support, as does the infrared James Webb Space Telescope. Yet the outer planets, galactic and extragalactic astronomy, high-energy astrophysics, and cosmology programs have been under increased fiscal pressure. Flagship missions flying at the peak of their scientific return such as Hubble and the Chandra X-ray Observatory were recently hit with major cuts to their operating budgets.

At least they fared better than older missions like Voyager. Budget makers have threatened to turn the probes off permanently to save a measly few million dollars a year.

Ironically, studies of solar physics and solar-terrestrial interactions, topics that are critical for astronaut safety, are also among the areas being slashed by NASA. The TRACE solar observatory and several magnetosphere probes have been put on the chopping block along with the Voyagers.

Only one Small Explorers (missions costing less than $120 million) program was selected this year instead of two. Last year's Medium-class Explorers (missions costing less than $180 million) proposals were postponed first to 2005 and now to at least 2006. On a larger scale, the Constellation-X follow-on mission to the Chandra X-ray Observatory is facing further delays, and the idea of merging it with the European Space Agency's XEUS X-ray Observatory is being floated.

Griffin's appointment marks the beginning of a new era at NASA set against the backdrop of the Bush initiative and the shuttle's return to flight. How he molds the agency in the coming months and years, and how the monies are divided in the next budget cycle, will define his tenure and will determine the future of space science in America.

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mission update *by jonathan mcdowell*

Astro-E2

JAPAN HAS BEEN a major player in space science since it first came on the scene in the early 1970s. Specializing in X-ray astronomy and high-energy solar physics, the Institute of Space and Astronautical Science (ISAS) drew international attention with its X-ray satellites Ginga (1987) and ASCA (1993). Both returned important results in areas where the United States and Europe had left gaps. Now ISAS, having since merged with two other Japanese agencies to form the Japan Aerospace Exploration Agency, JAXA, is preparing to launch three new major astronomy missions from the Uchinoura Space Center in Kagoshima prefecture. The first satellite, Astro-E2 (*S&T*: April 2004, page 28), is scheduled for launch around August 2005 aboard an M-V rocket. Guest observations by American astronomers will begin seven months later.

Astro-E2, like its ill-fated predecessor Astro-E (*S&T*: May 2000, page 26), is an X-ray observatory that will complement NASA's Chandra X-ray Observatory and the European Space Agency's XMM-Newton. The 1,700 kilogram (3,700 pound) spacecraft will debut a new type of high-spectral-resolution detector called a microcalorimeter. Astro-E2 carries five 40-centimeter (15.7-inch) X-ray telescopes with focal lengths from 4.5 to 4.75 meters. Four are equipped with CCD detectors and one with the microcalorimeter.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at*

Solar-B


ISAS/JAXA

Solar-B, the successor to Japan's solar observatory, Solar-A (Yohkoh), reached another milestone. Engineers at the Harvard-Smithsonian Center for Astrophysics have completed its X-ray telescope (XRT) and will ship it to NASA's Marshall Space Flight Center in Huntsville, Alabama, in June. The instrument will reach Japan a few months later, where it will be integrated with the main Solar-B satellite for launch in August 2006.

Working in the 200-to-2,000-electron-volt band, Solar-B's X-ray telescope has several times the resolution of its predecessor. In addition, the satellite's higher data-transmission rate, huge CCD detectors, and wide, 34-arcminute field of view will combine to yield the best full-Sun soft (low-energy) X-ray data set yet.

XRT is only part of the Solar-B mission — it piggybacks along with a 0.5-meter solar optical telescope (SOT), something solar physicists have been fighting to fly since the early 1980s. SOT has ⅕-arcsecond resolution in the 480–650 nanometer waveband, and it has an imager, a magnetograph, and a spectrograph. With its third Solar-B instrument — an extreme-ultraviolet spectrograph — Solar-B is the most capable solar-astronomy satellite ever. It is designed to operate for seven years after launch.

Astro-F

Another forthcoming mission is Astro-F, a 67-cm infrared telescope, which will make the first far-infrared all-sky survey since the pioneering 1983 Infrared Astronomical Satellite (IRAS) mission. The 1-metric-ton satellite will feature a high-tech, lightweight silicon-carbide mirror coated with a thin layer of gold and a liquid-helium cryostat to cool the whole telescope to 6° Kelvin (–449°F).

This isn't Japan's first venture into space-borne infrared astronomy. Sounding-rocket flights in the 1980s were followed by a modest 15-cm telescope on the 1995 Space Flyer Unit satellite.

Astro-F's all-sky survey is expected to catalog some 10 million objects, 50 times more than IRAS, using the Far Infrared Surveyor (FIS) instrument. The device will be cooled to only 1.8°K and will use four high-sensitivity germanium-gallium semiconductor detectors to cover the 50-to-200-micron range with a spatial resolution of less than 1 arcminute. Astro-F also carries an infrared camera (IRC) along with three subinstruments providing coverage from 2 to 26 microns. IRC has 2-arcsecond resolution across a 10-arcminute field of view.

After a two-month checkout period, Astro-F will first use FIS to survey the sky for six months and then use the IRC in pointing mode while FIS fills in the missing bits of surveyed sky. The satellite's liquid-helium cryogen will run out about 18 months after launch. When it's gone, FIS will become unusable. But the short-wavelength IRC can continue operating indefinitely without coolant.

Hubble's Prospects Brighten

UNDER ITS NEW CHIEF, Michael D. Griffin (July issue, page 24), NASA has resumed preparations for a possible shuttle flight to service the Hubble Space Telescope. Although a decision won't be made until after two successful post-*Columbia* shuttle missions to the International Space Station, the observatory's prospects look better now than at any time since Griffin's predecessor, Sean O'Keefe, abruptly canceled Hubble servicing in January 2004 (*S&T*: April 2004, page 24).

At an April 29th NASA press conference, Griffin said that a robotic servicing mission, once offered as a less risky alternative to a shuttle flight (August 2004, page 28), is no longer under consideration. Robotic servicing "is just not feasible within the time and the money that we have to allow for it," he explained.

— RICHARD TRESCH FIENBERG

mission update *by jonathan mcdowell*

WISE

NASA is planning a new mission to survey the infrared sky. Unlike Spitzer, which looks at small areas of space in detail, WISE (Wide-field Infrared Survey Explorer) will map the whole sky and create a catalog of infrared sources that can be followed up by the much-anticipated James Webb Space Telescope.

The first satellite to conduct an infrared sky survey, the Infrared Astronomical Satellite (IRAS), flew in 1983. It carried a 60-centimeter liquid-helium-cooled telescope. Scheduled for launch in 2009, WISE's smaller 40-cm, solid-hydrogen-cooled telescope is 1,000 times more sensitive than IRAS, thanks to advances in detector technology. WISE's data will be combined with shorter-wavelength, ground-based Two Micron All Sky Survey data to provide a comprehensive database of the infrared sky. However, WISE is sensitive only in the mid-infrared (3.5, 4.6, 12, and 23 microns). It won't supersede IRAS data in the far-infrared 60- and 100-micron bands. That's the job of Japan's ASTRO-F (August issue, page 25).

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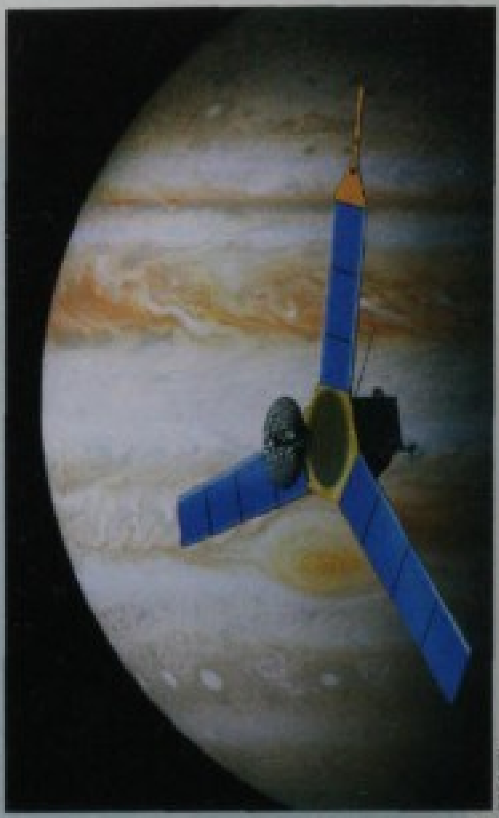
Juno


NASA/JPL

NASA has decided on its second New Frontiers mission, while the first in the series, the Pluto/Kuiper Belt–bound New Horizons, prepares for its January 2006 launch. The new mission, Juno, will examine Jupiter from an elliptical, polar orbit. This trajectory allows Juno to avoid the worst of Jupiter's intense radiation while still allowing the craft to study the global dynamics of the atmosphere, its chemical composition (including water and ammonia abundance), and the structure of the inner magnetic field.

The solar-powered Juno will briefly probe deep into Jupiter's deadly radiation belts — passing above the cloudtops at only 5,000 kilometers (3,100 miles) at closest approach. The low orbit allows scientists to look for evidence of a Jovian core.

Juno's proposed instruments include an ultraviolet imaging spectrograph, built to take spectacular ultraviolet pictures of auroras, and the Jovian Auroral Distributions Experiment (JADE), which will measure electrons and ions along Jupiter's magnetic-field lines. Juno also carries an imager built to shoot weather movies and to take polar pictures.

The mission is managed by the Jet Propulsion Laboratory, led by Scott Bolton (Southwest Research Institute), and will be built by Lockheed Martin. Launch is expected around 2010.

50 & 25 years ago *by leif j. robinson*

SEPTEMBER 1955

Neptune's Rotation "Neptune has an appreciably shorter rotation period than the 15.8 hours found spectrographically by J. H. Moore and D. H. Menzel in 1932, states Dr. O. Guenther, Muenster Observatory, Germany. He has analyzed photographic brightness measurements by J. Brouet in 1932, and from these finds the Neptunian day to be 12 hours 43.5 minutes."

Oops! Neptune's rotation period is now determined to be 16 hours 6.5 minutes, so Moore and Menzel had it just about right.

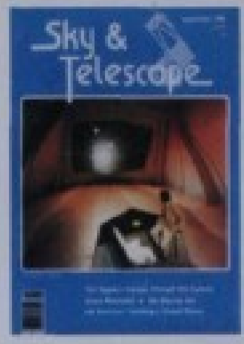
SEPTEMBER 1980

Mapping Venus "Knowledge of Venus has come slowly, . . . owing primarily to the opaque, searing atmosphere that surrounds it.

"But now, thanks to a radar mapper aboard the Pioneer Venus orbiter and to 1½ years of successful operation, scientists have pieced together a good idea of how the entire planet (except the polar regions) would look if its thick clouds could be stripped away. . . .

"According to Gordon Pettengill and Harold Masursky, . . . the planet possesses three general kinds of terrain. Most common is a planetwide belt of relatively flat rolling plains. . . . This terrain lies near the planet's mean radius of 6,051 km, the 'sea level' of an arid world. Another [terrain] . . . is below the mean radius, forming large shallow basins and valleys.

"The final [terrain] . . . sits at least 1 km higher than average, of which one third . . . is considered true highlands. . . . Maxwell Montes, the highest features seen, stand nearly 11 km above the mean radius."



Pioneer Venus was followed by four Soviet Venera spacecraft that encountered Venus in 1982 and 1983. Yet it was the radar imaging, surface-altitude measurements, and gravity mapping by NASA's Magellan orbiter in the early 1990s that revolutionized our understanding of Venus's surface.

Astronomy on TV "[*Cosmos*] attempts to convey astronomy to an enormous audience — estimated to approach 150,000,000 viewers worldwide. . . . [Carl Sagan] has amassed an arsenal of special effects guaranteed to dazzle even the most casual viewer. . . .

"Sagan's own production company and KCET have at their disposal $8,000,000 in funding."

The 13 hour-long segments of Cosmos *were unquestionably the most successful popularizations of astronomy ever. When will we see the likes of Sagan again?*

mission update *by jonathan mcdowell*

Spitzer

The Spitzer Space Telescope is celebrating its second anniversary and is continuing to return spectacular results. Nevertheless the infrared telescope's team had a brief scare on April 24th when the spacecraft went into hibernation after a gyroscope hiccupped. After troubleshooting the problem engineers revealed the culprit: a sticky relay. Cycling the relay restored it to operation, and engineers are convinced that the telescope's hardware remains in good shape.

Spitzer's liquid-helium coolant is being used up at about the rate expected before launch, which would allow the spacecraft to run to at least 2008. To help further postpone its eventual demise, mission planners are now grouping the telescope's long-wavelength observations into batches. This limits the number of times the coolant-hogging far-infrared detector needs to be chilled. The tactic should add several months to the life of the mission. Spitzer is currently trailing Earth in its solar orbit by about 28 million kilometers.


NASA / JPL / CALTECH

Cosmos-1/Volna

The ambitious privately funded Planetary Society solar-sail mission, Cosmos-1, was lost during launch on June 21st. The K-496 *Borisoglebsk*, a Kalmar-class submarine in the Barents Sea, launched the Volna missile that carried the ill-fated satellite.

Officials are still disputing exactly what went wrong — the rocket builders reported that the missile failed 83 seconds into flight, falling back to Earth from about 200 kilometers (120 miles). But other Russian scientists claimed to have telemetry from the satellite at 750 km during the apogee burn 15 minutes later; a failed apogee burn would have led to a crash into the Pacific Ocean. However, it's not unknown for stray signals to be confused with the real target. I strongly suspect that the apogee-burn report is wrong, and in any case, Cosmos-1 has not been heard from since.

If it had reached orbit, Cosmos-1 would have deployed 8 blades of aluminized Mylar spanning 30 meters. The planned 850-km orbit was high enough that solar radiation pressure of about 5 micropascals (7×10^{-10} pounds per square inch) would have helped create a resulting thrust of 0.03 Newton (kilogram meter per second squared). Cosmos 1 would have been the first spacecraft to use solar radiation pressure for propulsion.

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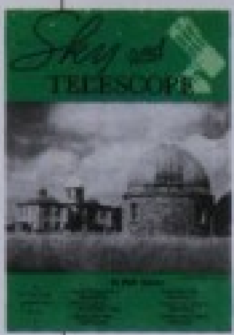
50 & 25 years ago *by leif j. robinson*

OCTOBER 1955

Nearest Stars "To find which kinds of stars actually are the most numerous, it is best to make a stellar census within a relatively small volume around the sun. The list given here is of all known stars within five parsecs — 16 light-years — of the sun. . . .

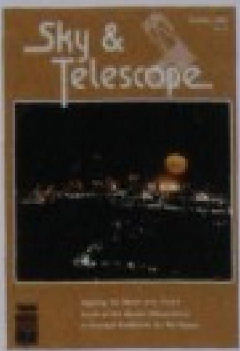


"Among these nearby stars, two facts stand out. The majority are faint; less than a dozen are visible to the naked eye. Double stars are common. Of the 42 entries in the table, 30 are single stars, 10 are double star systems, and two are triple systems."

Not counting multiple systems, Hipparcos satellite data and new surveys now yield 47 stars within 16 light-years of Earth. Nine of these are double systems and three are triple. One new addition, 2MASS 0253+16, jumped into sixth place among all systems, being only 7.9 light-years away.

OCTOBER 1980

Second Editor of *S&T* "August 4, 1980: Joseph Ashbrook, editor of *Sky and Telescope* since 1964, passed away at the age of 62.



"So diverse were the interests and talents of this major figure in science popularization — so varied were the lives he touched personally, scientifically, and through his typewriter — that no one person could write a proper appreciation.

"Therefore, I've asked a few of his friends to contribute their reflections. Together, these provide an overview greater than the sum of their parts. And that is what Joe wanted from every story."

Thus I began a four-page tribute to the man I succeeded as editor of S&T.

Hale Observatories Breakup "Two of America's most famous observatories are no longer jointly administered. California Institute of Technology and the Carnegie Institution of Washington had managed the Hale Observatories, consisting of Mount Wilson and Palomar Mountain observatories, for more than three decades."

At that time these sites were occupied by four of the most celebrated telescopes in the world, the 60- and 100-inch reflectors at Mount Wilson and the 200-inch reflector and 48-inch Schmidt at Palomar. Carnegie, responsible for Mount Wilson, later abandoned it, to focus its attention on the Las Campanas Observatory in Chile.

mission update *by jonathan mcdowell*

Suzaku

Only a month after its July 10th launch, the Japanese/American Suzaku X-ray observatory (formerly known as Astro-E2) lost the use of its X-ray Spectrometer (XRS), the first high-energy calorimeter to fly in orbit and the mission's flagship instrument. The calorimeter had been successfully cooled to 0.06°C above absolute zero in late July, and mission engineers had demonstrated the instrument's high-resolution capabilities during onboard calibration tests. But on August 8th, before the XRS took its first glimpse of the sky, all of the helium coolant boiled away due to a leak in its multistage cooling system.

Losing the XRS represents a severe blow to X-ray astronomy. The calorimeter was first planned to fly on the Chandra X-ray Observatory, but it split off in the early 1990s to fly on a different X-ray telescope that was soon canceled. After that, the XRS was added to the Japanese Astro-E mission, which failed to reach orbit in 2000 (*S&T:* May 2000, page 26). Suzaku is Astro-E's replacement mission.

Suzaku's other instruments, four CCD imagers and a hard-X-ray detector, continue to work well. But it was the XRS that would have made Suzaku a world-class mission.


NASA / KENNEDY SPACE CENTER

Return to Flight

After a two-year hiatus, the Space Shuttle returned to flight on July 26th. But NASA's space-flight troubles are far from over. Despite redesign efforts, the amount of debris hitting the orbiter on ascent, while only one-sixth as bad as before, was still unacceptable. A pair of small foam fragments fell from near the same region as the piece that fatally crippled *Columbia* – an area thought to have been fixed. Another piece of debris appeared to damage a thermal blanket on the side of the crew cabin.

The August 9th reentry and landing went off without incident, but the next mission, STS 121, will be delayed indefinitely while the debris problems are addressed. It seems that Space Station crews will have to wait until at least March 2006 for a return visit. And if that launch doesn't eliminate the scary flying pieces of foam, I suspect that an immediate end to the Shuttle program is likely.

Even if STS 121 restores confidence in the Shuttle, design of the replacement Crew Exploration Vehicle is expected to accelerate next year with the selection of a manufacturer and a basic design.

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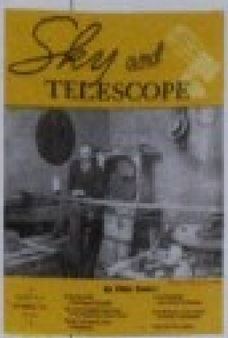
50 & 25 years ago *by leif j. robinson*

NOVEMBER 1955

Moon Mapping "The moon is receiving increasing attention from both amateur and professional astronomers, as our satellite now seems less remote and unapproachable than it did a few years ago. There is new interest in the precise mapping of the moon, and with this in the measurement of the relative elevations of points on the lunar surface. . . .



"Recently Dr. G. Schrutka-Rechtenstamm, at the Vienna Observatory, has published a catalogue of the altitudes of some 160 points, mostly near the central part of the moon's disk."

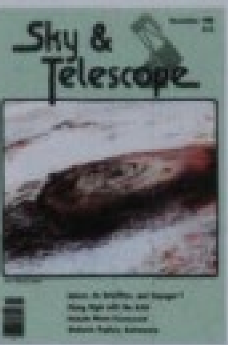
Then: Measurements were made from ground-based, near-side photographs with a millimeter ruler. Now: We have mapped the entire Moon in exquisite detail, including elevations, using the Clementine spacecraft.

Relativistic Radiation "Temperatures of millions of degrees would be required to produce the observed high intensities in the meter wave length range for the bright sources such as Cassiopeia A, Cygnus A, and the like. . . . Among the leaders in interpretation are two Soviet radio astronomers, I. S. Shklovsky and V. L. Ginsburg. They have suggested that the radiation comes from relativistic (very fast-moving) electrons, the motions of which are determined by interstellar magnetic fields."

They were correct to invoke so-called synchrotron emission for both the Cassiopeia A supernova remnant and the Cygnus radio galaxy.

NOVEMBER 1980

Early Space Flight "[Karel Jan Bossart] designed the Atlas missile, our country's first effective ICBM defense and, in the early 1960's, the only available launch vehicle capable of lofting the Mercury astronauts into orbit.



"The Atlas had four distinctive features in its day. It was the first successful missile which was aerodynamically unstable; it had the first gimbaled motors; when fueled, its fragile structure could not support its weight on the launching pad, relying instead on internal pressure within the fuel tanks to provide much of its structural rigidity; and finally, to improve reliability, all of its rocket motors were ignited on the ground."

The Mercury project first shot Alan B. Shepard Jr. into suborbit on a Redstone rocket in May 1961; an Atlas carried John Glenn into orbit in February 1962; Gordon Cooper made the last flight in May 1963. Mercury was the first step toward landing men on the Moon in 1969.

mission update *by jonathan mcdowell*

Venus Express

The European Space Agency (ESA) is turning its eye to Venus. Its new low-cost Venus Express spacecraft is a near-copy of the successful Mars Express (see page 30). Scheduled for launch on October 26th, Venus Express will reach its destination in April 2006 and enter an elliptical orbit that will bring it to within 250 kilometers (155 miles) of the Venusian poles.

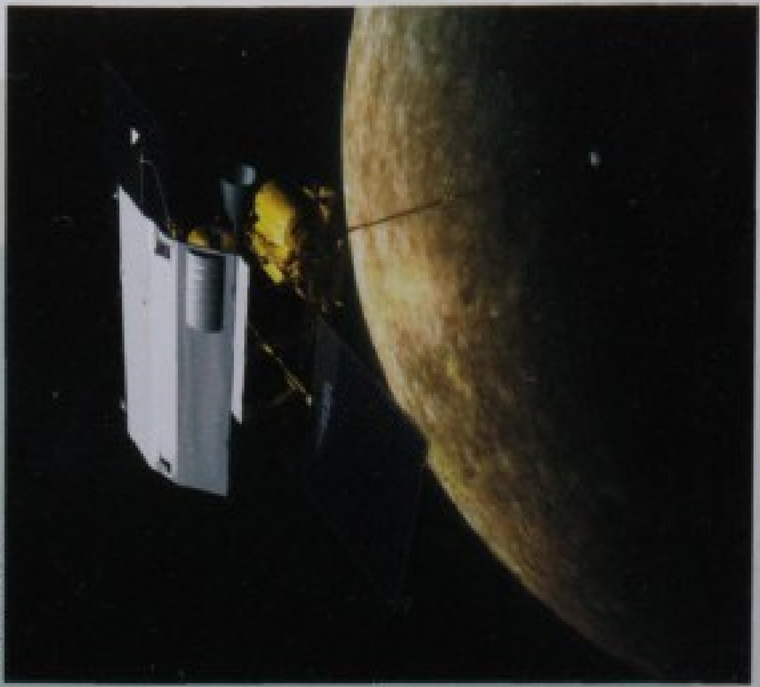

ESA

The spacecraft carries many of the same experiments as Mars Express, including infrared and ultraviolet spectrometers and a radio-science experiment. What's missing are the high-resolution stereo camera (HRSC), the visible and infrared mineralogical-mapping spectrometer (OMEGA), and the subsurface sounding radar altimeter (MARSIS), which have been replaced by a new Venus Monitoring Camera (VMC), an extra spectrometer, and an experiment to study the planet's magnetic field.

This is the first European mission to Venus and the first Venus probe from any country since NASA's Magellan completed its mission a decade ago. ESA's main science goals are to study the global characteristics and circulation of Venus's atmosphere, the air's composition as a function of altitude, and the interaction of the atmosphere with the surface and the solar wind.

VMC's ultraviolet, visible, and infrared bands will allow Venus Express to image both atmospheric cloud systems and surface features. The elliptical orbit allows VMC to see the whole planet at once when the spacecraft is at the farthest point in its orbit as well as imaging details as small as 200 meters (660 feet) when it's at its closest.

Messenger


NASA / JHU-APL / CIW

NASA's Messenger space probe marked its first year in solar orbit with a 2,347-kilometer-high (1,458-mile) flyby over Mongolia on August 2nd. Venus flybys in October 2006 and June 2007 will set Messenger up for its arrival at Mercury in 2008. That event will mark humanity's first visit to the innermost planet since Mariner 10 flew by in 1975.

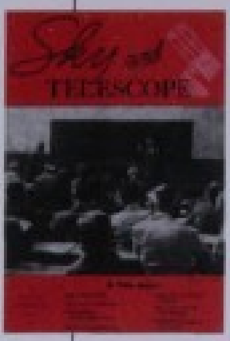
During the August encounter Messenger successfully tested its camera and made measurements of Earth's magnetosphere.

Jonathan McDowell, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

50 & 25 years ago *by leif j. robinson*

DECEMBER 1955

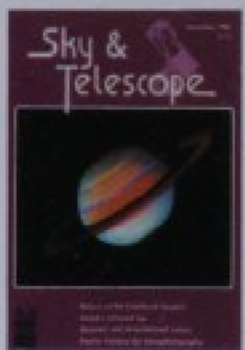
Newborn Stars "One of the most exciting and controversial papers was 'On the Nature and Origin of the T Tauri Stars,' by G. H. Herbig, of Lick Observatory. He attempted to give a positive answer to the question, 'Are the T Tauri variables new stars, recently formed or still forming within the nebulae, or are they ordinary field stars that have encountered the gas and dust clouds accidentally, and are in process of being modified — perhaps rather superficially — by their environment?' He presented evidence that the T Tauri stars as a class are newly formed. Two objects of stellar appearance are visible on Lick plates taken in December, 1954, and were not present on plates taken in January, 1947. Dr. Herbig stresses the fact that the apparently new objects did not develop out of any stars that had been visible at those positions in the past."



George Herbig's interpretation was correct. T Tauri stars are usually found in groups, embedded in dense patches of gas and dust from which they formed. Evidence for these objects' youth comes particularly from their abundance of lithium, an element that is destroyed early in a star's lifetime.

DECEMBER 1980

Seeing Red "Only recently have astronomers begun to probe the universe in what is now called the infrared wavelength region, between 10,000 angstroms (1 micron) and 1 millimeter. In the past 15 years the newly developed techniques of infrared astronomy have led to many exciting and revolutionary discoveries."



First Gravitational Lens "Observations of a pair of 17th-magnitude quasars on March 29, 1979, initiated a chain of discoveries that led astronomers to conclude that gravitational lenses have been detected. . . .

"The two objects . . . had nearly identical spectra. Also, their redshifts were both about 1.40. . . . These facts, coupled with the close proximity of the quasars in the sky, argued strongly for their physical association."

In December 1979 the Palomar 200-inch Hale Telescope detected a 19th-magnitude giant elliptical galaxy between the two images of the quasar 0957+561. It proved to be the lens that split the quasar's light into two components separated by 6 arcseconds.

mission update *by jonathan mcdowell*

Apollo Again?

Almost two years after President Bush introduced his "Vision for Space Exploration," NASA administrator Michael Griffin announced a human Moon-mission strategy he calls "Apollo on steroids." The new plan is indeed remarkably similar to Apollo, with a stubby Apollo-like module remaining in lunar orbit while a spidery lunar module transports a crew to the surface.

There are plenty of differences though. The new crew module carries at least four astronauts instead of three, and the beefy cylindrical service module will have solar panels and enough fuel to enter a polar orbit. Newly developed engines will burn methane fuel — propellant that can be manufactured on the Red Planet as part of the possible follow-on Mars program.

Instead of a single enormous Saturn-V rocket, NASA is now opting for a two-part approach. First, a new heavy-lift booster will launch an empty lunar module and a heavy translunar upper-stage engine into Earth orbit. Soon after, a smaller rocket will launch the crew module and the astronauts, who will dock with the lunar package before setting out toward the Moon.

The smaller crew-module rocket will consist of a single modified shuttle solid rocket booster that is topped by a new upper stage propelled by one Space Shuttle main engine. A crew module equipped with an escape rocket will ride on top of that. Meanwhile, the heavy-lift vehicle also uses shuttle components — an external tank with five shuttle engines mounted underneath, two shuttle strap-on boosters, and the translunar stage on top. This arrangement will annoy Boeing and Lockheed Martin, which wanted to sell their Delta and Atlas rockets for the job, but it saves the current shuttle workforce from major layoffs.

With Griffin's goal of launching a crew module in 2011 and a "seventh human lunar landing" by 2018, developing two new spacecraft and two new rockets will be a challenge. In the 1960s NASA engineers did the same job in a much shorter time period, but today's NASA isn't as agile as it used to be, and lunar missions are unlikely to have the same political priority they had during the Apollo era. Griffin's announcement, which came as the country was reeling from the projected cleanup costs for Hurricane Katrina, received a notably lukewarm reception in political circles.

Griffin claims the project can be accomplished for $104 billion over 13 years, requiring only a modest NASA budget increase as funds from the space station and shuttle are reallocated. But many observers are highly skeptical of the math, suggesting that even with the shuttle's retirement around 2010, there won't be enough money freed up to fund the early development costs. Worse, skeptics note, longer-term

NASA / JOHN FRASSANITO AND ASSOCIATES

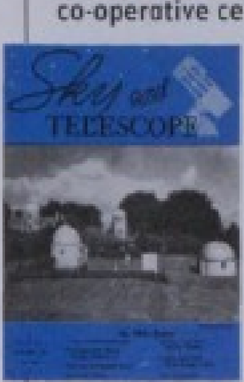
cost projections are far too optimistic. One leaked internal NASA projection showed $160 billion costs over the same period. Many observers, including me, fear that the worst outcome of all would be if most of the NASA budget over the next few years is moved from other space projects to the lunar mission but spiraling costs cause its cancellation before launch.

JONATHAN McDOWELL, a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.

50 & 25 years ago *by leif j. robinson*

JANUARY 1956

Desert Astronomy "It was urged [in 1953] that a co-operative center for all types of observation would provide a great stimulus to American astronomy. . . .

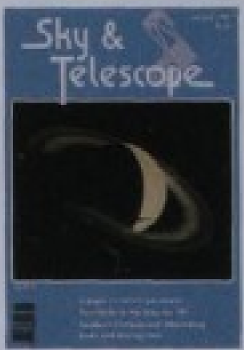


"Although the research to be done at the new observatory would provide ample justification for building it, of equal importance would be its educational functions."

Kitt Peak National Observatory, 90 kilometers (56 miles) southwest of Tucson, Arizona, was dedicated in 1958. Since then it has continued to fulfill its mission as a national facility for astronomical research.

JANUARY 1981

Spying on Saturn "[Voyager 1's] trajectory [over Saturn] offered distinct improvements over the viewing geometries available from Earth. First, it passed only 124,200 km from those gold-hued cloud tops — about one Saturnian diameter away and 10,000 times closer than we ever get. Second, Voyager 1 spent almost a full day beneath the ring plane. There its instruments made extensive observations of the rings' unlit side, in much the same way Pioneer 11 did during its 1979 pass. Third, the system was viewed from an ever-changing phase angle (the Sun-rings-spacecraft angle), which permitted important checks on the directions in which individual ring particles scatter light."



After Saturn, Voyager 1 headed out of the plane of the solar system. In 2004, at a distance of 14 billion km, it crossed the termination shock, where charged particles in the solar wind merge with interstellar plasma.

astro news briefs

LBT SEES FIRST LIGHT The first of two 8.4-meter primary mirrors comprising the Large Binocular Telescope saw first light on October 12, 2005. Using the mirror, LBT astronomers took this image of the edge-on spiral galaxy NGC 891 in Andromeda. When the second mirror is installed and the facility becomes fully operational in autumn 2006, the $120 million LBT will be used as a powerful interferometer with the light-collecting area of a single 11.8-meter mirror and the resolution of a 22.8-meter telescope. The telescope, which is located on Mount Graham in southeastern Arizona, will, among other projects, image exoplanets and study galaxy formation in the early universe.

NGC 891

LBTO / UNIVERSITY OF ARIZONA

TUGBOAT CAN SAVE EARTH In the November 10, 2005, *Nature*, NASA astronauts Edward T. Lu and Stanley G. Love describe how an efficient "tugboat" mission could deflect a potential 200-meter (660-foot) asteroid on course for Earth. Instead of physically attaching itself to the rough, loose surface of a low-gravity asteroid, the spacecraft could simply hover in the direction of towing, angling thrusters outward so their exhaust misses the body. Gravity acts as the towline. By applying continuous weak thrust with a nuclear-electric ion engine as the asteroid rotates, the tugboat can pull the asteroid into a nonthreatening orbit without carrying large quantities of propellant. "This gravitational-tractor-beam solution is a wonderfully elegant solution, and it is well matched in capability to the most likely asteroid size we would have to deflect on a realistic time scale," says Daniel D. Durda (Southwest Research Institute, Colorado).

DISCOVERY CHANNEL TELESCOPE Corning, Inc., has completed the 4.3-meter mirror blank for the Discovery Channel Telescope (DCT), a partnership between the TV network and Lowell Observatory. The 3,000-kilogram (6,700-pound) blank will be polished over the next two to three years. When fully operational in 2010, the DCT will study the outer solar system and distant stars and galaxies.

mission update *by jonathan mcdowell*

Venus Express

ESA / STARSEM S. CORVAJA

The European Space Agency's Venus Express launched from Kazakhstan last November 9th. The $257 million mission was based on the Mars Express design, which itself used the basic spacecraft developed for the Rosetta comet probe. Venus Express carries cameras, spectrometers, and other instruments to study Venus's atmosphere and near-space environment from an elongated polar orbit. It will arrive in April 2006.

The launch marks the first major use of the new Cebreros deep-space tracking station in Spain, which replaces the Villafranca site used since the 1970s. Villafranca has become the European Space Astronomy Centre, a research facility that centralizes ESA's astronomy operations.

Hubble Space Telescope

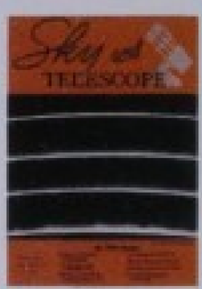
The fight to save the Hubble Space Telescope continues, with both bad and good news. Problems with the previous Space Shuttle *Discovery* mission mean further delays for the program, making it harder to fit a Hubble visit into the tight schedule remaining prior to the orbiters' retirement. On the other hand, the decision by NASA administrator Mike Griffin that the shuttle won't carry a de-orbiting module to Hubble makes a servicing mission much less expensive and much quicker to organize. Griffin's decision makes a great deal of sense, and I think the odds have now shifted in Hubble's favor.

In late August engineers turned off one of the three gyroscopes. With all three running, chances were that Hubble couldn't operate until the next shuttle visit. Saving one of them for later is expected to add an extra nine months to the telescope's lifetime.

In late 2005 the Hubble team discovered rapid deterioration in one of the four chips on the Wide Field Planetary Camera 2, the instrument used to take the majority of Hubble's most spectacular images. The other three WFPC2 chips, and the Advanced Camera for Surveys, are continuing their outstanding performance.

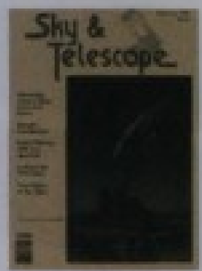
50 & 25 years ago *by leif j. robinson*

FEBRUARY 1956



Age of the Universe "Red shifts in the spectra of 620 galaxies and in 26 distant clusters of galaxies, obtained by Dr. [Milton] Humason, combined with red shifts of 300 galaxies measured by Dr. [Nicholas] Mayall . . . [suggest] the value of the Hubble constant, the measure of the rate of [cosmic] expansion, to be 180 kilometers per second per million parsecs, but this is provisional and may be uncertain by 20 per cent. It indicates the age of the expanding universe to be about 5.4 billion years."

The Hubble constant, a key factor in determining the age of the universe, had been shrinking continuously since 1936 when Edwin Hubble adopted 526 km per second per megaparsec. An age of 5.4 billion years was reassuring, for it could easily accommodate the age of Earth's oldest rocks. The 20 percent error was optimistic: the Hubble constant today is tightly constrained at about 70 km per second per megaparsec, yielding an age of around 13.7 billion years.



FEBRUARY 1981

Film's Last Hurrah "'Gas hypering' is the newest widely used term to enter the jargon of amateur astrophotographers. It refers to a process whereby a photographic emulsion, when soaked in hydrogen gas, is made more sensitive to faint light."

Stunning photographs were made with this technique, but their impact faded within a decade as charge-coupled devices (CCDs) took command.

mission update *by jonathan mcdowell*

Webb Space Telescope

Because of a $1 billion cost overrun, the James Webb Space Telescope's scheduled launch date has slipped two years to June 2013. After a scramble to investigate cost-saving measures — such as drastically shrinking the telescope's size — NASA decided to go ahead essentially as planned, but to stretch out the spending to keep within the agency's annual science budget. This still means that a billion dollars won't be available for other missions.

But there will be some cutbacks to JWST's capabilities. The 6.5-meter infrared telescope might not image perfectly at wavelengths shorter than 1.7 microns, since ground-based telescopes can cover that spectral region. The wavelength range of its Canadian Fine Guidance Sensor's tunable filter camera, one of four main instruments, was also scaled back. Such cuts will save more than $100 million.


NASA

Dawn

Another NASA mission is suffering from NASA's budget woes. The Dawn ion-drive asteroid explorer was originally scheduled to launch this June, and the spacecraft has already reached the integration and testing stage. But last October NASA Headquarters ordered the project to stand down. Technical problems have cropped up with the xenon fuel tank and the high-voltage power units in the ion engine, and officials were concerned that extra money might be required to fix things. The Dawn mission team is frustrated with the delay, but says that a year slip will still be within the mission's long launch window. The group hopes to receive the OK to start up again in time to send the probe off toward Ceres and Vesta in 2007.


NASA / ESA / HOWARD BOND / MARTIN BARSTOW

Sirius B's Mass Measured

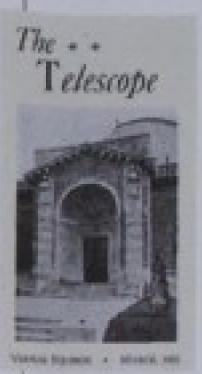
USING THE HUBBLE SPACE TELESCOPE'S imaging specrograph, a team led by Martin Barstow (University of Leicester, England) has measured the mass of Sirius B, the high-density core of a dead star. This white dwarf orbits Sirius A, the brightest star in the night sky. By measuring the degree to which the white dwarf's light is stretched (redshifted) by its powerful gravitational field (350,000 times Earth's surface field), Barstow and his colleagues determined that Sirius B contains 98 percent of the Sun's mass despite being smaller than Earth. This result closely agrees with previous measurements and theoretical predictions. In this Hubble image, Sirius A is the overexposed star with the diffraction spikes; Sirius B is the faint dot at the lower left.

The Hubble observations also revealed that Sirius A's temperature is approximately 25,000°C (45,000°F). — R. N.

75, 50 & 25 years ago *by leif j. robinson*

MARCH 1931

An S&T Precursor "With the publication of this number of *The Telescope*, there is inaugurated the first of a series of Quarterly Reviews of the work in progress at the Perkins Observatory.



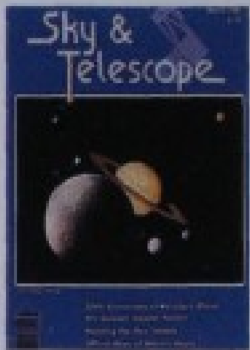
"In addition to reports from the Perkins Observatory itself, these issues will contain, from time to time, summaries of important discoveries in astronomy which may be of interest to the general reader."

In 1941 The Telescope, *published by Ohio Wesleyan University, would be merged with* The Sky, *published at New York City's Hayden Planetarium.*

MARCH 1956

Bigtime US Radio Astronomy "In his January budget message to Congress, President [Dwight] Eisenhower asked that $3,500,000 be appropriated to the National Science Foundation to construct a 140-foot [parabolic antenna] in the eastern United States, this instrument to be available to all astronomers for basic research."

This was the beginning of the National Radio Astronomy Observatory, which continues doing forefront research today. The 140-foot telescope in Green Bank, West Virginia, went into operation in 1965 and completed its last observation run in 1999.



MARCH 1981

The Quasar Engine "Since the discovery of quasars nearly 20 years ago, their physical nature has been a very perplexing problem to astronomers. . . .

"Observations of Seyfert galaxies suggest an obvious possible explanation of the quasar phenomenon, namely that they are the luminous nuclei of distant galaxies. . . . Precisely what powers these nuclei is not yet understood, though various manifestations of gravitational energy are frequently suggested."

Although many years were to pass, a consensus emerged among astronomers that quasars are powered by matter gravitationally falling into a supermassive black hole in the core of an otherwise normal galaxy.

mission update *by jonathan mcdowell*

New Horizons

On January 19th the $650 million New Horizons probe launched to the ninth planet, Pluto. The 465-kilogram (1,025-pound) spacecraft carries three cameras: an 8-centimeter-aperture (3-inch) instrument for visible and infrared imaging, an ultraviolet spectrometer, and a 20.8-cm telescope for long-range pictures. A dust sensor, an energetic-particle spectrometer, and a solar-wind instrument complete the small payload complement, together with the high-gain radio antenna (also used for science measurements). Unlike larger probes such as Voyager, the New Horizons instruments are fixed on the spacecraft instead of being mounted on a moving scan arm, so the whole vehicle must be pointed to aim the cameras.

As a tribute to Clyde Tombaugh, the man who discovered Pluto, a small amount of his cremated remains was placed onboard. The spacecraft will fly by Jupiter for a gravity assist in February 2007. In July 2015 the New Horizons flyby of Pluto and its three known moons will complete humanity's initial reconnaissance of all the traditional major planets in the solar system. But now there's 2003 UB_{313}, and maybe more to come. . . .

Stardust

The Stardust capsule landed successfully on January 15th in the highest-velocity spacecraft reentry ever. Its safe landing onto the Utah Test and Training Range marked the end of the probe's seven-year trek around the inner solar system.

Stardust launched in February 1999 and a year later deployed its aerogel collectors to soak up interplanetary and interstellar particles. Dust collection continued through the November 2002 flyby of asteroid 5535 Annefrank. In January 2004 Stardust reached its prime target, Comet 81P/Wild 2, and collected cometary particles on the back side of its aerogel samplers.

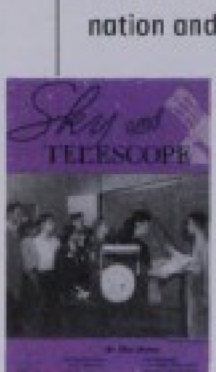
Soon after it landed, scientists examined the aerogel collectors and deemed the mission a triumphant success. According to lead scientist Donald Brownlee (University of Washington), Stardust may have collected more than a million microscopic specks of dust. The samples are undergoing analysis in Houston, Texas.

Stardust isn't the first vehicle to return to Earth from beyond lunar orbit. Most recently, in 2004, Genesis crash-landed at the Utah range at the end of its mission (*S&T:* December 2004, page 26). Fortunately, Stardust's parachutes deployed perfectly and didn't repeat Genesis's hard landing.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

50 & 25 years ago *by leif j. robinson*

APRIL 1956



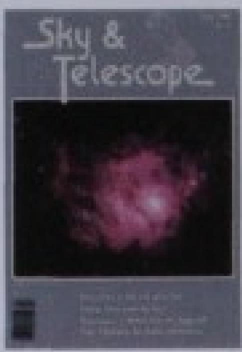
Good Counsel "Changes in the angles of illumination and observation alter the appearance of lunar scenery somewhat as a kaleidoscope redesigns its patterns. Mountain walls that tower tonight may appear insignificant tomorrow. Small craters that dot floors of larger rings under one illumination may be absent under others. Long clefts, clearly marked at times, vanish with the shifting of light and shadow. . . .

"Is it surprising, then, that so many dubious things have been seen on the moon? Among the oddities reported are snow, hoarfrost, vanishing craterlets and light streaks, gray or black areas of vegetation, and shadowy masses of moving animals. . . .

"Observers should distinguish between fact and fancy, moonlight and moonshine."

A frequent contributor to this magazine, Leland Copeland could not have presented a better case — especially in that innocent era — for caution in interpreting what one sees on the Moon.

APRIL 1981



Star Building "During the past decade the quest to understand star formation has become one of the most active endeavors in Milky Way research. . . .

"There is now a firm bridge connecting studies in the farthest infrared with ones at the shortest radio wavelengths. These studies, combined with spectrographic observations of objects that were out of reach 10 years ago, are giving us a fascinatingly complete picture of the physical conditions and processes at work inside the clouds of gas and dust. We suspect these clouds of harboring protostars and, in several cases, we have found some very young stars."

So wrote Bart Bok, one of the great pioneers in the study of star formation's early stages. Thanks to technology, our understanding of the process has continued to explode.

mission update *by jonathan mcdowell*

GLAST

The Gamma-ray Large Area Space Telescope (GLAST), NASA's next high-energy astrophysics satellite, achieved a major milestone last year when engineers completed the main detector array. Sixteen detectors assembled in a 4-by-4 grid make up the core of the instrument's Large Area Telescope. The telescope will detect gamma-ray photons with energies ranging from 20 million electron volts (MeV) to 300 billion electron volts (GeV), an energy span previously studied only by the European COS-B satellite in the 1970s and the Compton Gamma Ray Observatory's EGRET telescope in the 1990s.

GLAST's range represents a spectral region where only a few hundred sources are known and many remain unexplained. One class that GLAST will study in detail are blazars, in which gamma rays are beamed by relativistic jets of material emitted from the vicinity of supermassive black holes. Less than 100 of these mysterious objects are currently known, but GLAST (and AGILE; see above right) will find many more. It will also detect quasar jets, gamma-ray bursts, and pulsars.

GLAST is designed to observe very faint signals. In fact the high-energy gamma-ray count rates it will see are so low that astronomers will identify them only after they stack individual photons from many scans across a particular region of sky. The satellite's Large Area Telescope will spot objects 1/50 as bright as those in the EGRET catalog.

GLAST will locate sources to within about 1 arcminute, with a field of view covering 20 percent of the sky. NASA is scheduled to launch the four-ton observatory in 2007 into a low-altitude equatorial orbit.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

AGILE

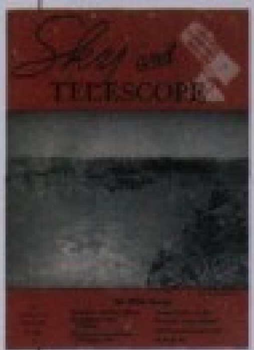
This May, the Italian Space Agency's Astro-rivelatore Gamma a Immagini LEggero (Light Imaging Gamma-Ray Astronomical Detector, or AGILE) is scheduled to ride into orbit, aiming to blaze the scientific trail for GLAST with a much smaller satellite. AGILE will catalog distant blazars and unravel the mystery of the unidentified gamma-ray sources in the galactic plane.

AGILE is the follow-up mission to the successful BeppoSAX satellite. It weighs 330 kilograms (730 pounds) — about one-tenth the mass of GLAST. It will carry an imager to study the 30 MeV to 50 GeV gamma-ray spectral range. AGILE is comparable to Compton's EGRET but with two major improvements: it is better at seeing sources away from the center of the field of view, and it has an extra detector, Super-AGILE, which simultaneously observes high-energy X-rays (15 to 45 kiloelectron volts).

Super-AGILE's ability to provide better locations and spectral information makes the satellite ideal for studying radio-loud active galactic nuclei, whose relativistic jets emit copious amounts of gamma radiation. It will also provide insights into high-energy gamma-ray sources in the galactic plane, whose nature is still unknown; and pulsars in supernova remnants, whose gamma-ray emission may seal the link between supernovae and cosmic-ray production.

50 & 25 years ago *by leif j. robinson*

MAY 1956



Meteorite Craters "Several circular objects were found that might conceivably have had a meteoritic origin, but the most promising was at Holleford, Ontario. . . .

"The Holleford crater is a circular depression approximately 100 feet deep and 1¼ miles in diameter. . . ."

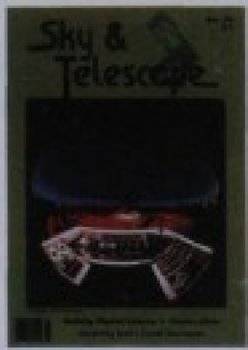
The Holleford crater turned out to be a real impact feature, joining more than 170 impact sites now known on Earth. As of 2005, a total of 29 had been found in Canada and 27 in the United States.

MAY 1981

The Milky Way a Cannibal? "Yes it is, conclude A. Rodgers and his colleagues at the Mount Stromlo and Siding Spring Observatories [in Australia]. This is based on their study of faint . . . [young] stars of spectral type *A* in the direction of the south galactic pole. . . .

"These *A* stars, lying several kiloparsecs away from the plane of the Milky Way, are well clear of the disk of the galaxy and form part of its halo. . . .

"An event satisfying [their origin] is the collision with and capture of a small gas-rich satellite galaxy by the Milky Way."



Further evidence for cannibalism comes from the long-known fact that our galaxy is pulling gas from one or both of its biggest close neighbors, the Magellanic Clouds. More recently, astronomers have found dwarf galaxies in the process of being gobbled up by the Milky Way (see page 16).

Book Review "The Most Up-to-Date Reference to the Worlds Around You"

That was the lead blurb in the first ad for The New Solar System, *arguably the most successful book ever published that describes contemporary planetary science. Under lead editor J. Kelly Beatty, it is now in its fourth edition from Sky Publishing and Cambridge University Press.*

news notes

NASA Science in Free Fall

Space-based astronomy faces a bleak future in the wake of recent mission cancellations and delays.

Among the victims in the latest round of deep cuts to NASA's science budget were the Dawn asteroid-rendezvous (above) and the Terrestrial Planet Finder (TPF) missions. Dawn was built to orbit the large main-belt asteroids Ceres and Vesta. TPF was being designed to search for life-bearing planets around nearby stars.

NASA'S ASTRONOMY PROGRAM is in a state of crisis as a growing number of space missions are falling victim to the budgetary ax. Smaller projects are suffering most in NASA's fiscal 2006 budget as funding is siphoned toward human spaceflight. Additional cancellations are projected in the 2007 budget partly to help finance the James Webb Space Telescope (JWST) and Hubble Space Telescope cost overruns (March issue, page 26). Unless Congress allocates more money for NASA, the slide will accelerate with the coup de grâce being a projected 15% cut for space astronomy in 2009.

In January NASA officials canceled the X-ray Nuclear Spectroscopic Telescope Array (NuStar) Explorer mission (S&T: February 2004, page 26). On March 2nd NASA's new head of science, former astronaut Mary Cleave, terminated the Dawn asteroid mission (this decision was under review at press time). Dawn had only a few months of work left before launch.

Congressional leaders and the scientific community questioned whether large, over-budget missions such as JWST should be protected at the expense of other needs, and challenged the prioritization of human exploration over robotic science. Astronomy is losing both the research jobs needed to analyze the data and the low-cost missions needed to round out a healthy science program.

It's very unusual for missions to be canceled so close to launch. The Dawn termination apparently saves only $30 million out of a $370 million project, and Dawn's

Stardust's Tiny Treasures

If comets coalesce in the coldest parts of our solar system, why do they contain crystals that formed under extremely hot conditions? That's the mystery confronting scientists working on the Stardust sample-return mission.

On January 15th the Stardust spacecraft safely returned dust from Comet Wild 2 to Earth (April issue, page 24). Shortly thereafter, team members began their analysis of the captured grains. Much to their surprise, the scientists found numerous minerals that formed very close to the Sun. But conventional wisdom says that Wild 2 should comprise ingredients that came together at the farthest reaches of the solar system, well beyond the orbit of Pluto.

Stardust's aerogel collection paddle contained thousands of particles. Most are less than 50 micrometers across. But around 45 grains are visible to the unaided eye.

In just the first few weeks since Stardust returned its cargo, astronomers sent out more than 150 samples to laboratories worldwide. Analysts have already detected a host of minerals, including olivine, spinel, anorthite, and pyroxene. Many of these crystals have melting temperatures higher than 1,100°C (2,000°F), which tells scientists that they formed in hot conditions.

How the crystals migrated from a hot spot to the cold outer solar system remains a mystery. Perhaps they were ejected outward early in the solar system's formation. Or maybe they were heated by a passing star. The answers will become clearer after the Stardust team conducts detailed isotopic measurements on the particles.

For now the researchers are still basking in the afterglow of a successful mission with the promise of amazing science results to come. "I just can't believe this actually is a piece of a comet that formed 4½ billion years ago," says science team leader Donald Brownlee (University of Washington).

These early findings are just the beginning. Stardust's collection paddle had two sides: one was designed to grab comet pieces, the other to grab interstellar dust. Astronomers plan to begin their initial analysis of the interstellar samples in the coming weeks. — David Tytell


Each particle that hit Stardust's aerogel collection paddle left a unique trail. By analyzing each trail, astronomers can learn about the particle's velocity at the time of capture and how much it broke apart during impact.

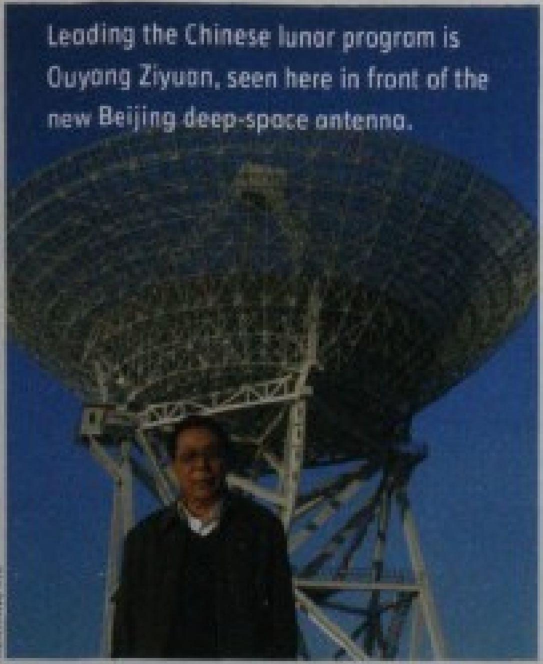
cost overrun was mostly due to previous delays imposed by NASA. The NuStar cancellation might be the most troubling, however. The mission was approved, on budget, and without technical problems. Killing a project in such good shape is unprecedented and belies earlier statements by NASA administrator Michael Griffin that missions were to be delayed rather than canceled.

Millions of dollars earmarked for managers and users of existing space observatories, such as the infrared Spitzer Space Telescope, have also been cut. These actions have raised further threats of layoffs and job shortages. This is even true for Hubble. There will be an influx of money in the 2007 budget to support the proposed servicing mission, but there is very little funding to pay for scientists to analyze the data it collects afterward.

The 2007 budget also delays indefinitely a Europa mission and the Terrestrial Planet Finder (S&T: April 2004, page 49), stalls the SIM interferometry testbed (S&T: April 2004, page 28), and slates the SOFIA airborne infrared observatory for near-certain cancellation (see page 8). SOFIA was in the final stages of construction. The Beyond Einstein series of high-energy missions, including Constellation-X (January issue, page 38) and the Laser Interferometer Space Antenna (LISA), is being kept alive with only a trickle of funding. Even important ground-based projects such as the long-planned Keck Interferometer outrigger telescopes have been sent to a premature grave.

Morale is plummeting in the US space-science community as senior scientists see years of work evaporate with a stroke of the financial pen, and young astronomy PhDs are wondering whether a career in the field is even possible. How US astronomy will take shape in the coming months and years remains in question as the fight begins over how to reslice the shrinking funding pie. — Jonathan McDowell

mission update *by jonathan mcdowell*



Leading the Chinese lunar program is Ouyang Ziyuan, seen here in front of the new Beijing deep-space antenna.

Chang'e 1

CHINA IS READYING its first interplanetary spacecraft, the Chang'e 1 lunar probe, for launch in April 2007. After liftoff from the Xichang spaceport in southern China, Chang'e 1 will enter a geostationary orbit before firing its engine to head for the Moon. Once there, it will slip into a 200-kilometer (120-mile) polar orbit.

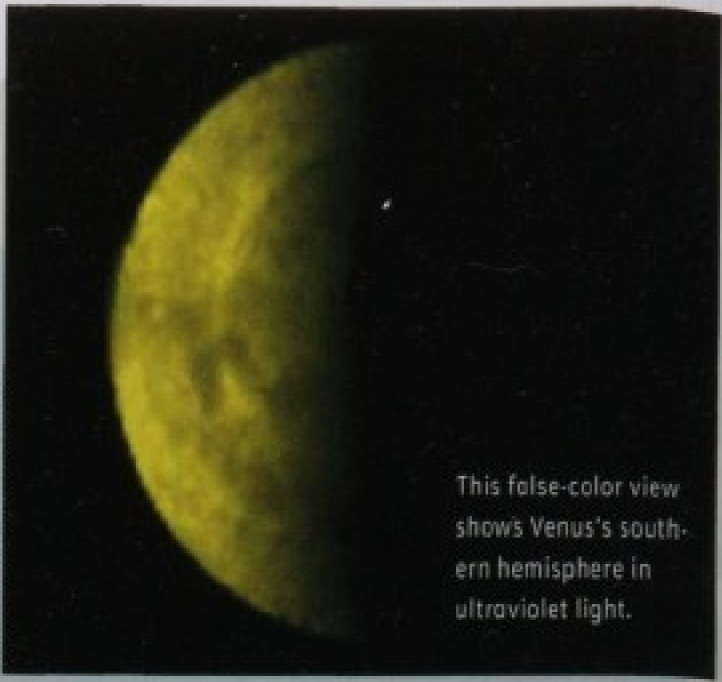
In preparation for the mission, China recently built a 50-meter deep-space antenna in Beijing. It joins a 40-meter dish in Kunming, 25-meter dishes in Shanghai and Urumchi, and 18-meter dishes in Qingdao and Kashi, to form a network that will be critical for Chang'e 1 as well as China's longer-term deep-space ambitions.

The probe will carry a low-resolution imager, a gamma-ray spectrometer, and a microwave radiometer to study the Moon's surface composition and temperature, and a laser altimeter to measure the height of topographical features.

China follows the US, the USSR, the European Space Agency, and Japan in becoming the fifth entity to launch craft to the Moon or beyond.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org/space/jsr/jsr.html.*

Venus Express



ESA / MPS / KATLENBURG-LINDAU, GERMANY

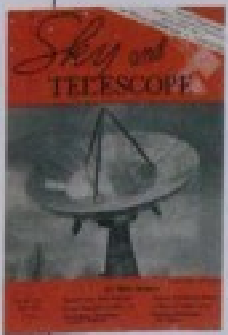
This false-color view shows Venus's southern hemisphere in ultraviolet light.

The European Space Agency ramped up its accomplishments on April 11th with the arrival of Venus Express (February issue, page 16) in orbit around the cloudy inner planet. The spacecraft switched on its engine, slowed by 1.3 kilometers per second, and fell into a barely captured orbit. The initial, elongated orbit arced out to 350,000 km, reaching its farthest point, apocytherion, on April 15th — halfway to the edge of Venus's gravitational sphere of influence. When the craft descended back toward the Venusian cloud tops on April 20th (within 400 km), it executed the first of a series of rocket firings aimed to bind it more tightly to its host planet. Once the probe reaches its final 24-hour elliptical orbit, it will begin a global study of Venus lasting at least two Venusian days — that is, 16 Earth months.

With the craft's near-twin Mars Express still in full stride, SMART-1 preparing to end its lunar-orbit mission, the Rosetta comet probe in cruise around the Sun, and the elderly Ulysses solar probe heading inward for its third perihelion pass in 2007, European solar-system exploration is experiencing an unprecedented level of activity.

50 & 25 years ago *by leif j. robinson*

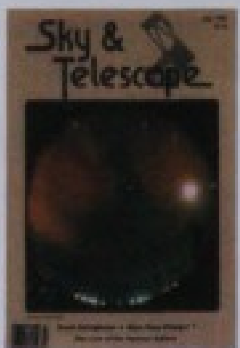
JULY 1956



Celestial Chemistry "There can now be no doubt that the stars do serve as atomic reactors in which heavy elements are produced. But not all stars do so in the same manner or with the same efficiency. Those of the sun's type are relatively inactive, though even they 'cook' the heavy elements on a small scale. The red giants and supergiants produce large nuclei copiously in their interiors, the novae and supernovae do so explosively, and the magnetic stars manufacture heavy elements near their surfaces by the betatron effect. . . .

"The new ideas on element building in stars come from the work of many astronomers. Of particular interest are the fundamental contributions of M[artin] Schwarzschild and [Fred] Hoyle on the internal temperatures of the giants and supergiants, of [William] Fowler and [Jesse] Greenstein on the formation of heavy atoms in an original hydrogen star, and of Fowler, G[eoffrey] R. Burbidge and E. Margaret Burbidge on nuclear reactions at the surfaces of magnetic stars."

It's sobering to realize that our understanding of the nucleosynthesis of elements heavier than hydrogen, helium, and lithium (which formed as byproducts of the Big Bang) is barely a half-century old.



JULY 1981

Remembrance "Amid the euphoria brought on by the spectacular success of [*Columbia*'s] first flight . . . work continues on the craft that will follow *Columbia* into space. The next Space Shuttle orbiter, dubbed *Challenger*, now sits in Rockwell International's Palmdale, California, plant."

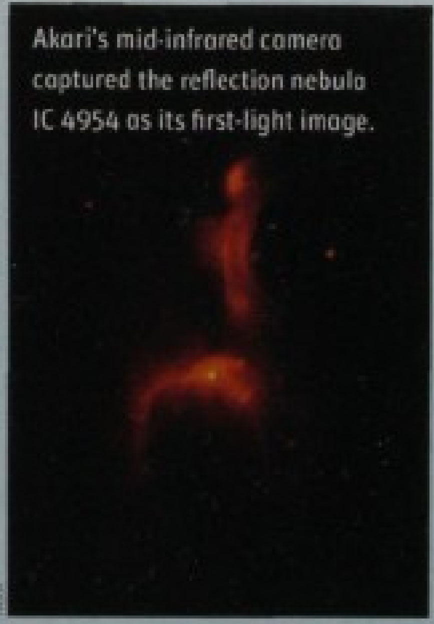
Both shuttles were involved in fatal accidents: Challenger *on January 28, 1986, and* Columbia *on February 1, 2003.*

mission update *by jonathan mcdowell*

SMART-1

The European Space Agency's SMART-1 mission is drawing to a close. The spacecraft used an ion engine to slip into a lunar polar orbit. But the irregularity of the Moon's gravitational field slowly makes that orbit more eccentric. By April 2006 it was in a 515-by-2,846-kilometer (320-by-1,768-mile) loop, with its low point shrinking and an impact predicted for August. In late June mission planners were to use the craft's conventional rocket motor to delay the collision until September 3rd. The target zone is Lacus Excellentiae, south of Mare Humorum, and the impact flash is predicted to be fainter than 11th magnitude. But if the dust cloud is large and extends outward enough, it could appear at magnitude 5.

The 2 km/sec collision will be studied at radio, infrared, and visible wavelengths. Observing the event will give astronomers good practice. NASA recently approved the Lunar Crater Observation and Sensing Satellite, which will hitch a ride in 2008 with the Lunar Reconnaissance Orbiter, detach, and self-destruct at the Moon's south pole in an attempt to detect surface water ice.


Akari's mid-infrared camera captured the reflection nebula IC 4954 as its first-light image.

Akari (Astro F)

Japan's infrared sky-survey satellite, Akari (formerly Astro F), finally ejected its telescope cover on April 13th — a crucial step that had been delayed for several weeks because the craft's Sun sensors had malfunctioned. The sensors determine Akari's orientation in space, and accurate attitude control is particularly important for any payload carrying super-cold liquid helium. If the telescope were to look accidentally at the Sun or Earth, heating could boil off the limited supply of coolant — the lifeblood of the instrument. Such a mistake happened when NASA's Wide-Field Infrared Explorer ejected its cover shortly after launch in 1999 (*S&T:* October 1999, page 30).

Mission engineers from the Japan Aerospace Exploration Agency (JAXA) have developed a new method to estimate attitude without the Sun sensors. To the relief of the Akari team, the satellite has since remained stable.

Akari's final checkout is well underway, the telescope is focused, and the two principal instruments have been tested. The main sky survey was scheduled to begin in mid-May.

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50 & 25 years ago *by leif j. robinson*

AUGUST 1956

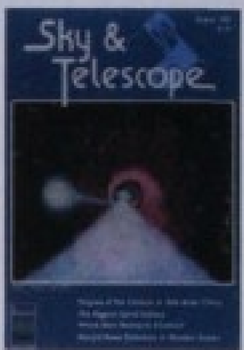
Venus Calling "Radio noise originating on the planet Venus has been detected by astronomers working independently at Ohio State University and the Naval Research Laboratory, Washington, D. C. Venus thus becomes the second planet to be observed at radio wave lengths, only a year after the first such observations of Jupiter. . . .

"Static from Venus consists of numerous brief bursts, lasting one second or less. . . . When the output of the receiver is played through a loudspeaker, a crackling sound is heard, not unlike the static from terrestrial thunderstorms."

The late John Kraus may have been spot-on in his interpretation. Several Soviet Venera landers (encounters from 1978 to 1982) as well as the American Pioneer Venus mission (1978) found evidence, albeit inconclusive, for lightning.

AUGUST 1981

Space Shuttle Poll "A Louis Harris poll indicated that 63 percent of 1,250 adults over 18 believed the United States should spend several billion dollars in the next decade to develop the full potential of the Space Shuttle. . . . This renewed enthusiasm seems to derive from an expectation that practical uses for the space program might be found in such areas as pharmaceutical development, chemical and biological research, and artificial-satellite refurbishment."



One wonders how low a percentage such a poll might yield today. After spending those billions of dollars, the promise of the shuttle — and of the International Space Station — remains unfulfilled.

Saturn Spins Slower?

When the Voyager spacecraft measured radio waves coming from Saturn with a pattern that repeats every 10 hours 39 minutes 22 seconds, scientists concluded that the variable signals indicate the planet's internal rotation period. But experts soon discovered that the period fluctuated erratically, suggesting that the radio signals probably originate from something that is not tied to the deep interior. In the May 4th *Nature* astronomers report that the ringed planet's actual spin period is longer: 10 hours 47 minutes 6 seconds. This is based on the detection by NASA's Cassini orbiter of a periodic signal in Saturn's magnetic field. But the observed signal doesn't decay with distance as it would if it were rooted in the planet's massive metallic-hydrogen interior. The new period's origin remains a mystery. —D. T.

mission update *by jonathan mcdowell*

Solar-B

A long-standing international collaboration is scheduled to reach fruition on September 23rd with the launch of Solar-B into a 600-kilometer (370-mile) polar orbit. This major solar observatory includes a 0.5-meter (20-inch) optical telescope from the National Astronomical Observatory of Japan and NASA, a UK/US-built extreme-ultraviolet spectrograph, and a 0.35-meter X-ray telescope built at the Harvard-Smithsonian Center for Astrophysics.

An M-V-7 rocket will carry Solar-B into space from Uchinoura Space Center near the city of Kagoshima on the island of Kyushu. After Solar-B separates from its booster, it will spend three weeks raising its orbit. Once terrestrial gases and contaminants trapped in the satellite have had time to escape, the observatory's three telescopes will begin staring at the Sun.

Solar-B's subarcsecond images will provide a detailed map of magnetic fields in the Sun's photosphere. It will also complement data from the European-American Solar and Heliospheric Observatory (SOHO), now 10 years into its vigil at the L_1 Earth-Sun Lagrangian point. The highly successful SOHO mission was recently extended to 2009, allowing it to overlap with Solar-B and NASA's Solar Terrestrial Relations Observatory (STEREO) mission.

Rosetta


Rosetto's 2007 Mars flyby

ESA / AOES MEDIALAB

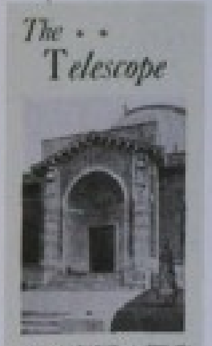
The European Space Agency's Rosetta comet probe continues its complicated 10-year voyage to 67P/Churyumov-Gerasimenko. In December 2005 it reached aphelion beyond the orbit of Mars, and since then it has been falling back toward the Sun. In September it passes perihelion at Earth's orbit. Here mission controllers will tweak the spacecraft's orbit so that near its next aphelion in February 2007, it will pass only 200 kilometers (120 miles) from the Martian surface. After the Mars gravity assist, Rosetta's perihelion will drop until it reaches the orbit of Venus, but before the probe comes that close to the Sun, another Earth flyby will send it out of the ecliptic plane.

Rosetta is mostly inactive during its long cruise, but in March it made long-distance observations of asteroid 2867 Steins, which it will encounter in 2008. In July it was due to carry out plasma studies as it flew near the tail of Comet 45P/Honda-Mrkos-Pajdusakova.

Jonathan McDowell, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org.*

75, 50 & 25 years ago *by leif j. robinson*

SEPTEMBER 1931

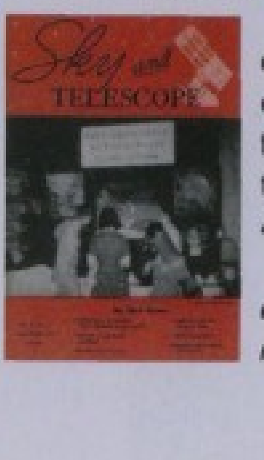


Dangerous Sun "To obtain an idea of the violence of the forces acting on solar prominences, we may consider the prominence of November 19, 1928. . . . In some two hours a mass of incandescent gases reached the height of 567,000 miles, which is more than seventy times the diameter of the earth. . . .

"In some cases it has been possible to trace the magnetic disturbances on the surface of the earth, and auroras, to such violent disturbances on the sun. The sun presumably ejects charged particles which, after some time, reach the earth."

Although solar physics was then in its infancy, this interpretation was basically correct. The real nasties are coronal mass ejections, identified in the 1970s, which can wipe out communications and electric power grids.

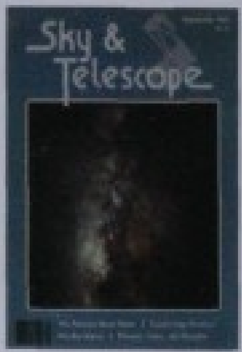
SEPTEMBER 1956



Earth's Age "Not long ago, three billion years seemed to be the most probable age of the earth's crust, but more recent investigations indicate that the actual value is appreciably higher. . . .

"By determining the relative abundances of the various isotopes of lead [in rocks] . . . [Researchers] find a mean value for the time since the formation of the earth's mantle of 4.3 billion years."

The most reliable modern scientific estimate for the age of Earth's oldest materials is 4.4 billion years. The best accepted age estimate for Earth itself is 4.55 billion years.



SEPTEMBER 1981

Faster than Light "For the past decade radio astronomers have been observing more and more extragalactic objects which are apparently expanding at speeds greater than that of light (*c*) . . . .

"A model now in vogue produces the apparent superluminal velocities by means of a beam of relativistic particles ejected from the source nearly along our line of sight. Due to the finite velocity of light, an outside observer sees a shortened time scale for events in the approaching beam, compared to that observed by someone moving with the particles themselves. As a result, the beam appears to move faster than it actually does."

This explanation is now widely accepted.

mission update *by jonathan mcdowell*

SOFIA

NASA has saved an airborne infrared observatory from cancellation. A review panel has concluded that the Strato-spheric Observatory for Infrared Astronomy (SOFIA), a joint project of NASA and the German Space Agency, should proceed to completion, with science flights starting as early as 2008. SOFIA is a modified Boeing 747 airliner with a 2.5-meter (98-inch) telescope looking out a hole in its side. Earlier this year it had been zeroed out in NASA's 2007 budget (June issue, page 8).

SOFIA was an obvious target in NASA's budget crunch (June issue, page 16) because of its high annual operating costs and the fact that the project was years behind schedule and millions of dollars over budget, in part because qualifying the aircraft for flight turned out to be more difficult than expected. Effective lobbying from Germany helped save the project. Perhaps more important, the review convinced NASA officials that SOFIA's technical problems were essentially behind it.


SOFIA's telescope

NASA's recent decision means that the Wide-field Infrared Survey Explorer (WISE) will proceed as well (*S&T*: September 2005, page 24). Astronomers were concerned that WISE would be sacrificed to restore SOFIA.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his Web site at www.planet4589.org.*

SIM PlanetQuest

The money for SOFIA's rescue had to come from somewhere, and the victim is the Space Interferometry Mission, also known as SIM PlanetQuest. This program had been scheduled to enter its development phase in the near future, but it will now remain in the design phase for at least the next several years. This move postpones SIM's launch indefinitely; it seems unlikely the spacecraft will ever fly.

In the current design, SIM consists of a 9-meter (30-foot) truss that will carry two 30-centimeter (11.8-inch) telescopes that would work together as an interferometer to achieve microarcsecond positional accuracy for stars as faint as magnitude 20. The mission could discover and measure the masses of Earth-size planets around nearby stars.

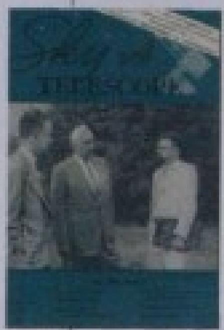
With the earlier reduction of the Terrestrial Planet Finder to laboratory studies, NASA has almost completely abandoned its commitment to search for life-bearing planets around other stars. "The extrasolar planetary science community is devastated," says Geoff Marcy (University of California, Berkeley).

The SIM cuts have one positive effect: they ease budget pressure on other near-term missions, such as the Gamma-ray Large Area Space Telescope, or GLAST.

50 & 25 years ago *by leif j. robinson*

OCTOBER 1956

Neutrinos for Real "For more than 20 years, physicists have postulated the existence of



neutrinos — uncharged elementary particles of extremely small mass — to explain an apparent violation of the law of conservation of energy. . . .

"At last, C. L. Cowan, Jr., F. Reines, and their associates have definitely observed neutrinos in the products of the Savannah River, South Carolina, atomic pile of the Atomic Energy Commission. In 1953, these Los Alamos physicists had tentatively identified neutrinos produced by the Hanford reactor [in Washington State]."

The first indisputable neutrinos from outside the solar system were observed in 1987, from the core collapse of Supernova 1987A. Reines (1918–98) won the Nobel Prize in 1995.

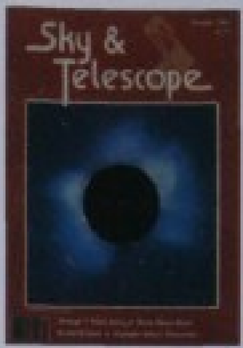
OCTOBER 1981

Stellar Activity Cycles "The one star we can study in detail, the Sun, exhibits cyclic activity with different periods. One cycle is due to rotation, 25 days at the solar equator. Of much longer duration is the still-enigmatic sunspot cycle of 11 years.

"What about other stars? . . .

"The existence of spots can be determined in a straightforward manner by monitoring the H- or K-line emission [from calcium] of the plages [bright patches in the solar chromosphere] which always accompany them.

"This method will work for any star that has an active chromosphere. . . .



"Among [46] main-sequence stars 19 showed clear evidence of rotation, while nine others revealed periodicity after mathematical analysis. . . .

"What of possible starspot cycles? [Arthur] Vaughan and George Preston have continued the work begun by [Olin] Wilson, who monitored H- and K-line fluxes from 1966 through 1977. By the end of 1980 about 15 stars essentially had completed an activity cycle, and six of them also have had rotation periods determined. The cycles take about five to 12 years, with 10-12 years occurring often — the Sun is clearly quite ordinary in this respect."

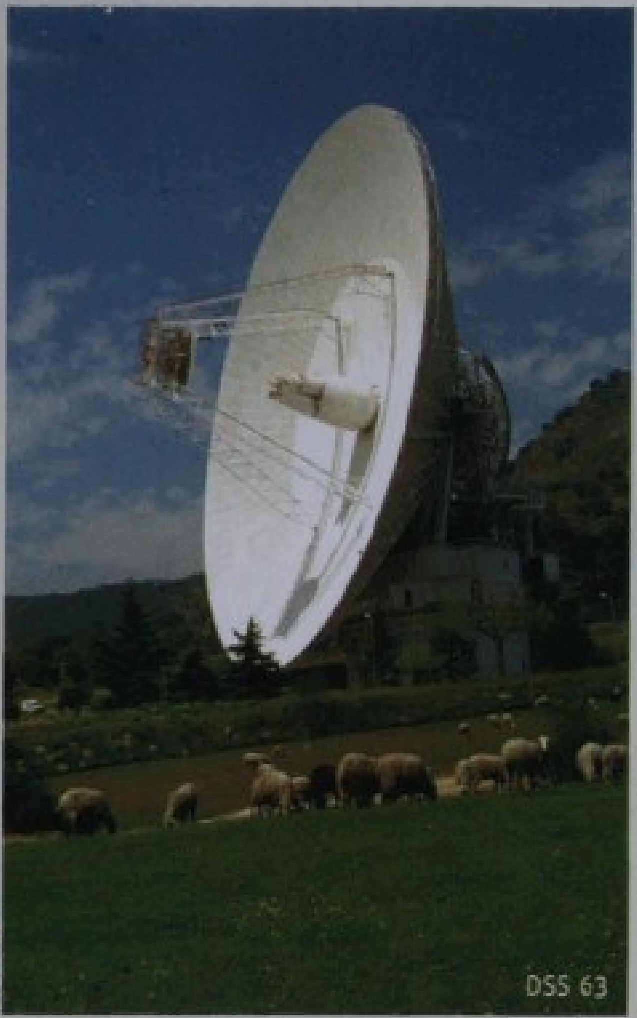
This simple technique was originally implemented with the 100-inch (1.5-meter) reflector at Mount Wilson Observatory. The project, now based at Lowell Observatory, continues to produce key data on solar-type stars.

mission update *by jonathan mcdowell*

Deep Space Station 63

DSS 63, the 70-meter (230-foot) Deep Space Network (DSN) antenna near Madrid, Spain, went offline in May for scheduled maintenance. But on June 22nd engineers discovered cracks in the altitude bearings that might take months to repair, threatening the return of data from several NASA deep-space missions.

The DSN has been NASA's main point of contact with interplanetary spacecraft since 1958. As Earth turns, a distant probe's faint radio signal comes into view of one of the three main sites at Goldstone, California, Canberra, Australia, and Spain. A handful of smaller dishes at each site handle data from probes and satellites that are either nearby or have lower data rates.


DSN / NASA / JPL

DSS 63

These smaller stations will be overloaded trying to capture faint signals from the Cassini spacecraft at Saturn and the high data flow from Mars Reconnaissance Orbiter. All the Mars orbiters and rovers were using DSS 63, and the competition for time on smaller antennas means that some of them will lose out. Certain data transmissions can be rescheduled to occur when a spacecraft is over Goldstone or Canberra, but the New Horizons Jupiter encounter on February 28, 2007, takes place when DSS 63 is pointed in its direction. This Pluto mission will have to be supported by smaller dishes if DSS 63 is not repaired by that time.

Gaia

The European Space Agency has awarded the contract to build the Gaia astrometry satellite to EADS Astrium in Toulouse, France. This company built many previous European space observatories, including Gaia's predecessor, Hipparcos. Gaia's detailed design phase began in March. The spacecraft will be launched in 2011 to the L_2 Lagrangian point 1.5 million kilometers (930,000 miles) from Earth, where it will measure distances to a billion Milky Way stars down to 20th magnitude.

Gaia carries two 1.5-by-0.5-meter primary mirrors, each with a 0.7° field of view and feeding an array of more than 100 CCD imagers for position determinations as precise as 20 microarcseconds for bright stars and less than a milliarcsecond for the faintest. Gaia also carries a spectrograph that will measure the line-of-sight velocities of 150 million stars down to magnitude 17.

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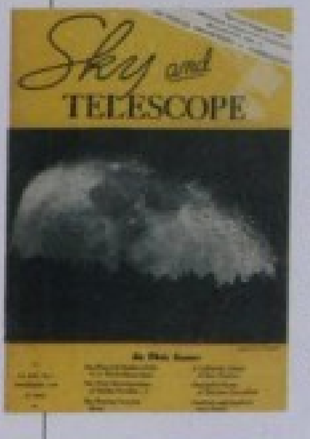
50 & 25 years ago *by leif j. robinson*

NOVEMBER 1956

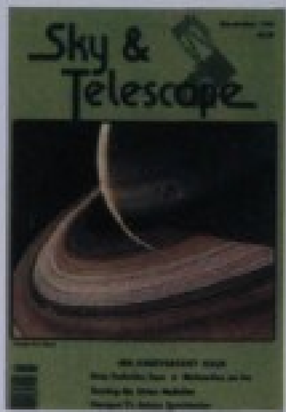
Cover Shot "The waning gibbous moon rising over Mt. Elden, Arizona, photographed by Arthur A. Hoag with the U. S. Naval Observatory 40-inch reflector at Flagstaff, on November 3, 1955. The atmospheric transparency and good seeing conditions are shown by the sharpness of the moon's features, less than half a degree above the horizon. The tree line is nine miles distant."



Originally operated since 1934 in Washington, DC, this wide-field Ritchey-Chrétien telescope was moved to Flagstaff in 1955. Today it is used for imaging and photometry with quartz optics installed in 1970. The Ritchey optics are now in a 1-meter telescope in Croatia.

NOVEMBER 1981

Intergalactic Probes "A number of quasars show absorption lines in their spectra that yield different line-of-sight velocities from that of the quasars themselves as determined from emission lines. In some cases, lines in the same object give numerous greatly different speeds, a particular instance being absorption features at wavelengths shorter than the hydrogen Lyman-alpha line.



"Jan Oort of Leiden Observatory . . . suggests diffuse hydrogen in superclusters between us and the quasars as the source of these features, which are generally less redshifted than the Lyman-alpha emission line."

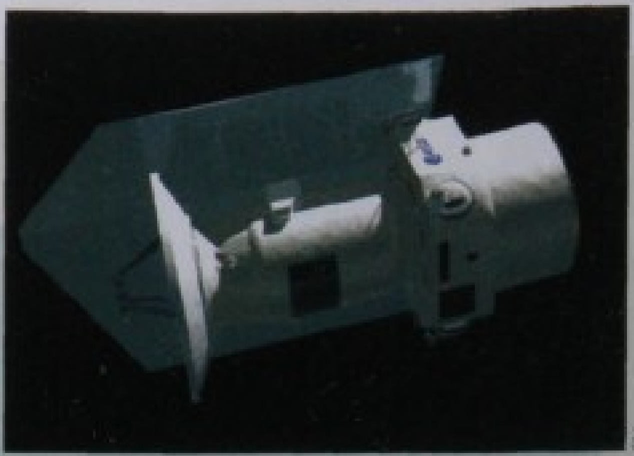
This discovery of what is now called the Lyman-alpha forest provides us with direct evidence of gas in intergalactic space. These lines provide astronomers with the opportunity to study this gas at a wide range of redshifts.

mission update *by jonathan mcdowell*

Mars Reconnaissance Orbiter

NASA's Mars Reconnaissance Orbiter reached its science orbit in early September. MRO arrived on March 10th in an elliptical 426-by-43,000-km (265-by-27,000 mile) polar orbit. In April the spacecraft dipped its low point (periapsis) into the Martian atmosphere, only 105 km above the surface. Atmospheric friction on each pass quickly lowered the orbit's high point. On August 30th mission controllers ended this "aerobraking" as MRO raised its periapsis to 210 km, safely beyond atmospheric drag. By September 12th the craft reached its near-final orbit of 250 by 316 km, with the low point over the south polar region. MRO then began to activate its instrument payload in preparation for initiating its primary science mission in November. At that point the orbit will receive a final tweak to lock it in the Sun-synchronous path ideal for the study of Mars.

Herschel Space Observatory



ESA

The launch of the European Space Agency's far-infrared Herschel Space Observatory is now planned for February 2008. The 3.5-meter telescope is being assembled at the European Space Research and Technology Center in the Netherlands. A liquid-helium cryostat arrived there in August for testing. Initial tests revealed unexpected thermal problems, so the cryostat is now being fixed.

Herschel will be the first large space telescope to study the submillimeter band, which bridges the spectral region between the far-infrared and radio. Herschel carries three instruments. The Photodetector Array Camera and Spectrometer (PACS) covers the 60-to-210-micron range. The Spectral and Photometric Imaging Receiver (SPIRE) works from 200 to 600 microns with very high spectral resolution. The Heterodyne Instrument for the Far Infrared (HIFI) operates from 150 to 600 microns.

HIFI is the first infrared instrument to use radio-telescope technology. PACS is also groundbreaking, with the first bolometer arrays that have no gaps between pixels, similar to imaging arrays. SPIRE is 10 times more sensitive than the ground-based SCUBA instrument, which observes in the same part of the spectrum but is limited by the brightness of the night sky. Herschel will give us the faintest look at astronomical objects at these wavelengths, where cold star-forming clouds and distant star-forming galaxies can be studied.

Herschel will be launched on an Ariane 5 rocket with ESA's Planck cosmic microwave background satellite and will be placed at the Lagrangian L_2 point, 1.5 million kilometers (930,000 miles) from Earth opposite the Sun.

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75, 50 & 25 years ago *by leif j. robinson*

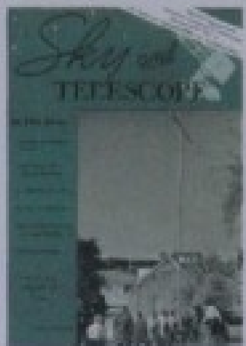
DECEMBER 1931

Which Universe? "It is difficult to solve the intricate problem of the structure of the universe without making some assumptions as to the distribution of matter in it. Einstein proposed a theory of the universe based on the assumption that it is static. . . . [Willem] De Sitter proposed another theory based on the fact that the universe is pretty nearly empty. . . . De Sitter's solution was considered nearer the truth because it accounted for the fact that the spiral nebulae . . . run away from us, and their velocity of recession is proportional to their distance from us. . . .

"[Georges] Lemaitre . . . put forward another solution . . . [which] is considered more nearly correct. . . . According to Lemaitre the universe is continually expanding. . . ."

Each step was closer to the truth, but there was (and probably is) a long way to go (see page 36).

DECEMBER 1956



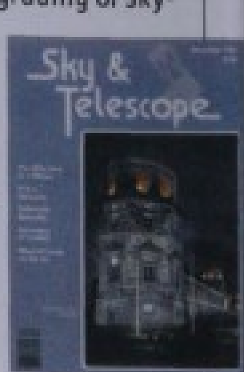
Sunshine "The Henry Norris Russell lecture [of the American Astronomical Society] was given by Joel Stebbins, Lick Observatory, who told how he and G. E. Kron had measured the apparent magnitude, color, and temperature . . . of the sun. . . . It is exceedingly difficult to place the sun accurately on the stellar magnitude scale, because it is 10 billion times brighter than the next brightest star, Sirius. . . .

"The apparent visual magnitude of the sun was found to be −26.73 . . . and its color index came out +0.53."

Not bad! The modern values are −26.75 and about +0.63; the color-measurement systems differed slightly.

DECEMBER 1981

Birth of a Classic "Wil Tirion's *Sky Atlas 2000.0* is more than just a precessional update of existing sky charts; it is a significant improvement in the way sky objects can be plotted on paper and an important upgrading of sky-mapping techniques."



With the appearance of this atlas, and its subsequent color edition, Tirion's place as the premier celestial cartographer of the time was assured. The second edition of this work, now coauthored with Roger W. Sinnott, is available from Sky Publishing.

mission update *by jonathan mcdowell*

Hubble Space Telescope

The aging Hubble Space Telescope continues to produce excellent science as its systems slowly degrade. The recent successful Space Shuttle missions have raised hopes that NASA will approve Servicing Mission 4 (SM4). The Hubble project is hoping for a January 2008 launch, but a spring 2008 flight seems more likely given scheduled assembly flights to the International Space Station (ISS). SM4 had been grounded after the *Columbia* tragedy, since astronauts visiting Hubble could not seek safety aboard the ISS in an emergency.

New gyroscopes are the most crucial item, since the current ones have a significant probability of failure by mid-2008. Replacing the spacecraft's batteries, expected to provide adequate power until 2010, is also a high priority.

These fixes would ensure a new 5-year lease on life, but Hubble's science capability is currently limited by the failure of its imaging spectrograph. SM4 would attempt to repair this important instrument. It would replace the old wide-field camera with an advanced camera (Wide Field Camera 3), as well as install the new Cosmic Origins Spectrograph. These two instruments would join the Advanced Camera for Surveys (ACS) and the near-infrared camera, adding the scientific equivalent of an entire new telescope.

Planck

FOLLOWING THE continuing success of NASA's Wilkinson Microwave Anisotropy Probe mission to study the Big Bang's afterglow (*S&T*: June 2006, page 22), and the awarding of the 2006 Nobel Prize for physics to John Mather and George Smoot for their work on the Cosmic Background Explorer satellite, the European Space Agency is preparing the Planck mission to study the microwave background.

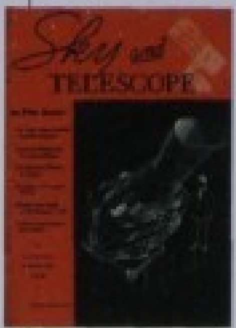
Planck will share a ride to space with the Herschel Space Observatory (December issue, page 30) and will join it at the Lagrangian L_2 point 1.5 million kilometers from Earth on the opposite side of the Sun. Planck will map the sky at a resolution of 5 arcminutes, allowing it to subtract the foreground contribution from bright extragalactic sources in order to obtain the best picture yet of the early universe's small temperature fluctuations.

JONATHAN MCDOWELL, *a Chandra X-ray Observatory staff scientist, provides updates of space missions on his website at www.planet4589.org.*

50 & 25 years ago *by leif j. robinson*

JANUARY 1957

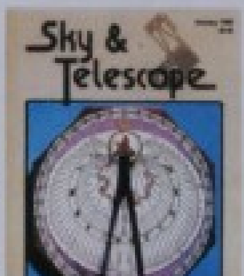
Revolutionary Camera "COVER: This sketch depicts one of the fast Schmidt-type cameras that will be used for precise photographic tracking of artificial satellites during the International Geophysical Year [July 1957 to December 1958]. Its optics have been designed by James G. Baker and its mechanical features by Joseph Nunn. Twelve of these 20-inch-aperture f/1 instruments will be operated in many parts of the world. . . ."



Baker-Nunn cameras provided some of the first precise positions for Sputnik 1 when it was launched on October 4, 1957.

Epochal Survey Completed "For seven years, practically the entire observing time of the 48-inch Schmidt camera has been occupied with the sky survey financed by the National Geographic Society. Beginning in July, 1949, the whole sky accessible from Palomar Mountain (north of declination −27°) has been photographed in red and blue light, requiring 879 plates in each color. The plates are each 14 by 14 inches square. The blue photographs have a limiting magnitude of 21.1, the red plates reach 20.0. . . .

"Dr. [Ira] Bowen points out the enormous mass of research material embodied in the atlas plates: 'Many decades will be required fully to exploit them. . . . In a special search of the plates Mr. [George] Abell has found and listed the positions of about 2700 very rich clusters of galaxies thereby increasing manyfold the number of known objects of this type. . . .'"



Bowen was right! This sky survey was mined throughout the remainder of the 20th century. It continues to be augmented by surveys at all wavelengths, from Earth and space.

JANUARY 1982

Shattered Glass "On display at Stellafane last August was a 48-inch flat, made by Alvan Clark & Sons in the 1880's. This piece of precision glasswork is historically interesting, for it tested some of the firm's most important lens work. Until John Briggs of Westport, Massachusetts, located the 300-pound disk, it had been missing for many years and was thought by all to have been destroyed. . . .

"Alas, the old flat met its end at Stellafane when warmth from the midmorning Sun caused a crack in the disk to spread across its diameter."

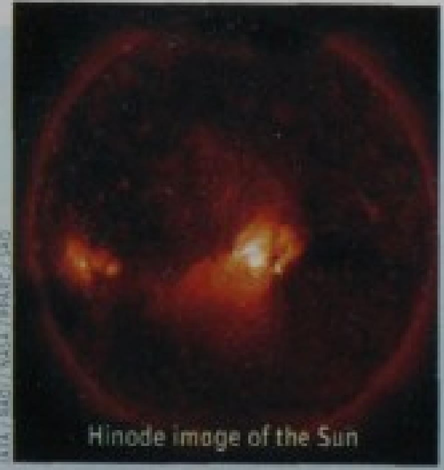
mission update *by jonathan mcdowell*

STEREO

NASA launched its STEREO mission from Cape Canaveral, Florida, on October 25, 2006. STEREO is an acronym for Solar Terrestrial Relations Observatory, but the name actually indicates its ability to return true stereo views of the Sun. STEREO consists of two probes, STEREO Ahead (A) and STEREO Behind (B). One probe will lead Earth by millions of kilometers and the other will trail it by a similar distance.

Optical and ultraviolet imagers, radio-burst monitors, and particle detectors will provide space-weather information. For the first time, scientists will study solar coronal mass ejections that hit Earth from the side, rather than just seeing storms that approach us head-on.

The two STEREO probes were due to fly past the Moon on December 15th. Thanks to clever orbital maneuvering, STEREO A's flyby puts it on an escape trajectory to a 344-day solar orbit, while STEREO B arcs out to 870,000 kilometers (540,000 miles) from Earth before coming back in for another lunar flyby on January 21st. After this second flyby, STEREO B will end up in a 389-day solar orbit.


Hinode image of the Sun

Hinode

The Japanese Space Agency's Hinode (pronounced EE-no-day) solar observatory has successfully completed its first-light observations. Hinode, Japanese for "sunrise," is the new name of the Solar-B observatory, which launched on September 22, 2006. Hinode carries the largest optical and X-ray solar telescopes ever sent into orbit, with instruments from Japanese, American, and British astronomers. The satellite reached its final 674-by-695-km orbit by October 2nd and settled down for two weeks of systems checks.

The X-ray Telescope, built at the Smithsonian Astrophysical Observatory, was activated on October 23rd. Its aperture door opened unexpectedly shortly after orbital insertion, but the malfunction caused no problems, and XRT is returning arcsecond-resolution images of solar flares.

The 0.5-meter Solar Optical Telescope, whose door was opened on October 25th, makes 0.2-arcsecond images of the solar photosphere, showing unprecedented detail in the granules, with bright spots revealing small areas that have intense magnetic fields.

The third instrument, the Extreme Ultraviolet Imaging Spectrometer, was activated on October 28th. It is returning ultraviolet strip images across the Sun and high-spectral-resolution observations that reveal differences between the solar corona, chromosphere, and photosphere.

Hinode is the first major orbiting solar observatory in 10 years, following the NASA-European Space Agency SOHO spacecraft, which has been operating since 1996, and Japan's Yohkoh, which sent back solar images from 1991 to 2001.

JONATHAN MCDOWELL, *a staff scientist for the Chandra X-ray Observatory, provides updates of space missions on his website at www.planet4589.org.*

50 & 25 years ago *by leif j. robinson*

FEBRUARY 1957

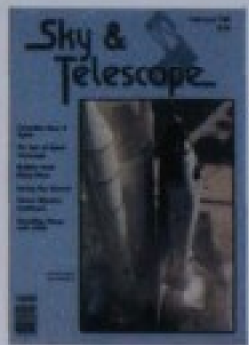
Sirius's Diameter "A novel type of stellar interferometer has been tested by successful measurement of the angular diameter of the star Sirius. . . .

"In these experiments, two searchlight mirrors 61 inches in diameter were pointed at Sirius. The photons of a star's light collected by such a mirror arrive at a fluctuating rate. If a second mirror is placed immediately alongside the first, the photons it collects will have identical fluctuations in their rate of arrival. But when the mirrors are several yards apart, the correlation between the two sets of fluctuations is reduced by an amount that depends on the angular diameter of the star. . . .

"The diameter of the star was found to be 0.0068 ± 0.0005 second of arc, agreeing well with the angular diameter of 0.0063 second computed from the known surface temperature and brightness of Sirius."

At Sirius's distance of 8.6 light-years, the most recent measured angular diameter of 6 milliarcseconds corresponds to 2.4 million kilometers (1.5 million miles), about 1.7 times the diameter of the Sun. In the 1960s a larger version of this stellar-intensity interferometer was built at Narrabri, Australia, as described by R. Hanbury Brown in the August 1964 S&T (page 64) The latest news on interferometric measurements of stars can be found in our article beginning on page 40.

FEBRUARY 1982



Oops! "On December 5th the crown jewel of astronomical optics — the most precise large mirror ever made — stared down from atop a huge stainless-steel coating chamber. Hundreds of preparatory tasks had already been completed, each one being checked off in a thick procedures manual. . . .

"Electron-beam guns fired; vaporized aluminum filled the chamber — 111 seconds later a 0.000065-mm-thick metallic layer rested on the pristine glass. After a two-minute pause, an overcoat of magnesium fluoride was similarly applied, to protect the fresh reflecting surface from oxidation and to enhance its ultraviolet reflectivity."

When I wrote those words, I didn't know that this crown jewel — destined to fly on the Hubble Space Telescope — would turn out to be flawed. Fortunately, Space Shuttle astronauts were able to install corrective optics.

mission update *by jonathan mcdowell*

Mars Global Surveyor

THE LONGEST MARS MISSION in history came to an end as Mars Global Surveyor (MGS) fell silent on November 2, 2006.

MGS was launched in November 1996. With its sister ship Mars Pathfinder, it marked NASA's return to the Red Planet 20 years after the success of Viking and four years after the ignominious failure of Mars Observer. Shortly after it was launched into solar orbit, mission controllers discovered that one of MGS's two solar panels had cracked during the unfolding process, raising fears of another fiasco. But MGS safely reached Martian orbit in September 1997 and became the first interplanetary craft to descend into its operational orbit by aerobraking, saving fuel by dipping into the planet's atmosphere.

Concern for the solar array forced more gentle aerobraking than originally planned, which delayed mapping by one year. Controllers learned to react quickly to changes in the Martian atmosphere. For example, a December 1997 dust storm forced them to raise MGS's orbital low point to avoid excessive panel heating. By March 1999 the initial 258-by-54,021-kilometer (160-by-33,567-mile) elliptical orbit had been reduced to the 367-by-438-km mapping orbit.

Early key results included the laser altimeter's discovery of an ancient northern shoreline, the Thermal Emission Spectrometer's mapping of hematite mineral deposits formed in liquid water (paving the way for the rover Opportunity's findings), and the magnetometer's detection of crustal magnetization from an ancient dynamo. But the Mars Orbiter Camera's 240,000 images are the probe's most familiar legacy, including spectacular shots of volcanoes, craters, canyons, sand dunes, and polar layered terrain.


Mars Global Surveyor

NASA / JPL

MGS completed its primary mission after one Martian year, in January 2001, but ultimately worked for four additional Martian years, revealing landslides, water-carved gullies, and recent geological activity.

The same solar array that nearly foiled the mission turned out to be its nemesis. Surveyor's last plaintive cries on November 2nd revealed that it was fighting to control the malfunctioning array drive. It was not heard from again. ✦

JONATHAN MCDOWELL, *a Chandra X-ray Observatory staff scientist, provides updates of space missions on his website at www.planet4589.org.*

75, 50 & 25 years ago *by leif j. robinson*

MARCH 1932

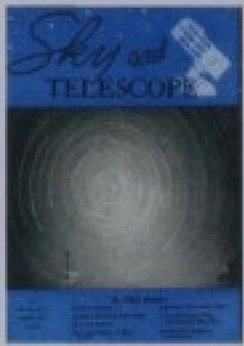
The Pulse of ATMs "Enthusiasm for building telescopes has grown country-wide. . . . Some two thousand enthusiasts have found a delightful hobby in grinding mirrors and building telescopes. . . .

"The lack of information as to sources of material and methods of working should no longer deter any ambitious worker. *Amateur Telescope Making* . . . is an invaluable handbook. . . ."

This volume and two subsequent ones have been topically rearranged and reissued by Willmann-Bell, Inc.

MARCH 1957

Dusty Moon "The lunar maria are probably low-lying regions covered with dust slowly being eroded from the moon's highlands, according to Thomas Gold. . . .



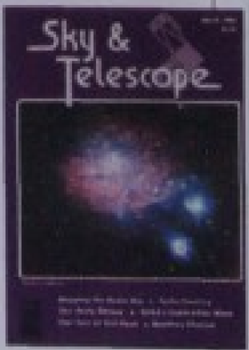
"Several physical processes should enable the dust from the lunar highlands to flow slowly over the moon's surface and to accumulate in low areas. Among these agencies are agitation by micrometeorite impacts, electrostatic effects, and evaporation-condensation cycles. The darker color of the maria may be produced by chemical action or X-rays; recently eroded parts of the crater wall and mountainous regions would show the light shade of the moon's underlying material."

Gold, a theorist, turned out to be wrong. Nevertheless, the possibility of a deep dust layer was a concern as NASA prepared for the Apollo 11 Moon landing in 1969.

MARCH 1982

Dino Killer "Did the impact of a small asteroid cause the extinction of the dinosaurs and other life forms 65 million years ago? Scientists began to consider the possibility when iridium-rich deposits dating to that time were discovered in Italy in 1978. Since then similar deposits have been found in several locations around the world. . . .

"A 1978 geomagnetic survey of the Yucatan peninsula . . . revealed in buried marine deposits a circular pattern of anomalous magnetic signatures 60 km across. . . ."



This was indeed the smoking gun. The Chicxulub crater in Mexico is consistent with the impact of a 10-kilometer (6-mile) asteroid 65 million years ago.

mission update *by jonathan mcdowell*

COROT

THE SEARCH FOR extrasolar planets received a boost on December 27, 2006, when a Russian Soyuz rocket launched the French COROT (Convection, Rotation, and Planetary Transits) space telescope into a polar orbit. The spacecraft, which weighs 630 kilograms (1,400 pounds) and is 4 meters (13 feet) long, is built around a 30-centimeter (12-inch) telescope.

COROT will make repeated precise measurements for five months at a time of the brightnesses of selected stars. Astronomers will look for tiny wiggles in the resulting light curves. Some of those wiggles will be due to oscillations in the stars themselves, a technique called asteroseismology that can be used to probe the stars' interior structure. But the most exciting variations will have the characteristic signature of transiting planets. When a planet passes between a star and Earth, it blocks out a small part of the light, so the star dims slightly for a short time interval (S&T: February 2006, page 28).

COROT won't take the sharpest pictures possible. In fact, its images will be deliberately defocused, which allows star brightnesses to be measured more precisely. The challenge is to measure differences of only a few photons in the 10 million or so photons per second coming from each star. The planets themselves are much too faint and close to their host stars to be imaged directly.

COROT will observe in the direction of Serpens (near the galactic center) and Monoceros (opposite the center), looking at tens of thousands of stars between 12th and 16th magnitude. Astronomers expect to find hundreds of new exoplanets, including several dozen that are only a few times larger than Earth but that are too small to be detected by ground-based techniques. We will have to wait for the larger US-led Kepler mission – set for launch in late 2008 – to push the transit technique down to Earth-size planets.

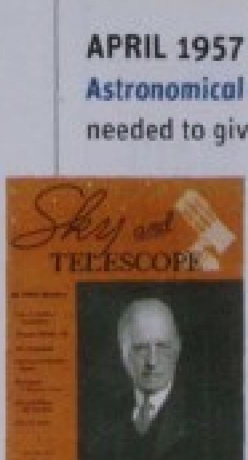
France has participated in joint European missions, but COROT is the first French-led astronomy satellite since SIGNE 3 thirty years ago. COROT was built by Alcatel Alenia Space in its Cannes factory, together with astronomy labs in Marseille and at the Paris Observatory. COROT is operated by France's space agency CNES (Centre National d'Etudes Spatiales) from the Toulouse Space Center.

JONATHAN MCDOWELL, *a staff scientist for NASA's Chandra X-ray Observatory, provides updates of space missions on his website at www.planet4589.org.*

50 & 25 years ago *by leif j. robinson*

APRIL 1957

Astronomical Giant "Many pages would be needed to give a full account of Henry Norris Russell and his work. . .

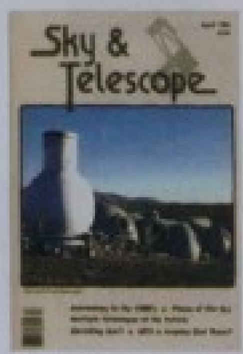


"No one individual in American astronomy has ever equaled his influence throughout five decades as consultant on problems and programs. He grew up with astrophysics. At Princeton, at the Bureau of Standards, at Harvard and at the western observatories, he advised, computed, speculated, incited. He also grew up with eclipsing star theory, with modern thinking on planetary origins, and with the deduction of the masses of the stars; in fact, he fathered these developments."

So wrote Harvard Observatory director Harlow Shapley, a student of Russell's. Russell (1877–1957) will always be remembered for developing, independent of Ejnar Hertzsprung, the diagram that plots stellar luminosities against surface temperatures, one of the most powerful tools in astronomy.

APRIL 1982

SETI "It is now over two decades since a short paper by Giuseppe Cocconi and Philip Morrison and a radio experiment by Frank Drake ushered in the current scientific approach to answering an age-old question. Are we alone, or do



intelligent creatures, in fact, inhabit other worlds? We have no answers yet, but empirical investigations . . . have barely begun. . . .

"It is easy to ridicule SETI in terms of 'little green men' and its seeming lack of practical benefit, but this is shortsighted indeed. Apart from the answer SETI might provide to a fundamental question, the search has value in forcing us to examine ourselves as an intelligent species on an isolated globe. In the end SETI teaches us as much about ourselves as about Them."

Woefully underfunded, the search for extraterrestrial intelligence continues at several different radio and optical observatories.

mission update *by jonathan mcdowell*

Hubble's Main Camera Dies

BALL AEROSPACE & TECHNOLOGIES CORP.

ON THE HEELS of the good news that NASA's flagship space telescope will get a shuttle repair visit in 2008 (February issue, page 15), astronomers received an unexpected reminder of the fragility of all space systems with the failure of the Hubble Space Telescope's main imager, the Advanced Camera for Surveys (ACS).

On January 27th, something in the ACS electronics shorted out and the spacecraft's sensors detected gas escaping into the instrument compartment. NASA's investigation of exactly what happened was not yet complete as this issue went to press. ACS had been operating on its backup power system since June 2006, when the primary power supply went out of action in an apparently unrelated failure.

The instrument consists of three separate cameras: an ultraviolet imager that engineers hope can still be operated, and two visible-light and near-infrared cameras that are now thought to be lost.

ACS was Hubble's newest and, by some measures, best instrument (S&T: March 2002, page 30). Installed by astronauts in a 2002 spacewalk, it nearly completed its official five-year design life. It superseded the smaller, less-powerful Wide Field and Planetary Camera 2 (WFPC2) as the main source of dramatic Hubble pictures and accounted for 80% of the telescope's observing time in 2005–06. The failure happened only hours after this year's deadline for observing proposals. Astronomers around the world were given less than two weeks to recast their proposals to use WFPC2 instead.

Next year's servicing mission will replace WFPC2 with the Wide Field Camera 3 (WFC3), which will have excellent near-infrared capability but won't be as good as ACS was in the visual band. WFC3 is less sensitive than ACS and has a smaller field of view with lower resolution.

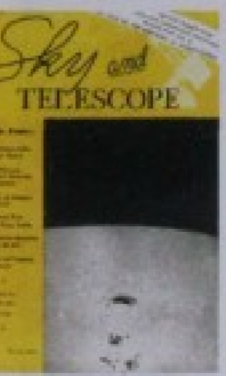
The orbiting observatory's Space Telescope Imaging Spectrograph, its main spectral detector, remains out of commission too. Shuttle astronauts will repair it and supplement it with the new Cosmic Origins Spectrograph (above). The spacewalk schedule seems so packed that a repair of ACS is very unlikely. Nevertheless, Hubble should still be a unique resource for researchers for years to come.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, writes a weekly newsletter on the space program at www.planet4589.org.*

50 & 25 years ago *by leif j. robinson*

MAY 1957

Early Interferometer "The largest radio telescopes of their type in this country, twin paraboloids each 90 feet in diameter, are being constructed by the California Institute of Technology at its new radio observatory near Big Pine, California. . . .



"They will be placed on railroad flatcars which will run on rails 1,600 feet long. The two antennas can thus be widely separated to form the components of an interferometer. . . . At a wave length of 40 centimeters . . . they together should determine positions of radio sources to 0.1 or 0.2 minute of arc."

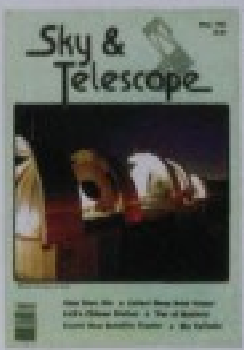
The Owens Valley Radio Observatory went on to comprise six 10-meter telescopes. The upgraded antennas — along with those of the Berkeley-Illinois-Maryland Association array — were moved to Cedar Flat, California, to form the Combined Array for Research in Millimeter-wave Astronomy (CARMA), dedicated on May 5, 2006.

Space Exploration Prognostication "By means of automatic observing and recording instruments, [artificial satellites] will study the earth from a distance, measure the magnetic field of the moon, and record the lunar surface in detail, including the never-seen far side. These experiments appear so near at hand that one may venture to say that in the next decade or so we will be living through the excitement of such explorations."

Victor Blanco's time frame was spot on. The Soviet Union launched Sputnik 1 five months later, and its Luna 3 photographed the Moon's far side in 1959. The US space probes Ranger 7, 8, and 9 imaged lunar boulders and tiny craters in 1964 and 1965. Spacecraft found the Moon to have no global magnetic field.

MAY 1982

Touchdown on Venus "The news that two Soviet spacecraft had reached the surface of Venus in March was not unexpected. American planetary scientists knew of the mission plan long ago. . . .



"Even so, the successful landings by Venera 13 on March 1st and by Venera 14 four days later set off a wave of anticipation among planetary scientists about to attend the 13th annual Lunar and Planetary Science Conference. . . . Representatives of the Soviet Venera teams came as well, giving their preliminary analyses of results."

mission update *by jonathan mcdowell*

THEMIS

NASA launched an ambitious aurora and space-physics mission on February 17th, when a single Delta rocket carried a cluster of five identical satellites called THEMIS (Time History of Events and Macroscale Interactions during Substorms) into a highly elongated Earth orbit. Each 125-kilogram (275-pound) probe has a rocket engine and an assortment of particle detectors and magnetometers to study space weather.

After a maneuvering phase lasting six months the probes will settle into different, but related, orbits spread out in Earth's equatorial plane. The orbits will be synchronized so that the five satellites will line up downwind from the Sun, along Earth's magnetotail, once every four days.

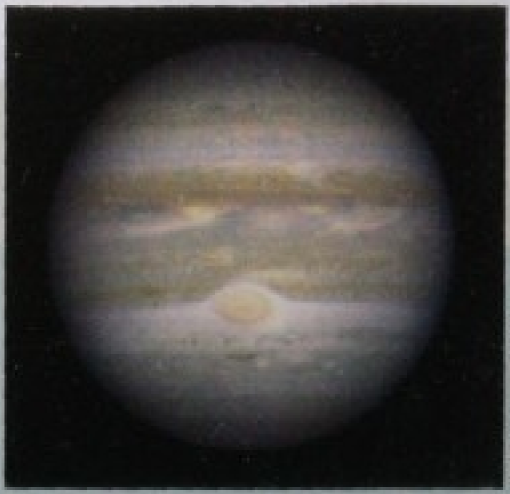
Spread throughout the equatorial magnetosphere, the THEMIS constellation will make simultaneous measurements of local conditions and study how the active auroras known as magnetic "substorms" develop. Researchers have two competing theories. One assumes that the process of "reconnection" in the magnetotail is important: parallel magnetic-field lines oriented in opposite directions pinch together, reconnect, and snap back, releasing energy the way a stretched rubber band does when it breaks.

The second idea says that turbulence closer to Earth triggers the substorms. It's not clear which effect happens first and causes the other. In either case, the release of energy sends particles down into Earth's atmosphere near the poles and generates dramatic, rapidly fluctuating auroras.

Twenty cameras throughout Alaska will monitor auroral activity at the same time. Aurora-like processes are thought to occur in the magnetospheres of dwarf stars and quasar accretion disks, so the THEMIS results could have broader implications for astrophysics.

Mars Reconnaissance Orbiter

MARS RECONNAISSANCE ORBITER'S High Resolution Imaging Science Experiment (HiRISE), operating in Martian orbit since late 2006, continues to return spectacular pictures of the Red Planet's surface despite some problems with bad pixels and increasing noise in some of the camera's detectors. Its ability to resolve the Viking landers and other hardware on the ground is impressive, but the half-meter-aperture HiRISE is also the biggest visible-light telescope to leave Earth orbit. HiRISE demonstrated its capability on January 11th when it captured Jupiter (above) with quality comparable to that of the Hubble Space Telescope.



NASA / JPL / UNIV. OF ARIZONA

When Mars Reconnaissance Orbiter took this picture, Jupiter was 3.88 astronomical units from Mars and appeared 51 arcseconds wide — only a trace larger than it ever appears from Earth.

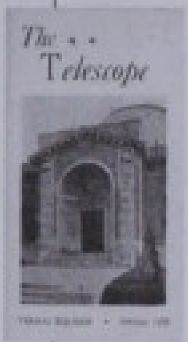
There's something moving about seeing real, high-resolution astrophotography taken from another world. I suspect that it may trigger a spate of requests from nonplanetary astronomers who would like to use a medium-size space telescope to look at galaxies and nebulae that are (in their eyes) more important than boring red rocks.

JONATHAN MCDOWELL *monitors spacecraft activity at www.planet4589.org.*

75, 50 & 25 years ago *by leif j. robinson*

JUNE 1932

Minor Planet Makeover "Most asteroids are of no particular interest individually."



True enough then, but today the discovery and observation of asteroids, along with trans-Neptunian objects, is one of the hottest arenas in astronomy.

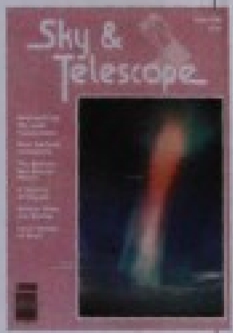
JUNE 1957

Spectacular Visitor "COVER: Comet Arend-Roland, as it appeared from an altitude of about 7,000 feet in the mountains east of Los Angeles, California, on the evening of April 24th. The picture was taken by Alan McClure. . . ."

McClure, who died in 2005, was the premier comet photographer of his generation (May issue, page 86). Comet Arend-Roland was a majestic sight visually, and at the time of the photograph it sported a tail some 30° long.

JUNE 1982

Gamma-ray Mystery "Since their discovery a decade ago, the mysterious celestial gamma-ray bursters have refused to give up the secret of their origin. To date no object detected at any other wavelength has been unambiguously identified with such a source. The lack of data has not hindered attempts at explanation, however, and theoretical models of the phenomenon abound."



Today this mystery is largely solved. Bursts lasting a couple of seconds or less result from flaring by highly magnetized neutron stars (magnetars), mergers of two neutron stars, or black holes swallowing neutron stars. Longer bursts come from core collapses of extremely massive stars.

Quasars Solved "Evidence is getting ever stronger that at least some quasi-stellar objects . . . are galaxies at cosmological distances. For $1\frac{1}{2}$ decades following the recognition of these curious objects, little progress in understanding them was made."

Today quasars are recognized as the cores of so-called active galaxies powered by supermassive black holes.

mission update *by jonathan mcdowell*

SELENE: Japan Shoots for the Moon

Japan is preparing to mount the most ambitious lunar mission since the Apollo and Luna flights of the 1960s and '70s. The SELENE (Selenological and Engineering Explorer) spacecraft, to be launched in mid- to late 2007, will have a mass of almost 2 metric tons after it arrives in its 100-kilometer (60-mile) polar orbit around the Moon. This is twice the weight of the planned US Lunar Reconnaissance Orbiter (LRO), which will follow a year later.

SELENE carries a multiband imager with a surface resolution of 20 meters (65 feet) and a stereo camera with 10-meter resolution. This bests previous lunar orbiters but will be much less capable than LRO's planned resolution of 0.5 meter. SELENE will also carry a laser altimeter to map topography, X-ray and gamma-ray spectrometers to study the composition of lunar rocks, deep radar to probe up to several kilometers underground, and high-definition television cameras. SELENE will also deploy two small subsatellites, Rstar and Vstar, into elongated orbits to map lunar gravity.

Japan's heavy-satellite missions in Earth orbit have had mixed success because of malfunctioning solar panels and power supplies. And its small asteroid probe Hayabusa is still struggling after a mixture of triumphs and setbacks (*S&T*: September 2006, page 34). Given this record, SELENE seems a big bite for JAXA, the Japanese space agency, to chew on, but if it's successful it will make major contributions to lunar science.

NASA Moon-Program Peril

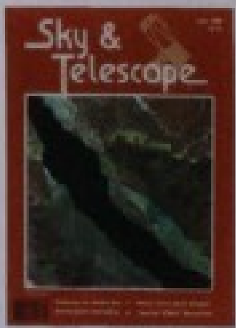
NASA's RETURN to the Moon is in disarray with the attempted cancellation of the Lunar Precursor Robotic Program, a series of orbiters and landers to pave the way for human exploration. The first launch – LRO (see left) and the piggybacked Lunar Crater Observation and Sensing Satellite (LCROSS) – will proceed in 2008. But several follow-on missions remain in doubt. Congress has stalled NASA's plans to ax them.

These missions would explore the lunar polar regions. One lander would evaluate surface conditions; another would roam a shadowed crater to search for ice and other volatiles. Later spacecraft would test key technologies to process lunar resources, vital for any long-term human outpost.

NASA leaders have expressed doubts about the need for extensive research prior to the arrival of astronauts, though the missions described above seem like obvious steps before beginning construction of an expensive lunar base.

JONATHAN MCDOWELL *monitors spacecraft activity at www.planet4589.org.*

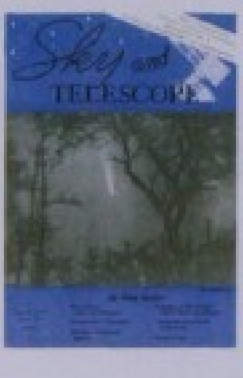
50 & 25 years ago *by leif j. robinson*



JULY 1957

Massive Science "On July 1st, when the International Geophysical Year formally begins, a multitude of scientific research programs will be started by 57 nations of the world. The United States will undertake many studies as its share in this largest co-operative scientific effort ever attempted. The IGY period will end on December 31, 1958."

The timing of the IGY was chosen to correspond with maximum solar activity, when Sun-Earth effects would be most pronounced (see page 24). Fifty years later, 2007 is being celebrated as the International Heliophysical Year.



Right After 50 Years? "At present the generally used value of the distance from the sun to the center of the Milky Way galaxy is 8,200 parsecs (about 27,000 light-years), from two accordant determinations. One of these was by Walter Baade in 1953, using the apparent brightnesses of 36 RR-Lyrae-type [pulsating] variable stars nearly in the direction of the galactic nucleus. The other result came from an analysis by Dutch radio astronomers in 1954 of the rotation of the galaxy. . . .

"A critical examination of both results revealed that they may be more uncertain than is often supposed. . . ."

The best estimates today remain at 24,000 to 27,000 light-years.

JULY 1982

Radio Sun "Since J. S. Hey's discovery of solar radio waves in 1942 our understanding of how the Sun emits such radiation has advanced steadily. This improvement is the result of our increased comprehension of radiation theory and fully ionized gases (plasmas), along with the development of new observational techniques. The continual struggle for ever better angular resolution, in particular, has resulted in the development of both new instruments and new ways to use them."

Cataclysmic Variable Stars "An entire CV – white dwarf, disk, and normal companion – could easily fit inside the Sun and, on the average, is no brighter than our star at all wavelengths. What makes such a system interesting is not its size or luminosity. . . . CV's are distinguished because they allow us to study gravitational accretion on an interesting time scale and over a wide statistical sample."

mission update *by jonathan mcdowell*

AGILE

THE ITALIAN SPACE AGENCY'S Astrorivelatore Gamma ad Immagini Leggero, or AGILE, satellite (Light Imaging Gamma-ray Astronomical Detector) reached orbit on April 23rd courtesy of India's first dedicated commercial launch, following a year-long delay (S&T: May 2006, page 26). AGILE took up an orbit 540 kilometers (335 miles) high and inclined 2.5° to the equator, ensuring that it avoids radiation belts that would decrease its sensitivity.

The Italian AGILE gamma-ray satellite flew into orbit aboard an Indian-built rocket from Satish Dhawan Space Centre. The 330-kilogram (730-pound) AGILE will spend two years observing gamma rays and X-rays using three detectors.

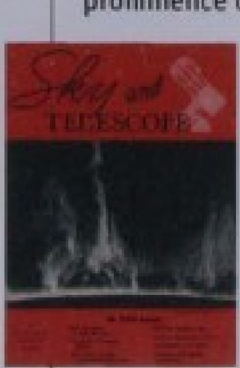
The spacecraft carries an imaging gamma-ray telescope as its main payload. This will detect gamma-ray photons between 30 million electron volts (MeV) and 50 billion electron volts (GeV) and will locate celestial sources to within about 10 arcminutes. A minicalorimeter will detect bright gamma-ray transients in the energy range 0.3 to 200 MeV. A third experiment, the Super-AGILE X-ray telescope, will study the sky between 15 and 45 kiloelectron volts (keV).

The first gamma-ray astronomy satellite was Explorer 11, launched in 1961. It detected only 22 gamma-ray photons at 50 MeV and set an upper limit on the brightness of the gamma-ray sky. The US Air Force Vela satellites, hunting for illegal nuclear explosions on Earth at energies below 1 MeV, accidentally discovered the now-famous gamma-ray bursts. Europe's COS-B in 1975 was the first successful high-energy gamma-ray mission, finding 25 sources across the sky. NASA's Compton Gamma Ray Observatory in 1991 raised the tally to more than 400, and its new Gamma-ray Large Area Space Telescope (GLAST) mission, planned for the end of 2007, is expected to find 10,000. Italian scientists, with a strong tradition in high-energy astronomy and cosmic-ray physics, will use AGILE to blaze the trail for GLAST.

JONATHAN MCDOWELL, *an astronomer at the Harvard-Smithsonian Center for Astrophysics, monitors spacecraft activity at www.planet4589.org.*

50 & 25 years ago *by leif j. robinson*

AUGUST 1957

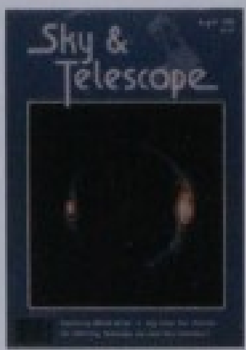


Sun Fire "COVER: This fine hedgerow prominence on the edge of the sun was photographed on September 20, 1956, with the 15-inch chromosphere camera at Sacramento Peak Observatory in New Mexico. The picture was obtained in red light, with a filter transmitting hydrogen-alpha radiation. . . .

"'Hedgerow' prominences . . . also appear as dark hydrogen filaments in monochromatic pictures of the sun's disk. This kind of prominence is not associated with sunspots. The hedgerows typically have a fine filamentary structure and often tend to form arches. Under special conditions, the arch ascends in a spectacular display of enhanced activity."

Fifty years later, anyone can view solar prominences in hydrogen-alpha light thanks to relatively low-cost filters and instruments like the Coronado PST.

AUGUST 1982



Gravitational Lensing "Would-be travelers to a black hole might encounter [the cover] scene en route. As portrayed by artist Jon Lomberg, the image of a distant galaxy is split by the massive, light-bending presence of an intervening black hole. Upon their approach to one of these enigmatic objects, 'opinauts' could use the breakdown of conventional space-time relations to view the past, the future, and even an assortment of 'antiuniverses.'"

Remarkably, only four years later Vahe Petrosian and Roger Lynds discovered real, gravitationally distorted arcs of very distant galaxies, shaped by the mass of largely dark matter in a cluster of galaxies lying along the line of sight. This lensing effect is now commonplace.

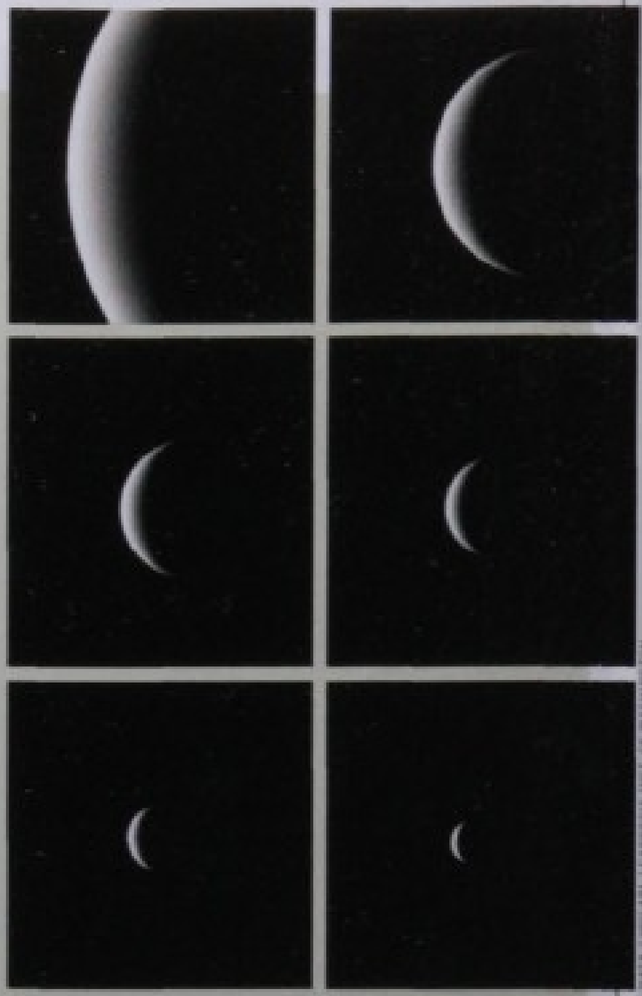
Neptune's Rings "On May 10th of last year, a handful of widely scattered observing teams witnessed an occultation by Neptune; as it turned out, two weeks later another occultation by the same planet was observed from Cerro Tololo in Chile.

"Investigators had hoped to turn up solid evidence for a Neptunian ring system. They did not."

A ring around Neptune was first found two years later, but occultation watchers were surprised by seeing evidence of it on only one side of the planet. Voyager 2 clarified the situation in 1989 when it imaged a weak ring containing three dense arcs. Six rings are now recognized.

mission update *by jonathan mcdowell*

Messenger



Destined to begin orbiting Mercury in 2011, NASA's Messenger spacecraft snapped these views of Venus after it flew by the cloud-shrouded world for a second time on June 5th.

NASA's Messenger spacecraft made its second flyby of Venus on June 5th, swooping to within 340 kilometers (210 miles) of the planet's cloudtops and surviving a 20-minute eclipse as it passed through its shadow.

Its name short for "Mercury Surface, Space Environment, Geochemistry, and Ranging," Messenger was launched in August 2004 and made a flyby of Earth a year later that dropped its perihelion inside the orbit of Venus. Its first Venus flyby on October 24, 2006, at the larger altitude of 2,990 km, altered Messenger's orbital period to match that of Venus and set up the craft for the more aggressive second flyby.

During the June encounter Messenger's full complement of instruments examined the shrouded world. The spacecraft performed visible-light and near-infrared imaging of the cloudtops, took ultraviolet and X-ray spectra of the upper atmosphere, and studied the planet's electromagnetic and charged-particle environment as it swept past at 13.5 km per second. Meanwhile, the European Space Agency's Venus Express made coordinated observations from its more sedate vantage in an orbit that takes it 66,000 km from the planet's surface.

Messenger has begun dropping sunward for its first encounter with Mercury next January 14th. Two such flybys in 2008 and a third in 2009, all at a height of 200 km, will shrink the orbit further from a 144-day period to 132, 116, and then 105 days. These times were carefully chosen to synchronize with Mercury's 88-day orbit around the Sun in 3:2, 4:3, and 6:5 ratios so that on March 18, 2011, Messenger arrives once more at the innermost planet — this time to stay.

The craft will fire its main engine to begin the first-ever orbital study of Mercury, the last of the classical planets to receive such in-depth attention. During a trio of flybys in 1974–75, Mariner 10 imaged less than half of the planet's Moon-like, cratered surface and discovered that Mercury has a magnetosphere. Planetary scientists eagerly await the data from Messenger to tease out more details of Mercury's structure and history and to complete the mapping of the inner solar system's planets.

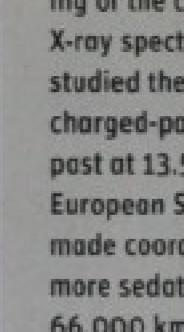
ESA's BepiColombo mission is expected to follow in Messenger's footsteps by arriving at Mercury in 2019. It will consist of two complementary satellites: the Mercury Magnetospheric Orbiter in a high orbit and the Mercury Planetary Orbiter in a low one.

Jonathan McDowell *monitors all manner of spacecraft activity at www.planet4589.org while working as an astronomer at the Harvard-Smithsonian Center for Astrophysics.*

50 & 25 years ago *by leif j. robinson*

SEPTEMBER 1932

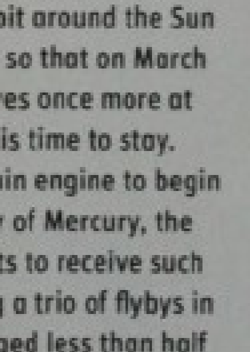
Texas Observatory "An agreement recently signed by the trustees of the University of Chicago and of the University of Texas makes possible the consolidation of resources for the establishment of a new observatory in the State of Texas.



"The University of Texas under the MacDonald [sic] bequest will build a large observatory to house an 80-inch reflector to be located in northwestern Texas. . . ."

The 82-inch (2.1-meter) telescope for McDonald Observatory was completed in 1939 and sited in the Davis Mountains 600 kilometers (375 miles) west of Austin. Named in honor of its designer, Otto Struve, in 1966, it remains in active use by astronomers.

SEPTEMBER 1957



Radio Giant "COVER: The 250-foot radio telescope at the Jodrell Bank Experimental Station of the University of Manchester, England, in a late stage of construction. In the foreground is seen the double circular track for rotation of the entire instrument in azimuth. Above center is the huge paraboloidal reflector, its interior partly covered with reflecting material. The dish is supported horizontally by trunnions on very tall supporting towers. . . ."

The Lovell Telescope, as it is now called, honors Bernard Lovell, a radio-astronomy pioneer. It has been refurbished twice and remains one the largest and most productive astronomical instruments in the world.

SEPTEMBER 1982

Jittery White Dwarfs "In the winter of 1964 Arlo Landolt discovered the first member of what later became recognized as a class of variable white dwarfs — the ZZ Ceti stars. . . .

"All members have multiple oscillation periods ranging from several hundred to more than 1,000 seconds. . . .

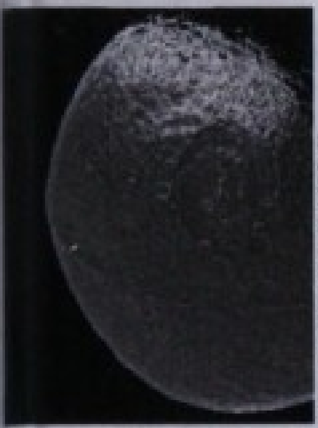
"All ZZ Ceti variables are white dwarfs [whose spectra exhibit only] absorption lines of hydrogen. The colors of these stars imply a very narrow range of surface temperature, from about 10,000 to 12,000° K. . . .

"Today they are known to be among the most abundant variables in our galaxy; . . . also among the best understood."

images including a nearly all-sky map at a wavelength of 9 microns, the first such census in the mid-infrared since the epoch-making Infrared Astronomical Satellite (IRAS) flew more than 20 years ago.

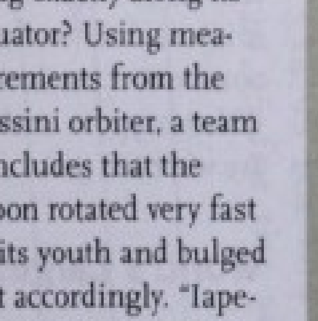
Walnut-Shaped Moon

WHY DOES Saturn's moon Iapetus have a big equatorial bulge and an eerily precise mountain range — the highest in the solar system — running exactly along its equator? Using measurements from the Cassini orbiter, a team concludes that the moon rotated very fast in its youth and bulged out accordingly. "Iapetus spun fast, froze young, and left behind a body with lasting curves," says NASA scientist Julie Castillo. As the moon cooled and its rotation slowed, it shrank slightly, and mountain-building stresses concentrated where the bulge was greatest.

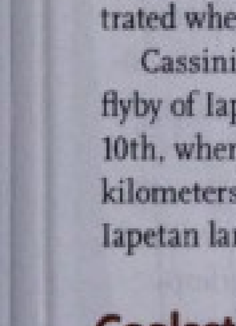

NASA / JPL / SPACE SCIENCE INSTITUTE

Cassini's long-anticipated closest flyby of Iapetus comes on September 10th, when the craft will speed just 1,000 kilometers (620 miles) above the weird Iapetan landscape.

Coolest Dwarf


UKIRT INFRARED DEEP SKY SURVEY

THE UKIRT Infrared Deep Sky Survey, being carried out with the United Kingdom Infrared Telescope in Hawaii, is only 5% done — but already, astronomers looking at its data have found the coolest solitary brown dwarf ever seen. A follow-up analysis of steam and methane features in the object's infrared spectrum pegs its temperature at about 650 kelvins (380°C, or 700°F). This puts it at the very bottom of spectral class T — or perhaps in the still-cooler proposed spectral class Y, for which no other object has yet been found.


JAXA

Mission Update *Jonathan McDowell*

Deep Impact

NASA has approved extended missions for two of its Discovery-class space probes: Deep Impact and Stardust.

Deep Impact intercepted Comet 9P/Tempel 1 in July 2005, reaching the comet near perihelion. The spacecraft flew only 500 kilometers (310 miles) from Tempel 1's nucleus as it slammed a 370-kilogram (800-pound) copper slug into the surface at 10 km per second (image at right).

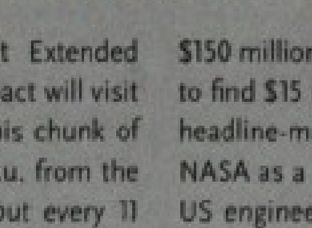

NASA / JPL-CALTECH / U. OF MARYLAND

Although Deep Impact captured the collision of its impactor with the nucleus of Comet Tempel 1, it never saw the resulting crater. Stardust is now scheduled to visit the comet in 2011 and survey the damage.

Although Deep Impact collected vast amounts of data on the comet and the collision (*S&T*: December 2005, page 16), it got no clear picture of the resulting crater; it was gone by the time the dust and vapor cleared. Tempel 1, a famous short-period comet, is now out at its aphelion 4.7 a.u. from the Sun, just within the orbit of Jupiter, and will next reach perihelion in 2011.

During its new mission (dubbed Extrasolar Planet Observation and Deep Impact Extended Investigation, EPOXI), Deep Impact will visit another comet, 85P/Boethin. This chunk of ice spends most of its time 9 a.u. from the Sun near the orbit of Saturn, but every 11 years it drops in as close as Earth's orbit.

Deep Impact will catch up to Boethin at its next perihelion, passing 500 km from it on December 5, 2008, and observing the nucleus with its cameras and infrared spectrometer. Along the way Deep Impact will act as a space telescope, making photometric observations of several stars with transiting exoplanets to improve our knowledge of their properties.


NASA / JPL-CALTECH / U. OF MARYLAND

Deep Impact's impactor snapped this view of the pocked surface of Comet Tempel 1's nucleus 90 seconds before smacking it at 10 km per second, creating one more crater.

Deep Impact will be sent on its way toward its new cometary target on New Year's Eve, when it will swing past the Earth 29,000 km above Mongolia.

Stardust

The Stardust probe used an aerogel dust collector to scoop up comet particles and dust in the asteroid belt. In November 2002 it flew by asteroid 5535 Annefrank. And in January 2004, for its primary mission goal, it sped by the nucleus of Comet 81P/Wild 2, collecting material from the comet's inner coma.

Two years later Stardust made a close flyby of Earth, dropping off its sample capsule in Utah (*S&T*: June 2006, page 17). While researchers examine its bounty of cosmic dust, the spacecraft has been in hibernation orbiting the Sun. For its new project, New Exploration of Tempel 1 (NeXT), the probe will pass Earth in January 2009 and head off to a 200-km flyby of Comet Tempel 1 in February 2011, to take pictures of the crater left by Deep Impact.

In recent years it's been difficult to secure funding for such extended missions. Sometimes it's easier to get $150 million for a shiny new spectacular than to find $15 million for a guaranteed, but less headline-making, science return. Indeed, NASA as a whole exists primarily to develop US engineering prowess and not to do science. So it can be hard to find room even in the science budget for new research that doesn't push innovative engineering.

The decision to reinvigorate Deep Impact and Stardust seems to reflect the strategy of NASA's new science boss, Alan Stern, who has also been pushing to fix the lack of money awarded to smaller projects. It will be interesting to see if Stern, a planetary scientist, adopts similar strategies in the astrophysics program.

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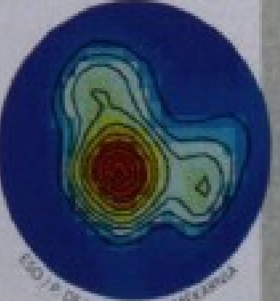
*Contributing editor **Jonathan McDowell** monitors spacecraft activity at www.planet4589.org.*

brightness. What happens is that carbon vapor leaving the star condenses into soot so thick that it blocks up to 99.9% of the star's light from view.

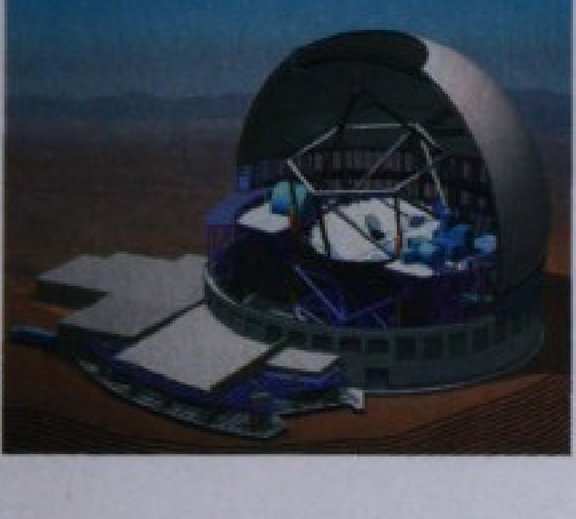
Recently astronomers used the European Southern Observatory's Very Large Telescope Interferometer to map two large, infrared-emitting smoke clouds as close as 30 astronomical units from RY Sagittarii, the second-brightest R Coronae Borealis star in the sky. This is the closest dusty cloud ever detected around an R CrB-type variable since the first such direct detection in 2004.


ESO / P. DE LAVERNY / D. MÉKARNIA

Thirty Meter Telescope

In August the hugely ambitious Thirty Meter Telescope Project received another $15 million from the Gordon and Betty Moore Foundation, in addition to the $35 million the foundation gave previously.

The title of the world's largest single, visible-light telescope will soon pass from the 10-meter Kecks in Hawaii to the 10.4-meter Spanish GranTeCan (see last month's issue, page 18). But the TMT will seize the title in a huge way. Its primary optic will consist of 492 individually controlled hexagonal segments combining into a single mirror 30 meters (100 feet) wide. A six-laser guide star adaptive optics system will be built right in. Site selection is scheduled for next May; locations in Chile, Hawaii, and Mexico are on the short list. Plans call for the telescope to begin operations in 2016.


TMT PROJECT

Mission Update *Jonathan McDowell*


BALL AEROSPACE & TECHNOLOGIES CORP.

Kepler Dodges Axe, Aims for Alien Earths

NASA's planet-finding Kepler mission is back on track for an early 2009 launch following a brush with cancellation. The ballooning cost of this space observatory, now exceeding $500 million, led to an ultimatum by NASA's science boss, Alan Stern. Some quick adjustments and a decision to shorten the primary mission from 4 to 3½ years squeezed Kepler back into its allotted budget.

The 1-ton spacecraft will travel in a 372-day orbit around the Sun, similar to that of the infrared Spitzer Space Telescope. Its Schmidt optics, with a 0.95-meter (37-inch) aperture, will rank as the largest telescope ever placed beyond Earth orbit, beating Mars Reconnaissance Orbiter's 0.5-meter HiRISE camera and the 0.85-meter reflector aboard Spitzer.

Kepler will spend all its time staring at a single field at the border of Cygnus and Lyra, along our galaxy's Orion spiral arm, monitoring 100,000 stars. In each star it will measure brightness changes of less than one part in 10,000, the degree of sensitivity needed to reveal any Earth-size planets transiting across the stars' faces. Ground-based telescopes have been very successful at finding Jupiter-class transiting planets, but smaller worlds require observing from above the atmosphere.

Fewer than 1% of Earth-size planets in Earth-size orbits around Sun-like stars will actually transit their stars from our viewpoint. So the telescope must monitor a lot of stars to find such planets even if they are common. Besides Sun-like G-type stars, Kepler will also watch many K- and M-class orange and red dwarfs. Early next decade, we may finally know how common other Earths are in the galaxy.

Astronomers are already compiling a catalog of target stars, using the 1.2-meter telescope on Mount Hopkins in Arizona to estimate their distances and sizes and to eliminate unworthy giants and variables. The mission is designed to find several hundred terrestrial planets with orbital periods of up to a year, which would put them in the "habitable zone" around their stars.

Kepler has a huge field of view — 105 square degrees — and a 95-megapixel camera that will track stars as faint as 15th magnitude. An onboard computer will analyze the images, create light curves for the stars of interest, and send only that data to the ground. This greatly reduces the time needed to talk to Earth, but it also means that the telescope can't observe serendipitous new objects even if they appear smack in its field of view.

SOURCE: NASA / ARC

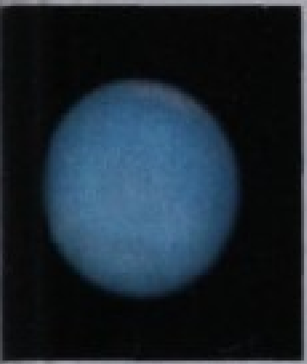
The Kepler spacecraft will stare at this field between Vega and the western wing of Cygnus, monitoring the light from 100,000 stars to find any small planets transiting them. Boxes show the coverage of the camera's CCD chips.

This limitation doesn't worry the Kepler team, which will likely be swamped with data. In addition to planets, the precise light curves should reveal tiny seismic oscillations in the target stars, a means of probing their interiors. ◆

***Jonathan McDowell**, an astronomer at the Harvard-Smithsonian Center for Astrophysics, reports on all manner of spacecraft activity at www.planet4589.org.*

Neptune's "Warm" Pole

Neptune's spin axis is tilted to its orbit by roughly the same amount as Earth's (28° vs. 23.4°). So you'd expect Neptune's poles to be colder than its equator. Not so. Using Europe's Very Large Telescope in Chile, Glenn Orton (NASA/JPL) and colleagues have found that the planet's south pole is about 18°F (10° Celsius) warmer than elsewhere.

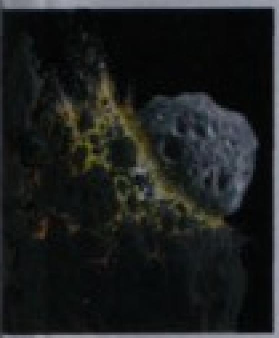


The pole-vs.-equator temperature imbalance probably affects why Neptune has some of the strongest winds in the solar system: up to 1,200 miles (2,000 km) per hour at certain latitudes. The south pole is at bottom in this Hubble image from April 2005.

The Source of the Dinosaurs' Asteroid

A giant impact created the 110-mile-wide Chicxulub crater in the Yucatán and wreaked global catastrophes that ended our planet's Cretaceous era; of that geologists are all but certain. But where did the impactor come from?

Three dynamicists find persuasive evidence that it originated in a titanic asteroid collision out beyond Mars some 160 million years ago. The bust-up produced the 3,000 known members of the Baptistina family of asteroids, named for the largest one, 298 Baptistina. They follow similar orbits and show similar surface compositions. The researchers found, by tracing the orbits back through time, that some of the original shards must have leaked into the inner solar system through orbital resonances with Mars and Jupiter. These, in turn, caused a prolonged asteroid shower peaking from 100 to 50 million years ago.



DON DAVIS / SWRI

Chromium in the Chicxulub debris on Earth strengthens the Baptistina connection. So does the relative rarity of such big impacts during other geologic eras.

Mission Update *Jonathan McDowell*

JHU / FUSE PROJECT

Kaguya: To the Moon!

Japan's SELENE (Selenological and Engineering Explorer) lunar mission got under way on September 14th with a picture-perfect launch from the island of Tanegashima. Once in space, the SELENE spacecraft was renamed Kaguya, after a lunar princess from Japanese folklore.

Japan's only previous Moon probe, Hiten, was launched in 1990. A modest 430-pound craft, Hiten was at the limit of what the Institute of Space and Astronautical Science (ISAS), the country's scientific space agency, could launch with its small Mu rocket.

ISAS merged with other government agencies in 2003 to form the Japanese Aerospace Exploration Agency, JAXA. One benefit of the merger is that spacecraft can now use JAXA's much larger H-IIA rocket. Even so, Kaguya is so heavy that the H-IIA could only propel it to a "phasing" orbit with an apogee of 145,000 miles (233,000 km), just 60% of the way to the Moon.

Kaguya's own engines were to pump up the orbit after several circuits of Earth and slip the craft into lunar orbit in early October. Kaguya will deploy two small subsatellites to measure the lunar gravity field, and then drop into a 60-mile-high mapping orbit to begin the most intensive scientific survey of the Moon since Apollo.

Contributing editor ***Jonathan McDowell*** *keeps track of spacecraft activity at www.planet4589.org.*

JAXA

Life and Death of FUSE

It's always sad to report that a hard-working space-science mission is over. But that time has now come for NASA's Far Ultraviolet Spectroscopic Explorer. Mechanical failure forced FUSE to wrap up its observing in August after eight very productive years in space.

Problems with the four flywheel-like devices used to point the spacecraft had interrupted observing several times in recent years, and on May 8th the last of these "reaction wheels" failed. Flight controllers at Johns Hopkins University in Baltimore managed to restart the wheel and resume the observing program on June 12th. But it stopped again one month later, this time for good. After several weeks of fruitless attempts to revive any of the four, the FUSE team finally accepted defeat.

The far-ultraviolet spectrograph and the spacecraft itself are otherwise in good working order. But to get starlight into the spectrograph's narrow entrance slit, FUSE must be able to point precisely at a target. Since it can no longer do that, NASA's Science Mission Directorate terminated the mission. By late October, researchers will have performed the final calibration tests with the instrument, and the spacecraft will be decommissioned.

Launched on June 24, 1999, FUSE has made the most detailed ultraviolet studies of stars to date. It discovered hot winds flowing outward from cool stars and recorded hot plasma in the halo of our galaxy.

Moreover, FUSE addressed a key cosmological question by measuring the deuterium (hydrogen-2) abundance in various parts of the galaxy. It established that some nearby interstellar regions exhibit low quantities of deuterium because it's locked up in dust grains, and consequently the total abundance of deuterium is higher than what theoretical studies of the galaxy's chemical evolution had predicted.

Skylights into Martian Caves

ON THE SLOPES of Martian volcanoes, roofs of lava-tube caves have apparently collapsed here and there. NASA's Mars Reconnaissance Orbiter has discovered seven entrances into deep voids high on the slopes of Arsia Mons. The one pictured here is 500 feet (155 meters) wide.

Now the hunt is on for more. Martian caves are of interest not only for their geologic context but as possible habitats. Future human colonists could use them to stay out of the dusty Martian winds and the harmful cosmic radiation that bathes the surface.

NASA / JPL / UNIV. OF ARIZONA

Imaging Mercury

USING THE amateur-pioneered technique of webcam image selection and stacking, astronomers using the 4.1-meter SOAR telescope in Chile have obtained clear images of Mercury (below). They show bright markings scattered across areas that were not imaged in 1974 and 1975 by Mariner 10, the only spacecraft to visit Mercury up to now. Radar imagery shows that the bright spots in visible light are centered on young craters, much like bright ray systems on the Moon.

G. CECIL / UNIV. OF N. CAROLINA

The long dearth of Mercury exploration is ending; NASA's Messenger craft makes its first flyby of the bare little planet on January 14th.

Automated Lunar Impacts

FOR DECADES astronomers hoped to see the flash of a meteoroid hitting the night side of the Moon, and in recent years amateurs have recorded a few of these events during strong meteor showers. Now the process has been automated. A project by astronomers at NASA's Marshall Space Flight Center takes simultaneous

Mission Update *Jonathan McDowell*

Dawn: Bound for Vesta and Ceres

After months of delay, the Dawn spacecraft escaped Earth on September 27, 2007, with a perfect launch. Dawn, the ninth NASA Discovery mission, will orbit the large asteroid 4 Vesta and the dwarf planet 1 Ceres in the next decade. Dawn also marks NASA's next step in using highly efficient ion propulsion for planetary exploration, following the successful Deep Space 1 technology mission.

Ceres, also classified as an asteroid (of the carbonaceous G type), is large enough for its gravity to mold it into spherical shape and thus qualify it for dwarf-planet status. Slightly smaller Vesta is more irregular in shape and is the prototype of the V-type asteroids, which have a denser, iron-rich composition. Ceres and Vesta are — at 580 and 320 miles across, respectively — more than 10 times larger than any asteroid previously visited by a spacecraft.

NASA / TONY GRAY & ROBERT MURRAY

Dawn lifted off last September 27th, bound for long-term study of the dwarf planet Ceres and the asteroid Vesta.

Dawn has three ion thrusters with 937 pounds (425 kg) of xenon propellant for interplanetary travel and asteroid orbit insertion. Two solar arrays spanning nearly 65 feet (20 meters) provide power for the ion drive and Dawn's complement of instruments, which include cameras, a visible/infrared mapping spectrometer, and a gamma-ray/neutron spectrometer.

The spacecraft is now on its way to a flyby of Mars in February 2009. The ion engines will then adjust the trajectory to match the orbit of Vesta, 2.3 astronomical units from the Sun. Dawn will rendezvous with Vesta in August 2011, go into orbit, and map it until May 2012, when the probe will return to solar orbit.

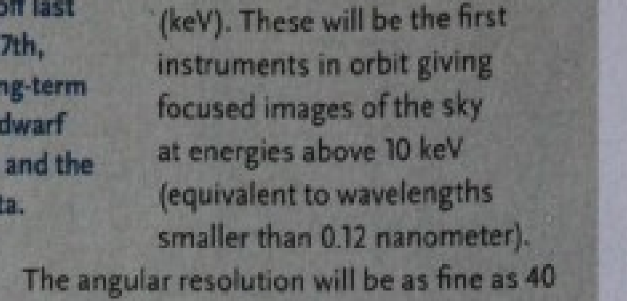
The ion engines will then slowly spiral Dawn outward until it reaches Ceres, at 2.8 a.u. from the Sun, in February 2015. It will repeat its science program there until its planned mission ends in July 2015.

NuSTAR Revived

NASA has reinstated the Nuclear Spectroscopic Telescope Array (NuSTAR), a Small Explorer mission, which is now scheduled for launch in 2011. The project was cancelled last year due to budget problems, but Alan Stern, leader of NASA's science mission directorate, squeezed out enough money to allow the restart, alleviating a drought in future high-energy astrophysics missions.

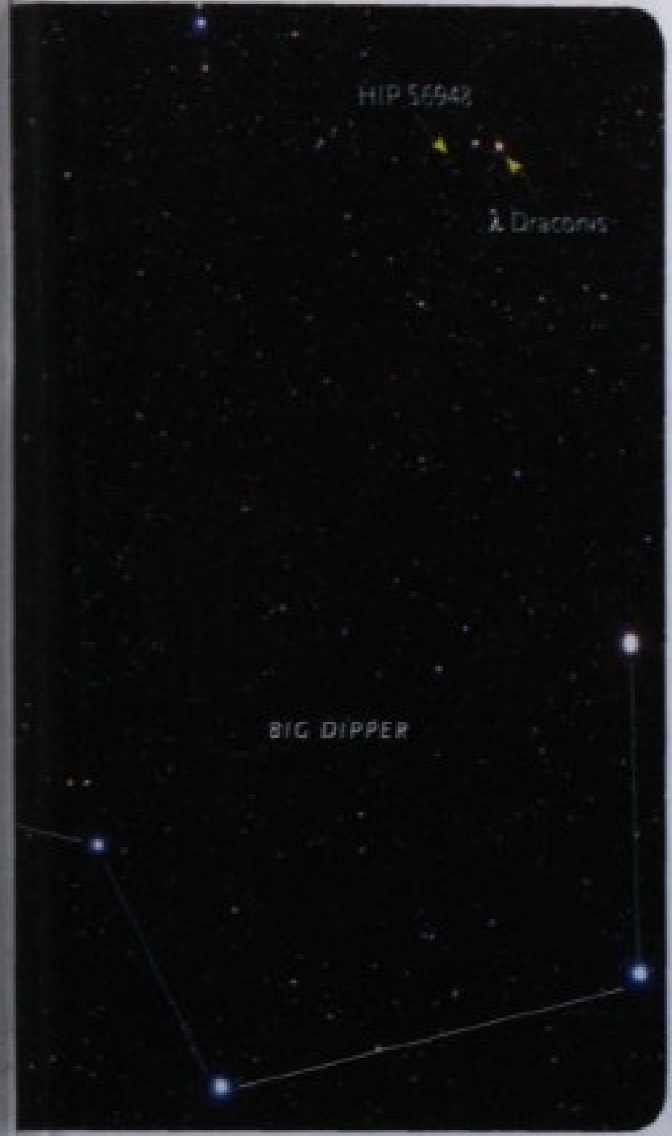
NuSTAR will carry three identical telescopes sensitive to "hard" X-rays with energies of 6 to 80 kiloelectron volts (keV). These will be the first instruments in orbit giving focused images of the sky at energies above 10 keV (equivalent to wavelengths smaller than 0.12 nanometer). The angular resolution will be as fine as 40 arcseconds, compared to 20 arcminutes for previous hard-X-ray missions. NuSTAR will make a census of active galactic nuclei in fields well observed at other wavelengths. It will also examine the Milky Way's own center and map supernova remnants to study the production of the chemical elements.

***Jonathan McDowell** provides more spacecraft updates at www.planet4589.org.*



CALTECH

NASA's NuSTAR satellite will carry three high-resolution X-ray telescopes having very long focal lengths.

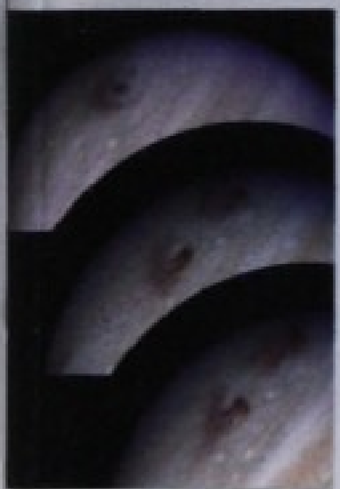


the Sun's lithium abundance much better.

Yes, it has been examined for planets. No, none have been found . . . yet.

Do We Really Need Jupiter?

DID THE EMERGENCE of advanced life on Earth require a giant planet like Jupiter in the solar system, to sweep out most of the comets that would otherwise cause catastrophic impacts on Earth? Conventional wisdom has said yes, but Jonti Horner and others from the UK's Open University find that a giant planet doesn't reduce extinction-causing impacts as much as has been thought. This means there's more wiggle room in what it takes to make a solar system habitable.



Horner also theorizes that killer impacts may not always be detrimental to life — in fact, they might speed up evolution. "It may be that if you have too few impacts, life

Mission Update

Jonathan McDowell

China's First Interplanetary Spacecraft

China's space-science program took a major step in October with the launch of its first deep-space probe, Chang'e 1, to study the Moon. The 2½-ton craft — named for the Chinese Moon goddess — is based on a communications satellite but with improved thermal protection and a bigger communications antenna.

A Chang Zheng (Long March) 3A rocket launched Chang'e 1 from Xichang into a temporary geostationary orbit. The spacecraft then spent a week slowly pulling away from Earth until October 31st. By November 7th it had entered a circular, 125-mile-high polar orbit around the Moon, ready to begin close-up studies of the surface.

The scientific payload includes a stereo camera with a resolution of around 400 feet (120 meters) and a laser altimeter with similar accuracy. Researchers will use them to create a three-dimensional map of the surface. Chang'e 1 also carries a gamma- and X-ray spectrometer and a microwave radiometer to study the chemical and thermal properties of the lunar surface.

China built a special 165-foot deep-space communications antenna outside Beijing to communicate with the probe, an investment that will support future deep-space missions.

China's Chang'e 1 is a retooled communications satellite now orbiting 125 miles (200 km) above the lunar surface.

Satellite Practice

The highest-altitude mission flown previously by China was Tan Ce 1, one of two Double Star satellites launched in 2003 for a collaborative research project with the European Space Agency. The Double Star spacecraft worked with ESA's four Cluster satellites to monitor energetic events in Earth's magnetosphere.

According to the China National Space Administration (CNSA), Tan Ce 1 provided useful practice in controlling satellites far from Earth. Its apogee of 49,100 miles put it twice the distance of the geostationary satellites that China had launched up to that point, but only 20% of the way to the Moon. Tan Ce 1 re-entered the atmosphere and ended its mission in October 2007.

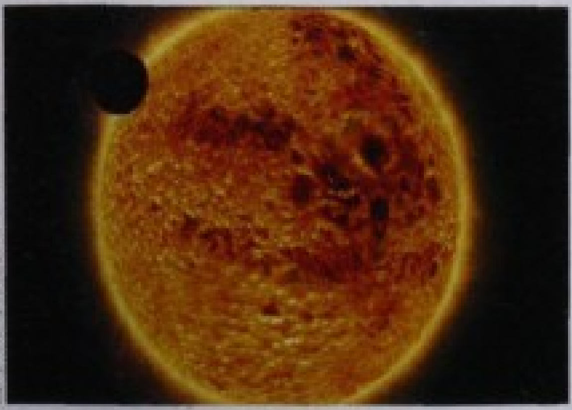
Stepping to the Moon

The Asian exploration of the Moon begun by Japan's Kaguya (*S&T*: December 2007, page 17) and China's Chang'e 1 will continue with Chandrayaan 1 in 2009. The Indian Space Research Organization's (ISRO) craft will, like its Chinese counterpart, first occupy a geostationary transfer orbit before using its onboard engine to reach lunar orbit.

In the early days of space exploration, US and Soviet launchers relied on direct-ascent trajectories, which sent the Luna and Pioneer missions toward the Moon without first orbiting Earth. In the early 1960s the prevalent technique involved placing the rocket's upper stage in a circular, low-Earth "parking orbit" before continuing on.

Since the 1980s, however, most launch vehicles have been optimized to send payloads to a "geostationary transfer orbit," with a low perigee and an apogee near 22,240 miles (35,800 km), to serve the communications-satellite industry. It turns out that a lunar probe can be launched with the same method. Once a spacecraft is circling Earth, instead of firing an engine at apogee to circularize the orbit high over the equator, a comparably long burn is made at perigee to elongate the orbit out to the Moon's gravitational influence. This means that today, any country with the technology to launch a geostationary satellite already has the ability to mount a lunar program.

***Jonathan McDowell** examines spacecraft from all nations at www.planet4589.org.*



ESA / NASA / FREDERIC PONT

duced opposite results about the planet's atmosphere.

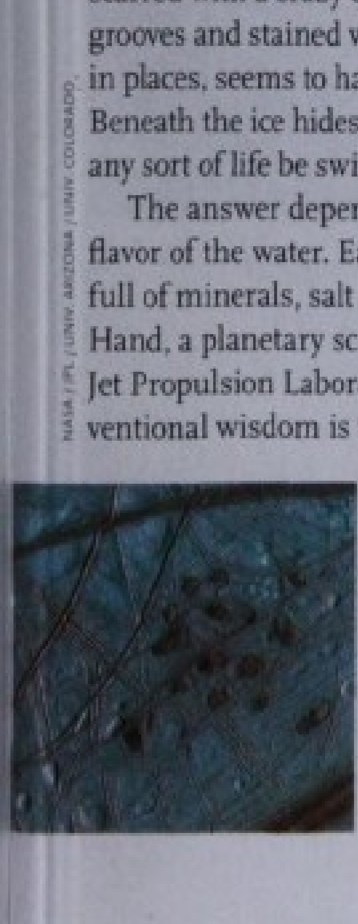
Astronomers used a spectrograph on the Hubble Space Telescope to examine the star with and without the planet in front of it. The difference revealed spectral evidence from the tiny fraction of light skimming through the planet's atmosphere on its way to us. Signs of sodium, potassium, and water were expected — but not seen. The best explanation, the researchers say, is dust haze obscuring the planet's upper atmosphere.

Astronomers using the ground-based but much larger Hobby-Eberly Telescope in Texas performed a similar project. They detected sodium in the planet's atmosphere, though just barely. Apparently dust doesn't completely block light from filtering through.

Europa's Bitter Sea

The icy shell of Jupiter's moon Europa is scarred with a crazy quilt of cracks and grooves and stained with brown stuff that, in places, seems to have oozed out of them. Beneath the ice hides a global ocean. Could any sort of life be swimming there?

The answer depends partly on the flavor of the water. Earth's oceans are full of minerals, salt in particular. Kevin Hand, a planetary scientist with NASA's Jet Propulsion Laboratory, says the conventional wisdom is that Europa's ocean is dominated instead by magnesium sulfate, $MgSO_4$. "If you take a bunch of chondrites — space rocks — and crunch them to form a planet or a moon, the domi-



NASA / JPL / UNIV. ARIZONA / UNIV. COLORADO

Mission Update *Jonathan McDowell*

GLAST at Last

In late November, the Gamma-ray Large Area Space Telescope (GLAST) arrived at the Naval Research Laboratory in Washington, DC, to undergo its final tests before launch.

Built at the General Dynamics factory in Gilbert, Arizona, GLAST has already survived two rounds of stringent evaluation there. Vibration testing subjected the satellite to a spectrum of shaking that simulated the rattle of the rocket ride to orbit. Electromagnetic testing ensured that the spacecraft's varied electronic components won't interfere with each other or with sensors such as the magnetometers used to determine the satellite's orientation.

NASA / GENERAL DYNAMICS

NASA's Gamma-ray Large Area Space Telescope (GLAST), scheduled to launch in May, will map the high-energy universe.

Now GLAST will suffer the thermal-vacuum test, a major rite of passage for all spacecraft. The satellite is placed in a large chamber, and the air is pumped out. Then engineers repeatedly bake and freeze the craft to simulate the harsh conditions of space as it shifts back and forth from sunlight to darkness in Earth orbit. "Thermal vac" is the last major checkout before GLAST gets shipped to Cape Canaveral for launch in May.

GLAST's main instrument, the Large Area Telescope (LAT), developed by a team based at Stanford University, accounts for more than 65% of the satellite's mass. It will map the gamma-ray sky at energies from 30 million to more than 300 billion electron volts. The Italian satellite AGILE is the only other spacecraft currently observing in this regime (*S&T:* August 2007, page 22).

The satellite's second instrument is the GLAST Burst Monitor (GBM). It's a follow-on to the Compton Gamma Ray Observatory's BATSE telescope, which discovered the uniform distribution of gamma-ray bursts (GRBs) throughout the sky and set the stage for the understanding of their extragalactic nature.

Swift Restored to Service

NASA's Swift gamma-ray observatory completed three years in space on November 20th, by which time it had discovered 284 GRBs. Astronomers have found redshifts for almost 100 of these.

Trouble with the craft's gyroscopes developed on August 10th, resulting in a two-month cessation of observations. Engineers developed a workaround for the problem, and the satellite has returned to full operation.

Although GRBs remain Swift's main focus, active galaxies and galactic neutron stars have become a larger part of the observing program as astronomers accept Swift as one of their standard space-based discovery tools.

GLAST and Swift will complement each other. Swift will be able to determine more accurate locations for bursts discovered by the GBM, and GLAST can provide better spectral data for Swift sources.

Contributing editor ***Jonathan McDowell*** *provides insight on many space missions at www.planet4589.org.*

STEFAN IMMLER (NASA/GSFC) / SWIFT SCIENCE TEAM

Last year Swift caught two supernovae in one galaxy, MCG +05-43-16 in Hercules, some 380 million light-years distant.

The diagram at bottom left is not to scale. The large hole is 180 times the diameter of the small one, and even the large one (700 a.u. wide) would be only about 1.6 mm wide at the scale of their separation here.

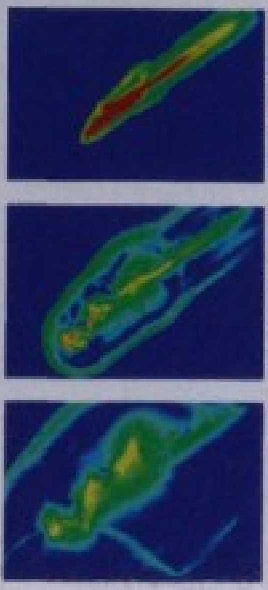
Stars Born in the Middle of Nowhere

Rarely do stars form outside of galaxies, but it happens. Astronomers using an ultraviolet telescope on the GALEX spacecraft have spotted many young star clusters in intergalactic space not far from M81 (left) and M82 in Ursa Major. The two galaxies, familiar to backyard observers (see page 51), underwent a close flyby or collision about 200 million years ago. Radio astronomers see far-flung streamers of gas around the pair dating from that event. The blue clusters spotted by GALEX (for instance, near the cross above) lie in one such streamer and seem to have formed since the time of the collision. It's the first time young stars have been seen this far from a galaxy.

NASA / ESA / D. DE MELLO

Tunguska Blast Revised Downward

New computer modeling has revised the power of the great 1908 airburst near the Tunguska River in Siberia from 10–40 megatons down to only 3–5 megatons of TNT. That's still the equivalent of a large hydrogen bomb. The new work included full 3-D modeling of the incoming object's material as it broke



M. BOSLOUGH & D. CRAWFORD / SANDIA NATL. LABS

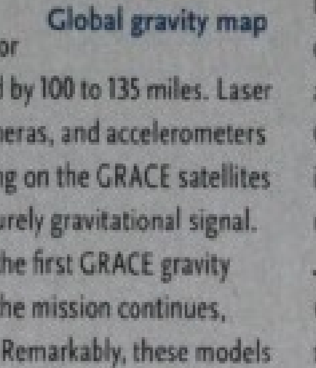
Mission Update *Jonathan McDowell*

The Lumps in Our Planet

For two centuries, scientists have been trying to determine the exact shape of our planet's *geoid*, the imaginary surface that's everywhere perpendicular to the downward pull of gravity and coincides with mean sea level. Although Earth is roughly an ellipsoid — 26 miles (42 km) smaller through its poles than across its equator — variations in density create localized deviations of up to 300 feet (100 meters). Thanks to two remarkable satellites, the geoid is now known to an accuracy of around 0.4 inch (1 cm).

In March 2002, a converted Russian intercontinental missile launched twin geodetic satellites into closely spaced polar orbits around Earth. These Gravity Recovery and Climate Experiment (GRACE) spacecraft, built by a German-American collaboration, perform accurate measurements of their mutual separation using radio links and GPS receivers.

Deviations of Earth's gravitational field from perfect spherical symmetry impart different accelerations to the two satellites, causing tiny shifts in the distance between them. As the leading satellite approaches a lumpy gravity anomaly, it's pulled and speeds up; once past, it slows down. Then the second satellite does likewise as it crosses the region. Analysis of these data at the University of Texas, Austin, at NASA's Jet Propulsion Laboratory, and at Germany's GeoForschungsZentrum has yielded a precise description of gravity variations as the satellites fly over every point on the globe.



Global gravity map

The German Space Operations Center in Oberpfaffenhofen controls the two spacecraft, which maneuver every month or two to remain separated by 100 to 135 miles. Laser retroreflectors, star cameras, and accelerometers detect other forces acting on the GRACE satellites in order to isolate the purely gravitational signal.

Researchers released the first GRACE gravity model in July 2003, but the mission continues, extended through 2009. Remarkably, these models describe how our planet's gravity field varies with time due to shifts in ocean currents and seasonal changes in snowpack and groundwater. Using GRACE data, scientists detected accelerated melting of Greenland's ice sheet, with its implications for climate change.

Shaping Up the Moon

NASA has selected a new Discovery mission that will do for the Moon what GRACE is doing for Earth. The project will be led by MIT's Maria Zuber and launched in 2011. Its rather contrived name, Gravity Recovery and Interior Laboratory, yields the snappy acronym GRAIL. Because the Moon has no atmosphere, the mission's two spacecraft will fly much lower, only 30 miles above the crater rims.

The two GRACE craft

The GRAIL craft will be derived from a Lockheed Martin design used for the Air Force's XSS-11 microsatellite, which demonstrated precise station-keeping in order to sneak up next to and photograph other satellites.

NASA's Lunar Orbiter missions in the 1960s discovered mass concentrations (*mascons*) under the Moon's surface that disturbed their orbits. These posed a navigation challenge to the Apollo spacecraft and would be fatal to any low-altitude orbiter lacking its own propulsion. Over time, the Moon's irregular gravity field would alter the spacecraft's orbit until its lowest point dipped below the surface. The resulting crash would, of course, not be heard in the lunar vacuum.

Selenodesy, the study of the Moon's shape, was bolstered by the Lunar Prospector and Clementine missions in the 1990s and is currently being greatly improved by Japan's recently deployed lunar orbiting triad of Kaguya, Ouna, and Okina (*S&T*: December 2007, page 17). GRAIL should achieve a further hundredfold improvement in the accuracy with which we can map the selenoid.

Contributing editor ***Jonathan McDowell*** *tracks the progress of space missions at www.planet4589.org.*

GLOBE: NASA / UNIV. OF TEXAS CENTER FOR SPACE RESEARCH; GRACE: NASA / JPL

HE 0437-5439, seems to be flying not from the Milky Way's center but from the Large Magellanic Cloud (LMC, on the bottom of the previous page). The trouble is, the LMC contains no supermassive black hole. However, astronomers find that a hole with a mere 1,000 solar masses could suffice. One team suggests, "This is the first observational clue that a massive black hole exists somewhere in the LMC."

A Neutron Star's Hard Core

What's in the middle of a neutron star? Pressures and densities there are so great that nuclear-matter theory gets vague about what it predicts.

SALLY & CURT KING / ADAM BLOCK / NOAO / AURA / NSF

Some real-world evidence now comes from two neutron stars more massive than usual. Most of the ones whose masses can be estimated top out at 1.4 Suns, as expected for collapsing giant-star cores. But in two globular clusters, including M5 pictured above, radio astronomers recently announced millisecond pulsars (fast-spinning neutron stars) that seem to contain about 1.9 and 2.7 solar masses. They presumably got that way by accreting a lot of extra matter after they formed.

Their existence means that neutron-star matter is more incompressible ("harder") than theorists expected. Otherwise gravity would have squeezed the stars right down to become black holes. This argues that their innermost matter is not compressed into a sea of undifferentiated "quark matter," but rather remains as distinct neutrons (a neutron is three quarks bound together). Pure quark matter, physicists think, would be more compressible.

Mission Update *Jonathan McDowell*

Voyager 2 at the Edge

The Voyager 2 spacecraft has passed another milestone on its 30-year journey, crossing a boundary that means it's soon to exit a physical edge of the solar system.

As the Sun and solar system move through the local interstellar medium (at 25 km per second), the solar wind and its entrained magnetic field blow a comet-like bubble moving through the thin interstellar gas and leaving a wake behind. The bubble is larger than the orbits of Neptune and Pluto. On the inner edge of the boundary, called the *heliopause*, the solar wind's outward velocity drops to zero as it's pushed back around the boundary into the tail of the *heliosheath*.

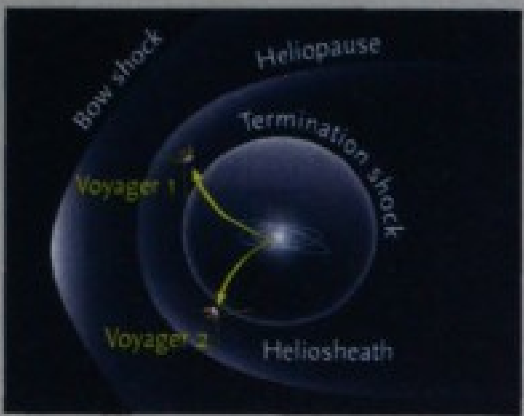
In August 1992 the plasma-wave instruments on Voyagers 1 and 2 detected radio emission from the heliopause (*S&T:* October 1993, page 30), generated where the solar wind crashes into the interstellar medium. It wasn't until December 2004, when 94 astronomical units from the Sun (8¾ billion miles), that Voyager 1 passed through the *termination shock*, where the solar particle flow becomes subsonic, and made the first direct measurements of the heliosheath, a transition region between the shock and the interstellar gas.

Voyager 2 unexpectedly reached the shock front on August 30, 2007, while only 84 a.u. from the Sun. Its instruments measured the velocity of particles in the surrounding plasma dropping from around 400 km per second in the solar wind to only about 100 km per second in the heliosheath.

The next, and most important, milestone is crossing the heliopause, which marks the true boundary of the solar system, electromagnetically speaking. This will happen when one of the Voyagers sees the flow direction change and the magnetic-field strength rise. At that point it will become the first human artifact to enter true interstellar space.

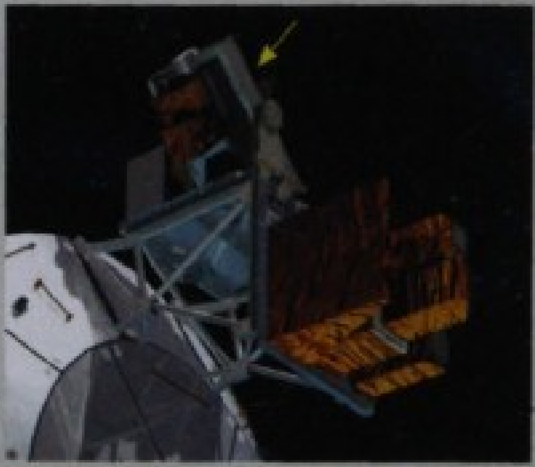
Voyager 1, in Ophiuchus, is heading nearly upstream toward the oncoming solar wind, while Voyager 2, in Telescopium, is moving sideways to the Sun's motion. The heliopause may be reached in only 5 to 10 years — increasing the chance that Voyager 2 will still be alive to report back from the event.

The next chance to study the termination shock won't come until the 2030s, when the New Horizons probe will head toward Sagittarius after its flyby of Pluto.



S&T: CASEY REED

The Voyager 2 spacecraft has joined its twin in the heliosheath. One of them may cross the heliopause, the true outer boundary of the solar system, in a few years.



ESA / D. DUCROS

The International Space Station now has a trio of astronomical instruments (arrowed) on the Columbus module added in February.

Space-Station Astronomy

The European Space Agency's Columbus module for the International Space Station (ISS) rode to orbit on the Space Shuttle *Atlantis* on February 7th. Although its pressurized compartment to house European astronauts got the most publicity, the module also boasts some scientific instruments, including an astronomical experiment dubbed Solar.

Solar carries three solar-physics instruments. They will accurately study the Sun's total energy output from the extreme ultraviolet to the mid-infrared, a critical parameter for climate-change studies.

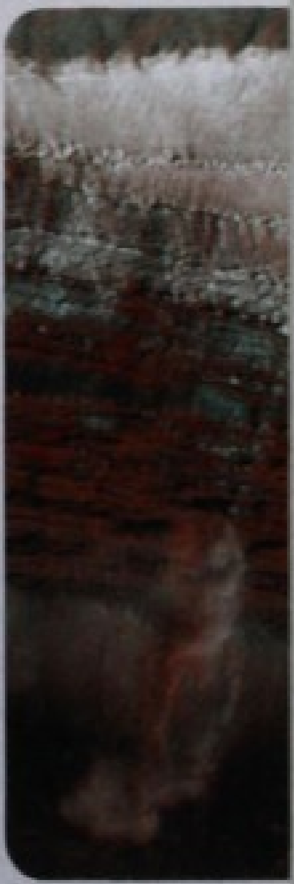
The Solar Variable and Irradiance Monitor consists of 16 different detectors. Three of them incorporate the difficult technology of absolute radiometers, which directly measure the wattage of radiation collected, instead of calibrating their energy scale using workarounds such as standard stars.

The other instruments face similar challenges. Calibration will be tricky with the spectrophotometers, which will collect extreme-ultraviolet photons using grazing-incidence telescopes. The Solar Spectral Irradiance instrument has flown in space several times on Spacelab missions lasting up to two weeks.

Solar's instruments will be controlled from a science mission center in Brussels, Belgium, working in concert with the main Columbus control center in Oberpfaffenhofen, Germany.

Four Martian Landslides Caught in the Act

Like a creeping glacier calving off chunks as you watch, a vast ice cliff marking the edge of Mars's north polar cap has been seen shedding four dusty avalanches *at once* — in a single image taken by the Mars Reconnaissance Orbiter. The enormous, high-resolution shot caught four widely separated little landslides happening along the 2,300-foot (700-meter) high cliff. Apparently the polar ice is on the move. "It really surprised me," says discoverer Ingrid Daubar Spitale. "It's great to see something so dynamic on Mars. A lot of what we see there hasn't changed for millions of years." The top of the cliff is at the top of the image at right.



NASA / JPL / UNIVERSITY OF ARIZONA

NASA / JHU-APL / CIW

Mare Mercury

On Sun-baked Mercury, enigmatic "smooth plains" cover pretty much everywhere that isn't a crater. For 30 years astronomers have wondered whether the plains are lava flows or thick blankets of impact debris. Close inspection of the recent Messenger spacecraft images seems to settle the issue: they're lava plains. Just about all of Mercury is one big, heavily cratered "mare," like the patches of dark lava plains on the Moon.

Mission Update *Jonathan McDowell*

Ulysses Says Goodbye

The odyssey of Ulysses is coming to an end after a successful 18-year mission orbiting the Sun.

Ulysses was one of the European Space Agency's first deep-space projects, following the Giotto comet probe. It had a tortuous gestation as a joint NASA/ESA out-of-ecliptic mission and then as the International Solar Polar Mission, featuring twin probes — one of which was cancelled when the US dropped out, leaving bitter transatlantic feelings.

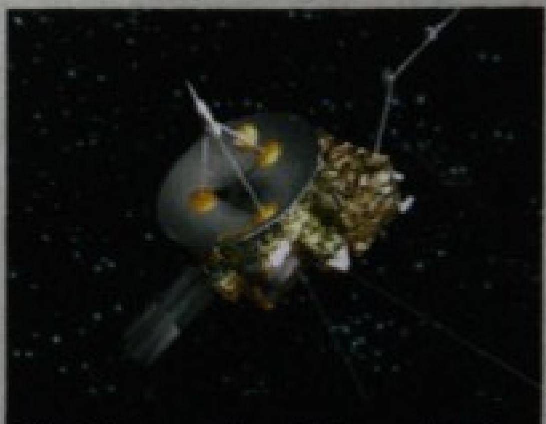
The mission faced further delays following the *Challenger* accident in 1986 and the cancellation of the Shuttle-Centaur upper stage. In October 1990, however, the Space Shuttle *Discovery* deployed the probe with a three-stage solid-rocket system that accelerated it to 15.2 km (9.4 miles) per second toward an encounter with Jupiter — the fastest Earth escape until the New Horizons launch in 2006.

The Jupiter flyby in February 1992 sent Ulysses into the first artificial-satellite orbit to pass over the poles of the Sun. The initial swing over the solar south pole in 1994 was followed by the first northern pass in 1995. Two orbits later, Ulysses was completing its third northern polar pass at the start of 2008.

As its aging radioisotope generators continued to run down, the probe's hydrazine fuel was in danger of freezing. But the loss of the main X-band radio transmitter on January 15th prompted researchers to wrap up the science program by the end of June. The backup S-band transmitter can't return enough data to make it worthwhile continuing.

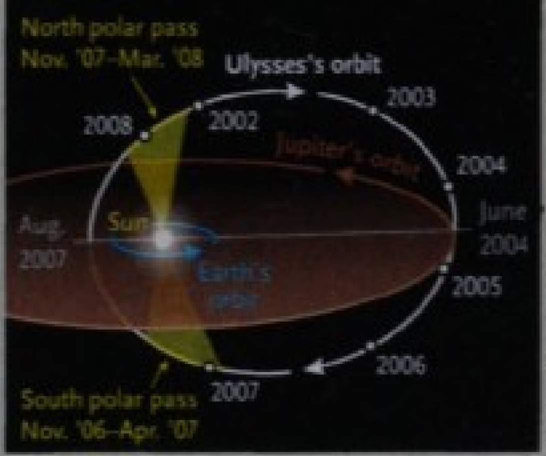
Ulysses leaves an extensive scientific legacy. It discovered that the solar wind at high latitudes flows a fast and steady 750 km per second compared to a wildly fluctuating and slower 400 km per second near the ecliptic. The fast wind is also cooler, thinner, and more directly reflects the composition of the Sun's photosphere than the slow wind, which is affected by conditions in the chromosphere.

Ulysses also discovered that the magnetic field in the solar wind has a similar strength at all latitudes, disproving earlier theories that predicted stronger fields near the poles.



ESA

After 18 years and nearly three orbits of the Sun, Ulysses has finally succumbed to the harshness of space.



S&T: CASEY REED

Looking for Dark Matter

Now that the International Space Station (ISS) has its solar telescopes (May issue, page 15), there's hope that it may also fulfill its obligations for cosmology.

During early station planning in the 1980s and 1990s, scientists expected that the orbiting facility would host a slew of "attached payloads" that would spend a few years bolted to the unpressurized truss. As the ISS assembly schedule slipped and the budget ran over, these external science payloads fell by the wayside. All that remains is the 7-ton Alpha Magnetic Spectrometer (AMS), which will use a magnet cooled by liquid helium to search for antimatter and dark-matter particles.

A prototype detector made a brief flight on Space Shuttle *Discovery* in 1998 to confirm the basic design. The particle-physics detector is well suited to the station because, unlike an astronomical telescope, it doesn't need to be pointed or held very steady, and its large mass made it a natural fit for a shuttle launch.

Unfortunately, the decision to retire the shuttle in 2010 left AMS without a ride, and the expensive instrument seemed destined to remain earthbound as higher-priority payloads took the final cargo spaces on NASA's winged spaceships (May issue, page 96).

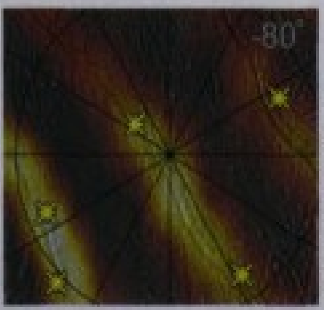
Now, Congress is telling NASA to find a way to launch it, even though this could mean savage cuts to other missions. Adding an extra shuttle flight isn't cheap, since it ties up resources that could otherwise be reassigned to the Constellation exploration program. The alternative of redesigning AMS to allow it to fly on its own would cost as much as several smaller science satellites.

Contributing editor ***Jonathan McDowell*** *tracks space missions at www.planet4589.org.*

To read more about any of these stories, go to **SkyandTelescope.com** and search for the keyword SkyTelJul08.

What Is Inside Enceladus?

When the Cassini spacecraft skimmed past Saturn's moon Enceladus on March 12th, its infrared spectrometer recorded heat glows all along the lengths of the "tiger stripe" cracks near the south pole of the icy little world. The image here overlays part of the the low-resolution heat map (color) on a high-resolution surface view. The cracks are about 100 miles long. Yellow asterisks mark sites of active ice-powder geysers. Most of Enceladus's surface is colder than −200°C, but the warmest stretch of the cracks measured −93°C (−135°F). This increases the likelihood that Enceladus has a liquid ocean under the ice.

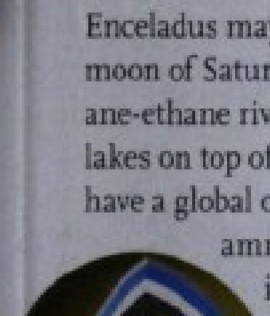


NASA / JPL / GSFC / SWRI / SSI

And it's a rich brew. Cassini flew right through a spray plume and detected not only water but carbon dioxide, carbon monoxide, methane, and more complex organic (carbon-based) compounds; these may include ethane, acetylene, propane, and others.

Titan's Free-Floating Crust

Enceladus may not be the only oceanic moon of Saturn. Big Titan, with its methane-ethane river channels and apparent lakes on top of a "bedrock" of ice, seems to have a global ocean deep inside, probably ammonia water, that keeps the ice crust detached from the interior.



NASA / JPL

The evidence is several years of radar data that show Titan is rotating not quite in lockstep with its 16-day orbital period and other gravitational influences, as dynamicists had expected. Moreover, Titan's rotation has actually *changed* by a trace even since Cassini began watching.

Shifting seasonal winds in the northern and southern hemispheres could exert a spin-altering torque on Titan. But this

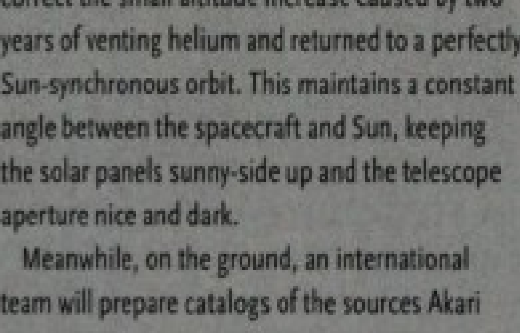
Mission Update *Jonathan McDowell*

Akari Warms Up

Japan's Akari infrared observatory has opened a new chapter of its mission. It was launched in February 2006, and by August 2007 it had surveyed 94% of the celestial sphere (*S&T:* October 2007, page 16). But on August 26th the satellite used up the last of its 45 gallons (170 liters) of liquid helium, after which its 27-inch (68-cm) main telescope began to warm up from its operational temperature of 6 kelvin (6°C above absolute zero). This forced the retirement of Akari's Far-Infrared Surveyor, which is sensitive to infrared light with wavelengths between 50 and 180 microns. Akari's shorter-wavelength detectors still operate, thanks to mechanical coolers that keep the focal plane at about 40 kelvin.

In early December Akari was maneuvered to correct the small altitude increase caused by two years of venting helium and returned to a perfectly Sun-synchronous orbit. This maintains a constant angle between the spacecraft and Sun, keeping the solar panels sunny-side up and the telescope aperture nice and dark.

Meanwhile, on the ground, an international team will prepare catalogs of the sources Akari



Akari imaged 94% of the sky at infrared wavelengths, as seen in this low-resolution thumbnail.

detected, which will supersede the 20-year-old Infrared Astronomical Satellite (IRAS) survey and provide rich target lists for new observatories such as the European Space Agency's soon-to-be-launched Herschel satellite (*S&T:* December 2006, page 30). By the time you read this, engineers should be recalibrating Akari's instruments for the "warm phase," so they can make longer observations of specific targets.

JAXA (2)

When Japan's Akari spacecraft ran out of liquid-helium coolant, one of its main cameras became useless. But more science can still be done with its other instruments.

A Russian Phoenix Rises

The Russian-led Spektr Rentgen-Gamma mission is once again proceeding toward launch after yet another miraculous resurrection.

SRG (also known as Spectrum X Gamma), an international mission that features an array of telescopes, should have been orbited in the early 1990s but fell victim to the fall of the Soviet Union (*S&T:* October 2001, page 28). The launch date gradually slipped into the following millennium. As other missions such as NASA's Chandra X-ray Observatory superseded SRG's technology, it seemed unlikely that the spacecraft would ever fly.

Indeed, although the new plan envisages lofting a spacecraft named Spektr Rentgen-Gamma around 2011, it has almost nothing in common with the original mission — the telescopes, instruments, rocket, and orbit all have changed.

The new SRG features the Extended Röntgen Survey with an Imaging Telescope Array (eROSITA), a German-led imaging system. It will make an all-sky survey at the X-ray energies of 2,000 to 10,000 electron volts per photon and will make up for the ABRIXAS satellite, which failed shortly after launch in 1999 (*S&T:* October 1999, page 30). SRG's seven X-ray telescopes are similar to those on ABRIXAS but have been enlarged to improve the survey's sensitivity to hot gas in distant galaxy clusters.

Also aboard will be a second, higher-resolution imager: the Astronomical Röntgen Telescope X-ray Concentrator (ART-XC). Its proposed US component would use innovative multilayer optics for 25-arcsecond imaging.

The new SRG will now be launched by a Soyuz rocket into a low orbit, probably from a newly built Soyuz pad in French Guiana.

Contributing editor ***Jonathan McDowell*** *follows experiments in Earth orbit and beyond at www.planet4589.org.*

red vision, however, you'd see it glowing deep red, as in the infrared image on the right of the facing page.

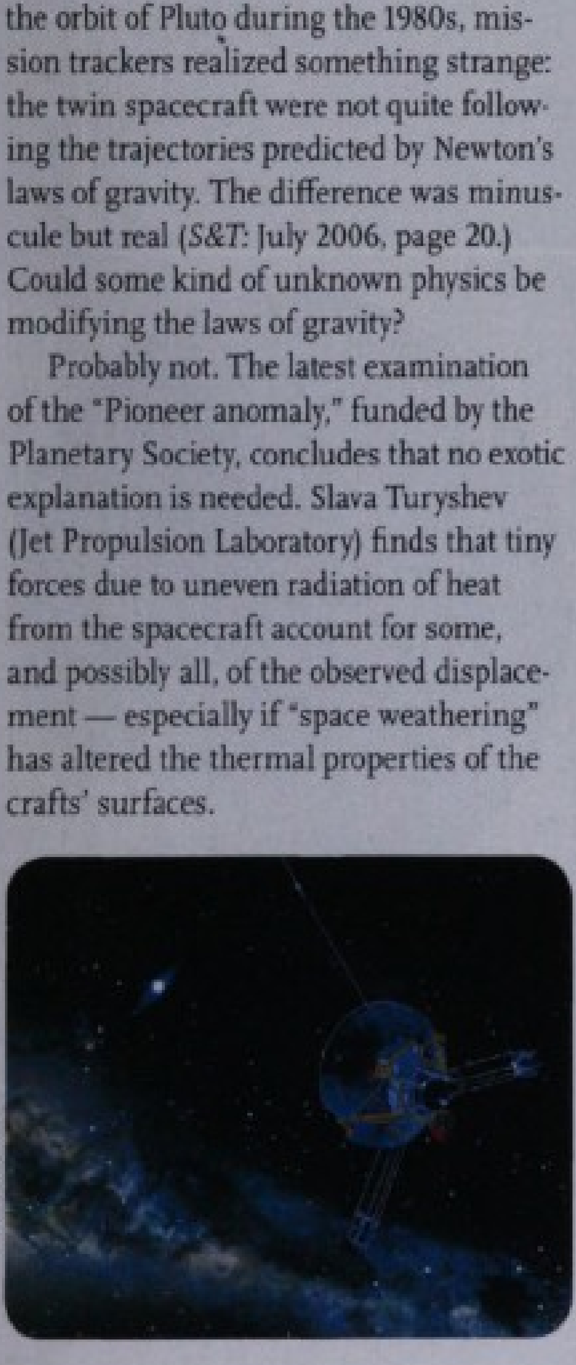
Other less-than-red-hot brown dwarfs are known, but this one is apparently the first that's cool enough to show ammonia in its spectrum. And that places it in a new proposed spectral class: Type *Y*.

The object, designated CFBDS J005910.83–011401.3 (or just CFBDS 0059), is about 40 light-years away in Cetus. Its discoverers estimate that is has a run-of-the-mill brown-dwarf mass of 15 to 30 Jupiters. But in terms of *temperature*, they're calling it a bridge between brown dwarfs and giant planets. Both Jupiter and Saturn emit a little internal heat of their own as a weak infrared glow, though for this, no one has yet invented a spectral type.

"Pioneer Anomaly" Solved?

As Pioneer 10 and 11 cruised out beyond the orbit of Pluto during the 1980s, mission trackers realized something strange: the twin spacecraft were not quite following the trajectories predicted by Newton's laws of gravity. The difference was minuscule but real (*S&T*: July 2006, page 20.) Could some kind of unknown physics be modifying the laws of gravity?

Probably not. The latest examination of the "Pioneer anomaly," funded by the Planetary Society, concludes that no exotic explanation is needed. Slava Turyshev (Jet Propulsion Laboratory) finds that tiny forces due to uneven radiation of heat from the spacecraft account for some, and possibly all, of the observed displacement — especially if "space weathering" has altered the thermal properties of the crafts' surfaces.



DON DAVIS / NASA

Mission Update *Jonathan McDowell*

Nanosatellites Reach Orbit

Probably the smallest astronomical satellite ever, AAUSat 2 from Aalborg University in Denmark, carries a tiny, 200-gram gamma-ray-burst detector within its 4-inch cubic shell. The half-pound (1-kg) satellite was launched into polar orbit on an Indian rocket on April 28th, along with an international cluster of other nanosatellites.

AAUSat's experiment was developed by the Danish Space Research Institute, which built the WATCH gamma-ray-burst monitors that flew on the Soviet Granat observatory from 1989 to 1998 and the European EURECA satellite in 1992–93. The new detector has a single-pixel cadmium-zinc-telluride crystal that's sensitive to X and gamma rays ranging from 5,000 to 300,000 electron volts. Engineers mainly want to see how well it all works, to help plan future missions with larger versions of the technology.

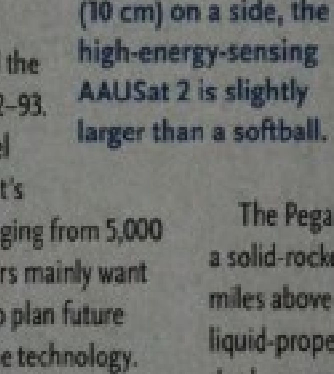
MORTEN BISGAARD (AALBORG UNIV.)

Measuring 4 inches (10 cm) on a side, the high-energy-sensing AAUSat 2 is slightly larger than a softball.

Collecting Interstellar Atoms

NASA's Interstellar Boundary Explorer (IBEX) is expected to soar into high orbit in August and begin mapping the boundary of the *heliosphere*, the realm of the Sun's influence.

IBEX will make the first astronomical use of a new technique called *neutral-atom imaging*, pioneered by satellites studying particle acceleration in the Earth's magnetosphere. Unlike free electrons and protons, the paths of neutral atoms aren't bent by the magnetic fields that permeate interplanetary space. Thus the direction they're coming from when they hit a satellite pinpoints where they originated, allowing a neutral-atom "telescope" to make pictures of the sky.



The spinning IBEX spacecraft has two single-pixel neutral-atom cameras that cover different energy ranges. They have 7° fields of view and point in opposite directions. They will slowly map the intensity of the neutral atoms reaching Earth's vicinity from all around the sky.

The atoms they will see are expected to be mostly from the edge of the solar system, where energetic particles in the solar wind interact with atoms in the interstellar medium. Comparing the observed map with theoretical models should reveal the strength of the "termination shock" and allow scientists to generate a three-dimensional model of the heliosphere.

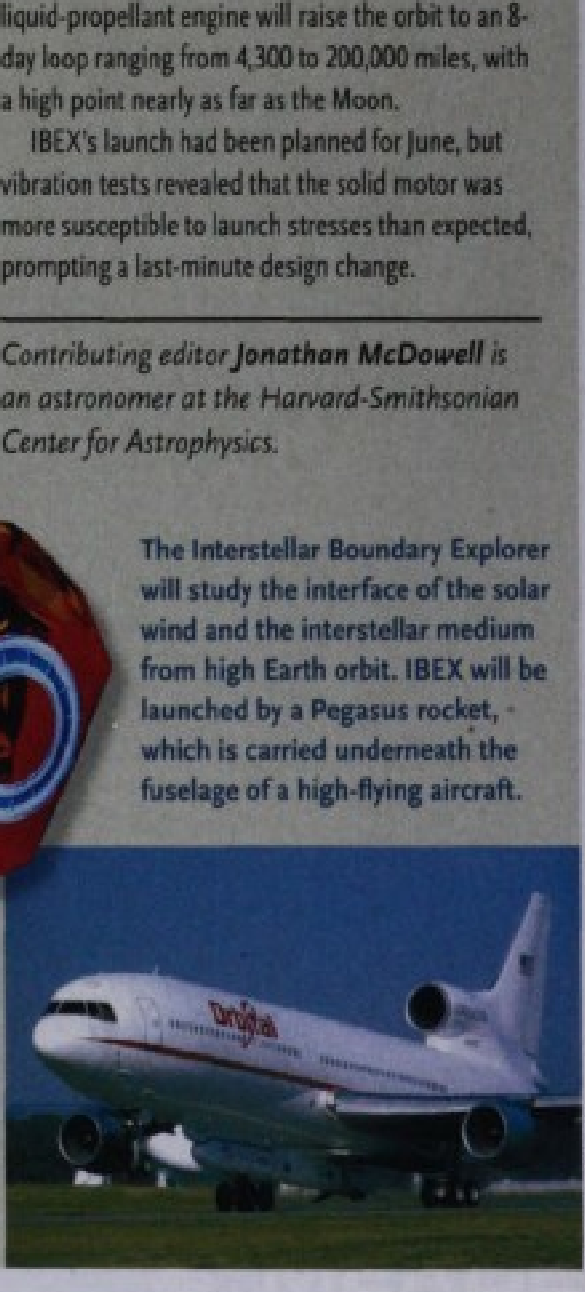
To make these measurements, the 175-pound IBEX must get as high as possible above Earth's magnetosphere. The Orbital Sciences Stargazer airplane will take off from Kwajalein Atoll in the Pacific and release a Pegasus rocket while over the ocean. The extra eastward velocity provided by a launch near the equator lets IBEX carry an additional 6 pounds compared to a conventional Florida departure.

The Pegasus will send IBEX into low orbit, where a solid-rocket motor will boost it more than 54,000 miles above Earth. Over the following weeks, a liquid-propellant engine will raise the orbit to an 8-day loop ranging from 4,300 to 200,000 miles, with a high point nearly as far as the Moon.

IBEX's launch had been planned for June, but vibration tests revealed that the solid motor was more susceptible to launch stresses than expected, prompting a last-minute design change.

Contributing editor ***Jonathan McDowell*** *is an astronomer at the Harvard-Smithsonian Center for Astrophysics.*

The Interstellar Boundary Explorer will study the interface of the solar wind and the interstellar medium from high Earth orbit. IBEX will be launched by a Pegasus rocket, which is carried underneath the fuselage of a high-flying aircraft.



ORBITAL SCIENCES (2)

More Supernovae: A White Dwarf's Messy Blowup

Type Ia supernovae are critical tools for cosmologists, because they offer a way to measure really big cosmic distances independent of redshift. So it would be nice to know how they work. Astronomers know the broad outline: an overloaded white-dwarf star starts to collapse under its own weight, and this sets off thermonuclear fusion that suddenly consumes it completely. But supercomputer models are showing that the process is anything but simple.


DOE / NNSA / ASC / ALLIANCE FLASH CENTER

As soon as thermonuclear "burning" starts near the compressed white dwarf's center, the "reaction flame" forms a huge bubble that rises to the surface in less than a second and bursts out of one side of the star (top right in frame from movie above). The bubble debris flows around the star and collides on the far side. This collision ignites a faster, more powerful thermonuclear shock wave that detonates the entire remaining star from the outside edge inward. Further work should refine this complicated model and show whether it happens in all cases or just some.

Jupiter's Three Red Spots

Jupiter's atmosphere has been going through an upheaval in the last couple years, and now it sports not just one red spot, not just two, but three. In May the Hubble and Keck telescopes joined a campaign (led in part by amateurs) to track the spots as they develop.

No one really knows the cause of their color. The most popular hypothesis is that they dredge up chemicals from the deep that turn red when exposed to sunlight.


IMKE DE PATER / MICHAEL WONG

Mission Update *Jonathan McDowell*

Hinode Has a Hitch

Japan's Hinode solar observatory (April issue, page 64) has run into communications problems. In late 2007 the X-band antenna, the primary means to send back images and data, began behaving erratically. The problem worsened in early 2008 and the Hinode team switched to a backup antenna, which uses the lower, S-band frequencies and has less capacity. It was like downgrading from broadband to a dial-up modem for your Internet connection.

Even after doubling the number of times per day that the ground contacts the spacecraft, Hinode cannot return as much information as before. The Japanese space agency, JAXA, is adding extra ground dishes to the tracking network, compressing files on the spacecraft, and tuning observing strategies to make fewer rapid-fire observations that need extra bandwidth. To ensure that the mission will return to its former productivity in time for the approach of solar maximum (expected in 2012), flight controllers will optimize such techniques while Hinode spends extended periods in Earth's shadow from May to August.


S&T: CASEY REED

Japan's Hinode spacecraft will mark two years in orbit in September.

Faster Solar Snapshots

The visible-light and X-ray images from Hinode, and the extreme-ultraviolet images from NASA's Transition Region and Coronal Explorer (TRACE) satellite, have focused solar physicists' attention on the dynamic waves and shock fronts coursing through the Sun's atmosphere. A new mission set for launch in December will let us study quicker processes on the Sun.

The Solar Dynamics Observatory (SDO) will watch the Sun from geostationary orbit with three instruments. A key feature of these experiments is their high *cadence*, how fast they take pictures. SDO will also cover the Sun's full disk at once, unlike the narrow fields seen by the telescopes on TRACE and Hinode.


NASA / GSFC

NASA's Solar Dynamics Observatory (SDO) is the next step in scrutinizing our star.

The Atmospheric Imaging Assembly (AIA) will cycle through eight 16-megapixel solar images, taken through eight narrowband filters, every 10 seconds. Pictures can be taken every 2 seconds through a single filter if desired. (TRACE's best speed is about once a minute.) AIA consists of four extreme-ultraviolet telescopes, each with two swappable filters, that will pick out emission-line radiation from particular ions in specific regions of the solar atmosphere, from the corona down to the transition region between the photosphere and chromosphere.

The Helioseismic and Magnetic Imager (HMI) has a 5½-inch (14-cm) visible-light telescope and will take polarized images at slightly different wavelengths to measure Doppler-shift velocities and magnetic-field strengths. This will tell astronomers about the local solar weather and let them probe the interior of the Sun with solar seismology.

Finally, the Extreme Ultraviolet Variability Experiment (EVE) will measure variations in the energy output of the Sun with much higher spectral resolution than previous missions, with the same high cadence as the other SDO instruments.

GLAST Reaches Orbit

High-energy astronomers breathed a sigh of relief when NASA's GLAST observatory (the Gamma-ray Large Area Space Telescope; see the June issue cover story) successfully launched on June 11th. Shakedown operations are continuing; GLAST should begin its science work in mid-August.

In keeping with tradition, by the time you read this NASA may have renamed GLAST for some distinguished, and deceased, high-energy astronomer.

Contributing editor ***Jonathan McDowell*** *provides spacecraft news as he orbits the Internet at www.planet4589.org.*

and broke up. Amateurs working online have led the tedious job of examining noisy SOHO images for the tiny moving specks of "unidentified frying objects." As a result of their efforts, the count of SOHO comets recently passed 1,500.

The one in the picture on the previous page is unusually obvious against the Sun's streaky corona. The flat disc at the bottom is an occulting mask, and the white circle marks the Sun's edge.

The Sun Twists its Pitches

The more closely we examine the Sun, the more complicated it looks. At the annual meeting of the Solar Physics Division of the American Astronomical Society, space scientists presented a movie of a coronal mass ejection that shows the Sun not just blowing off a puff of gas, but giving it a strong magnetic twist. The amount of energy that went into the twist was probably enough to affect whatever it is that causes coronal mass ejections in the first place.

SAO / NASA / JAXA / NAO

How Little Asteroids Go Double

About 15% of small asteroids that pass Earth are not single but double. That's way too many to have formed by collisions, which is probably how some larger asteroids got their moons. A new study finds that instead, sunlight can make a small asteroid spin up so fast that it flies apart.

NASA

Researchers invoked the YORP effect, which can make a small body gradually spin up or slow down as it absorbs sunlight and re-radiates it as heat. For a spherical object, the slight radiation pressures involved have no net effect on rotation. But if an asteroid is irregular, as most small ones are, infrared heat radiates at some angles more than others, causing a tiny torque. In computer simulations, a loose, "rubble-pile" asteroid can spin up this way to the point of shedding rubble that, in some cases, reaccumulates to form a small satellite close by.

The image at left shows the Clearwater Lakes in Canada, caused by the impact of a binary asteroid about 290 million years ago. The larger lake is 20 miles (32 km) wide. Double craters like this are more common in the solar system than random chance would suggest.

Dark-Sky Park in Pennsylvania

Bit by bit, the world is acting to reduce wasted artificial light in the night sky. The managers of Cherry Springs State Park in north-central Pennsylvania have gone further, taking stringent measures to re-create some of the darkest skies in the eastern United States. Cherry Springs was recently declared an International Dark-Sky Park, only the second site to earn this designation from the International Dark-Sky Association. Vacationing telescope users take note.

To read more about any of these stories, go to SkyandTelescope.com and search for the keyword SkyTelOct08.

Mission Update *Jonathan McDowell*

Messenger Returns to Mercury

NASA's Messenger probe is heading back for its second pass by the innermost planet on October 6th. This time it will zoom 200 km (125 miles) above Mercury's equator on the opposite side of the planet from the first flyby in January (May issue, page 24).

The region beneath at closest approach was seen by Mariner 10 in the 1970s, but Messenger will provide much more detail, and it will also image more of the planet's previously unseen part. Messenger will look too for changes in Mercury's thin atmosphere since its first visit, using particle detectors and an ultraviolet spectrometer.

MERCURY: NASA / JHU-APL / CARNEGIE INST. OF WASHINGTON; ROSETTA: ESA / AOES MEDIALAB

After the first encounter, spacecraft navigators at Messenger's mission control (at Johns Hopkins University's Applied Physics Laboratory in Maryland) were pleased to discover that the trajectory was only 2 km off the planned position. This leaves the probe on track for its third flyby, in August 2009, with only minimal adjustments. Messenger will finally take up orbit around Mercury in March 2011.

Rosetta's First Asteroid

Europe's Rosetta spacecraft is in the fourth year of its decade-long odyssey to Comet 67P/Churyumov-Gerasimenko. After dawdling around the inner solar system with two flybys of Earth and one of Mars to gain velocity, Rosetta entered the asteroid belt this year. On September 5th it will perform its first flyby of a previously unvisited celestial body, passing 800 km from the minor planet 2867 Steins.

Discovered in 1969 and named for Latvian astronomer Karlis Steins (1911–83), the 10-km rock is a rare E-class asteroid: one poor in iron, probably due to its parent body melting and the iron sinking to its center at some point in the past. After the encounter, Rosetta will loop in for another Earth flyby in 2009 to pump up its orbital energy for a pass by the 100-km-wide asteroid 21 Lutetia in 2010. The comet rendezvous comes in 2014.

*Contributing editor **Jonathan McDowell** provides updates on more space missions at www.planet4589.org.*

Lunar Reconnaissance Orbiter Delayed

Launch of NASA's Lunar Reconnaissance Orbiter was pushed back when the U.S. Air Force's X-37B experimental spaceplane took its October launch slot. LRO is now expected to fly at the end of February 2009.

LRO is a key step toward returning astronauts to the Moon. In early August it finished its spin and vibration tests and was prepared for thermal-vacuum testing at the Goddard Space Flight Center in Maryland. The LRO mission includes a secondary payload, the LCROSS (Lunar CRater Observation and Sensing Satellite), which will now have to be aimed at a different crater to adjust for changed lighting conditions.

LRO's slip means that India's Chandrayaan-1 Moon probe, which was delayed to October, may still beat the American probe to Earth's neighbor. The Chinese Chang'e-1 and Japanese Kaguya (with its subsatellites Ouna and Okina) are the only spacecraft currently in the lunar vicinity.

NASA / LRO

NASA's Lunar Reconnaissance Orbiter is designed to find safe landing sites for astronauts, locate resources they can use, and study the Moon's radiation environment.

International X-ray Observatory

NASA's Chandra X-ray Observatory and Europe's XMM-Newton X-ray telescope are both nine years old, yet they remain astoundingly productive. But they won't last forever, and startups of two proposed follow-on projects, the U.S. Constellation-X and ESA's XEUS, have been repeatedly delayed. Now those two projects have been merged in a plan to develop a single International X-ray Observatory (IXO) mission that would combine some aspects of both.

ESA / DLR / FU BERLIN

On July 23rd ESA's Mars Express took the highest-resolution images yet of Phobos's full disk, with a resolution of 3.7 meters per pixel. This section is 4 miles (6.4 km) wide. Full images: www.esa.int/SPECIALS/Mars_Express.

IXO would have a large X-ray mirror and an extensible optical bench that would put its instruments at a focus at least 20 meters from the mirror — twice the length of Chandra. The instruments are expected to include improved versions of the imagers and grating spectrometers used on the current missions, and a version of the super-high-spectral-resolution calorimeter that flew unsuccessfully on the Japanese-U.S. Suzaku mission when Suzaku lost its coolant.

The IXO project is only a study for now, and even if approved for development it would not fly until late next decade. So astronomers are hoping that Chandra and XMM-Newton will stay healthy for years to come.

Brief Notes

Cassini completed its 4-year primary mission at Saturn on June 30th. The next day it began its extended "Cassini Equinox Mission" to continue exploring the Saturn system, beginning with another close flyby of Enceladus on August 11th (see page 19) and an even closer one on October 9th.

Europe's **Mars Express** made several close flybys of Phobos in July and August, returning high-resolution images of the little moon's hilly, dusty surface, as shown above.

Contributing editor ***Jonathan McDowell*** *provides updates on more missions at www.planet4589.org.*

lar wind. The next "event" is predicted to come in January 2009, and sure enough, the first changes in the star's spectrum have begun. This time astronomers hope to figure out the whole picture.

Our "Goldilocks" Solar System

Not too hot, not too cold. . . that's just part of what it takes to make a nice world like ours. Recent planet-building computations have found a new constraint. The protoplanetary disk of gas and dust that spawns a planetary system (see page 32) must be neither too massive nor too sparse.

NASA / JPL / TIM PYLE

If it's too massive, many giant planets will form. They interact and pull each other's orbits into chaos, expelling or wrecking any smaller worlds. Too little mass, and big planets wouldn't form at all. Our own solar system, which does have giant planets but in safe, distant, nearly round orbits, appears to be an unusual, right-on-the-balance case.

This in turn suggests that having giant planets in round orbits is somehow important for a terrestrial planet to develop intelligent life. If this were not so, we would be unlikely to finds ourselves in a system of this unusual type.

To read more about any of these stories, go to SkyandTelescope.com and search for the keyword SkyTelNov08.

Phoenix Races the Calendar

By the time the Mars Phoenix lander completed its 90-sol primary mission on August 26th, NASA had already extended the mission for at least another month. The lander has been digging deeper into the Martian soil and finding icy material about 5 cm below the surface. Chemical analyses have identified salts and perchlorates, while the camera has imaged clouds passing over the landing site. A microscope provided the first close-ups of Martian soil particles.

In its extended mission, Phoenix continues trying new methods to analyze ice-rich samples, which have shown a tendency to stick to the robot arm's soil scoop. But Phoenix is in a race against time as the bitter Martian arctic winter sets in. The lowering Sun drains the efficiency of the solar panels, and critical components will start to freeze. In April the landing site will fall into round-the-clock polar darkness until next July.

NASA / JPL / CALTECH / UNIV. OF ARIZONA / TEXAS A&M UNIV.

In early September, NASA's Phoenix Lander inserted the four needles of its thermal and electrical conductivity probe into the ground for a full Martian day, or sol, to measure changes in the soil from day to night.

The Infrared Eye of WISE

As the Spitzer Space Telescope nears the end of its primary, cryogenic phase, work on NASA's next infrared observatory is advancing. The telescope for the Wide-field Infrared Survey Explorer (WISE) is having its focus checked at the Space Dynamics Lab in Utah, before being shipped next year to Colorado, where the spacecraft bus is assembled.

SPACE DYNAMICS LAB / UTAH STATE UNIVERSITY

Engineers lower the WISE telescope's optics into the observatory's cryostat.

Spitzer gave deep, detailed looks at narrow fields. WISE, a much smaller craft, will map the whole infrared sky at several wavelengths. Its telescope will scan the sky continuously as the satellite orbits Earth. To avoid blurring, a small mirror will pivot to counteract spacecraft motion long enough to let WISE make tiled images in 10-second snapshots.

For optimum sensitivity, WISE's four infrared cameras will be swathed in a block of solid hydrogen at a temperature of 8 kelvins, while the telescope is kept at a comparatively balmy 20 kelvins. Compared to the liquid helium used in most infrared space telescopes, solid hydrogen is much lighter and doesn't evaporate as easily, making the mission cheaper and longer-lasting.

Launch of WISE is planned for November 2009. The first sky scan should begin the following month and be complete by summer 2010. The resulting celestial maps will be at wavelengths of 3.3, 4.7, 12, and 23 microns, and will reach hundreds of times fainter than the classic IRAS map of the infrared sky from the 1980s. WISE's near- and mid-infrared data will complement the recent sky survey by Japan's Akari satellite, which operated in the far infrared (July issue, page 15).

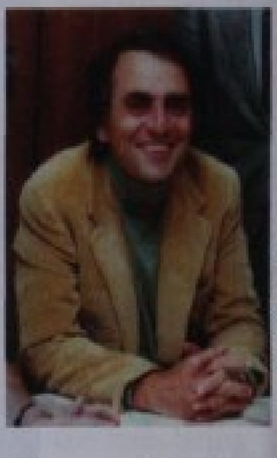
Contributing editor ***Jonathan McDowell*** *provides updates on more missions at www.planet4589.org.*

News Notes

that it has been successfully launched and is working, NASA has followed tradition and renamed it for a human. It's now the Fermi Gamma-ray Space Telescope, or Fermi for short. Get used to it.

Of the 12,000 names submitted in NASA's call for public participation, that of the Italian-American physicist Enrico Fermi (1901–54) stood out. Among Fermi's many contributions to high-energy physics, he was the first to suggest a workable way for cosmic-ray particles to be accelerated to near-light speeds — just the kind of thing Fermi was built to study.

For Carl



THE PLANETARY SOCIETY

To help staff future exoplanet research, and to honor the early inspiration of many current astronomers, NASA has begun funding Carl Sagan Postdoctoral Fellowships in Exoplanet Exploration. Like no other astronomer of his time, Sagan (1934–96) popularized astronomy, astrobiology, SETI, and the crucial worth of science and critical thinking. He lived to see the discoveries of just the first few exoplanets.

Low-Polluting Streetlights

The next big thing in streetlights will be light-emitting diodes, which not only use less power than current bulbs, but can also be more accurately aimed. The proposed Energy Star rules for these future streetlights include a "full-cutoff" provision from the outset, so that no light beams skyward. The world is learning. ✦

To read more about any of these stories, go to SkyandTelescope.com and search for the keyword SkyTelDec08.

measuring the Sun's limb with much better precision than is possible even during eclipses. The result? The Sun's rotation causes its midsection to bulge a tiny trace more than predicted. The expected bulge, 7.8 milliarcseconds, is about the apparent width of a dime in Boston seen from San Francisco. But researchers announced in October that the Sun is actually oblate by a hair more than 8 milliarcseconds. Moreover, this bulge becomes even more pronounced, by another 10.8 milliarcseconds, during times of high solar activity.

NATIONAL SOLAR OBSERVATORY

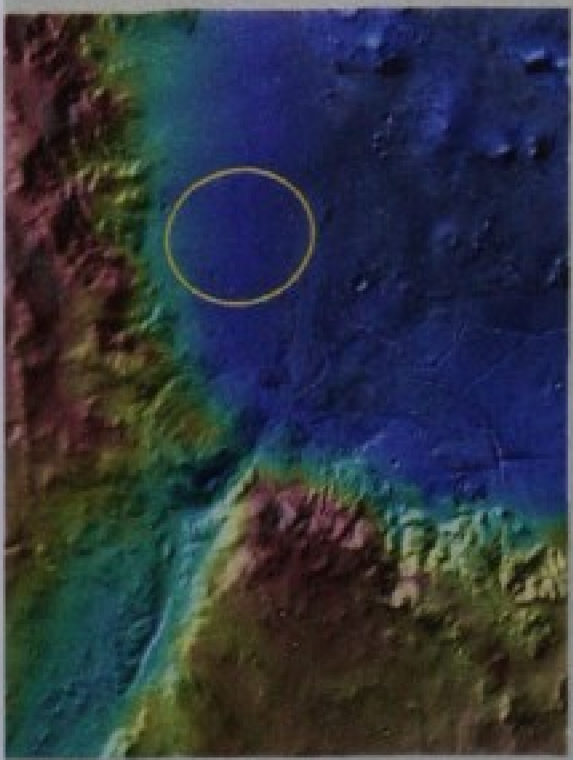
Whenever you measure anything with new precision, whole new phenomena are likely to come into view. The Sun's changing girth apparently arises from magnetic ridges on its surface that subtly mimic the texture of a cantaloupe's skin. The deviation from a perfect ellipsoid has implications for how the Sun pulls on Mercury, how the solar core is shaped, and perhaps how acoustic waves propagate throughout the Sun's interior.

Little Asteroid Makes Big Splash

There's nothing like an asteroid hitting Earth to grab attention. The asteroid in question, 2008 TC_3, was only about the size of a car. Nevertheless, the near-Earth asteroid hunters at the Catalina Sky Survey on Mt. Lemmon in Arizona caught it in their imagery early on October 6th. Just 19 hours later it struck the upper atmosphere over northern Sudan and exploded with the energy of about 1,000 or 2,000 tons of TNT. The airburst was recorded by an infrasound sensor in the International Monitoring System, which listens for surreptitious nuclear tests. This was the first time an Earth-impacting object was seen before it hit. It won't be the last.

To read more about any of these stories, go to **SkyandTelescope.com** and search for the keyword **SkyTelJan09.**

Mission Update *Jonathan McDowell*



NASA / MRO

One site in the running for NASA's Mars Science Laboratory is a flat, apparently boulder-free slope of ancient lakebed sediments in Holden Crater. This infrared image by the Mars Reconnaisance Orbiter is color coded by surface composition. The frame is 75 miles (120 km) wide.

Mars Science Laboratory: Landing Sites

NASA's ambitious Mars Science Laboratory (MSL) remains scheduled for launch in late 2009, despite major budget overruns and threats of cancellation last fall. The probe is the agency's next major Mars mission; it features a super-rover that will dwarf the Sojourner, Spirit, and Opportunity rovers that have brought mobility to Martian exploration.

The rover itself will weigh 1,900 pounds (850 kg), five times greater than Spirit and Opportunity. The entire spacecraft will weigh 3,400 kg, making it the heaviest U.S. Mars probe since the Vikings of the 1970s.

Where should MSL land? Mars scientists recently voted on their favorite regions, all in dried-up lakes and riverbeds that could reveal details of Mars's watery past. Three sites led the polling. Two are near each other among the Nirgal Vallis riverbeds lying between the Valles Marineris canyon region, the huge Argyre Planitia basin, and the dark Margaritifer Sinus albedo feature. Eberswalde crater (at latitude 23.86° south, longitude 326.73° east) seems to have a river delta with possible lake sediments. Holden (26.38° S, 325.08° E) is a huge, 150 km crater with an apparent dried-up river, Uzboi Vallis, feeding into it. The third leading site, Gale (4.49° S, 137.42° E) is a large crater lying south of Elysium Planitia with an odd, 5-kilometer-high mountain in the middle.

MAVEN and Mars's Dwindling Atmosphere

Following the success of the Mars Phoenix lander on an icy northern plain, NASA has chosen the second in its planned series of small Mars Scout missions. MAVEN, the Mars Atmosphere and Volatile Evolution mission, should launch in November 2013. The probe will be an orbiter making dips into the red planet's upper atmosphere starting in September 2014.

Among other things, MAVEN will try to find out what happened to Mars's original atmosphere — in particuler, how fast water, carbon dioxide, and nitrogen are leaking away into space today, and how the upper atmosphere interacts with the solar wind. Data from Mars Global Surveyor indicate that the great "Halloween" solar flare of October 2003 temporarily changed the density of Mars' upper atmosphere by a factor of 10. Similar events could cause a significant amount of atmosphere to be blown away by the solar wind sporadically. ✦

*Contributing editor **Jonathan McDowell** provides updates on more missions at www.planet4589.org.*

NASA

Out of 20 proposals for the next Mars Scout mission, NASA chose the $485 million Mars Atmosphere and Volatile Evolution (MAVEN) project as likely to have the best science value and lowest risk.

To get astronomy news as it breaks, visit SkyandTelescope.com/newsblog.

producing dust. And as co-discoverer Bruce Macintosh points out, "All three seem to be orbiting in the same plane, and they're going around in the same direction. This would imply they formed in a protoplanetary disk, like planets do."

The near-infrared image at far lower left shows the three objects after processing to reduce the star's overwhelming glare. Crosses mark their positions on images taken on earlier dates, showing orbital motion.

3. In addition, a French team has imaged a glowing speck at the inside edge of the famous debris disk around Beta Pictoris, an *A*3 star 63 light-years away. The object is about 8 a.u. from the star, and its infrared brightness suggests that it has 8 Jupiter masses.

NASA / JPL / SPACE SCIENCE INSTITUTE

New Close-ups of Enceladus

On October 31st the Cassini spacecraft made its second close flyby of the rumpled icescapes hiding geyser vents on Saturn's moon Enceladus. The frame below is a tiny snippet of one of the panoramic images available online at the Cassini imaging team's website, ciclops.org. The frame is 3.4 miles (5.5 km) wide; pixels are 40 feet (12 m) across. The ice boulders littering the folded surface are typically the size of a gymnasium.

Mission Update *Jonathan McDowell*

IBEX Begins Work

NASA's Interstellar Boundary Explorer has begun its mission to map the edge of the solar system, by detecting neutral particles coming from the interface beyond the orbit of Pluto where the solar wind hits the interstellar medium (*S&T:* August 2008, page 15). The spacecraft isn't going there. It's in an elliptical Earth orbit that brings it nearly to the distance of the Moon.

NASA's IBEX observatory is designed to map and analyze neutral (uncharged) atoms that are accelerated at the solar system's edge.

NASA / GODDARD SPACE FLIGHT CENTER / WALT FEIMER

Chandrayaan-1 at the Moon

India's first Moon mission began with the launch of the Chandrayaan-1 probe on October 22nd. Within three weeks it worked its way into a 100-km circular orbit around the Moon, where its Indian-built Terrain Mapping Camera began imaging the surface with 5-meter resolution. In addition to Indian instruments, the probe carries experiments from NASA and several European countries. Attached to Chandrayaan-1 was a 29-kg Moon Impact Probe that was ejected toward the surface, taking images on the way down in a replay of NASA's Ranger missions of the early 1960s. Lunar images were not available at press time; check www.isro.org/Chandrayaan.

To test its camera, Chandrayaan-1 looked back at Earth on its way out. Southwestern Australia shows through morning clouds at right.

INDIAN SPACE RESEARCH ORGANISATION

XMM-Newton Dodges a Bullet

European X-ray astronomers had a scary few days in October when the XMM-Newton high-energy observatory fell silent. On October 18th, an hour after it flew out of range of its Chile tracking station, another tracking station near Madrid failed to pick up its signal. That's not unheard of for satellites; a loss of signal can be due to something as easily corrected as a mis-typed aiming command, or a cosmic-ray hit on a computer chip requiring the spacecraft to be rebooted. Flight controllers at the European Space Operations Centre in Darmstadt ran through standard procedures to fix such problems, but none of them worked; there was still no signal from XMM-Newton.

Fears that the venerable observatory had broken up in a deadly runaway spin, or had been destroyed by space debris, were allayed when ground-based telescopes showed the spacecraft intact in orbit. Then, on October 21st, ESA's big 35-meter deep space antenna in Australia captured a mysteriously faint signal from the spacecraft. Analysis of the signals suggested that one of the settings of the satellite's radio transmitter had failed. The 34-meter NASA dishes at Canberra and Goldstone were borrowed to shout "Reset the switch!" at the tops of their electronic voices, and that did the trick.

The recovery capped a nervous week in which NASA's Chandra X-Ray Observatory suffered a minor reboot when a cosmic ray zapped a computer bit, and the Hubble telescope's reactivation temporarily failed. With all three of these major space observatories finally back in service, astronomers began breathing a lot easier.

Contributing editor ***Jonathan McDowell*** *provides updates on more missions at www.planet4589.org.*

Mission Update *Jonathan McDowell*

Juno: Return to Jupiter

NASA's second New Frontiers mission, the Juno probe to orbit Jupiter (*S&T*: September 2005, page 24), is moving into its construction phase.

In 1995 NASA's Galileo orbiter dropped a probe into Jupiter's atmosphere, which destroyed it when it was 1% of the way to the planet's center. To probe the deeper interior, Juno will skim close above the cloudtops and use remote sensing methods. By measuring slight variations in Juno's orbit, researchers will map Jupiter's gravity field well enough to reveal the distribution of matter inside the planet. Juno's JIRAM instrument (Jovian Infrared Auroral Mapper) will determine the composition of the lower atmosphere down to where the pressure is 7 times Earth's surface pressure. The MWR (Microwave Radiometer) will allow Juno to infer the temperature profile all the way down to 200 times Earth pressure.

Particles-and-fields instruments named JEDI (Jupiter Energetic particle Detector Instrument), WAVES (Plasma Wave Instrument), FGM/SHM (Fluxgate Magnetometer/Scalar Helium Magnetometer), UVS (Ultraviolet Spectrograph), and JADE (Jovial Auroral Distributions Experiment), together with JIRAM, will characterize the magnetosphere and aurora. And the JunoCam imager will return the most detailed close-up images of the Jovian clouds ever seen.

Juno is expected to launch in August 2011 for a roundabout, five-year journey including an Earth flyby in 2013. Once at Jupiter the probe will take up an elliptical path around the planet's poles, dipping to within 5,000 km (7% of a Jupiter radius) from the tops of the clouds. It will make 32 orbits during its one-year primary mission. The current plan is then to crash Juno into Jupiter's atmosphere.

Juno will be the first outer-planets probe to use solar panels instead of nuclear-powered thermoelectric batteries. To gather the weak solar energy at Jupiter, the panels will span a circle 20 meters (66 feet) across.

NASA / JPL

Dawn on Track to Asteroids

After a little more than a year in space, the Dawn probe has completed the main phase of using its super-efficient (but low-power) ion engine to help it on its way.

NASA / MCREL

Dawn will fire its xenon-ion engine (blue exhaust streak in this artist's concept) to work its way into orbit around Vesta.

On October 31, 2008, the engine was shut down after using 72 kg of xenon propellant and thrusting 82% of the time since December 2007.

Dawn's initial orbit around the Sun was 1.0 by 1.62 a.u. at its closest and farthest points, but the ion drive enlarged the orbit to 1.22 by 1.68 a.u. A small tweak with the ion engine three weeks later adjusted Dawn's track for a flyby of Mars in February 2009, which will send the craft into an orbit that stretches out to 1.8 a.u. The ion drive will be needed again to get Dawn as far as its first target, the asteroid Vesta, whose closest point to the Sun is 2.1 a.u. Dawn will reach Vesta in 2011, map it from orbit, and then take off for Ceres, which it will begin orbiting in 2015.

HST Servicing Mission

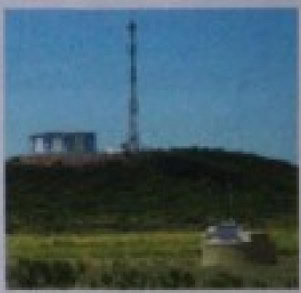
After many months of delay, the long-awaited servicing and upgrade mission for the Hubble Space Telescope (October 2008 cover story) is set for launch May 12th. The fuel tank and boosters for the servicing mission were assembled at Kennedy Space Center in early December. Meanwhile, engineers at Goddard Space Flight Center rushed to get Hubble's replacement command data processor ready for flight.

Contributing editor **Jonathan McDowell** *provides updates on more missions at www.planet4589.org.*

by blue-green algae. Without ongoing photosynthesis, free oxygen could not persist. The group's work suggests new ways that extrasolar planets might show spectral evidence for life that exists in the present or that existed in the distant past.

New Eyes on the Cosmic-Ray Sky

Scientists from many countries gathered at the foothills of the Argentine Andes last November to mark the completion of the Pierre Auger (oh-ZHAY) cosmic-ray observatory. Its 1,600 water-filled detectors, spread across 1,200 square miles (3,000 square kilometers), are designed to detect ultrahigh-energy particles striking the top of Earth's atmosphere and trace back their cosmic origins. The fastest of these particles, mostly protons, can carry the kinetic energy of a well-pitched baseball — up to 10 million times the punch of particles in the biggest accelerators on Earth. On average, only one of these superparticles hits a square kilometer of the upper atmosphere per year (*S&T*: March 2008, page 24).



PIERRE AUGER OBSERVATORY

The project went online in 2004 with about half its detectors in place. By late 2007 researchers had already found that the most powerful "baseball particles" appear to emanate from areas having galaxies with active galactic nuclei: ultrabright objects powered by supermassive black holes.

A second field of detectors, which the team would like to build in southeastern Colorado, would cover the northern sky.

The project records ultrahigh-energy cosmic rays in two ways. The photo above shows one of the 1,600 detectors that records "air showers" from high-altitude collisions. On the hill is one of four buildings where fluorescence detectors watch (at night) for simultaneous glimmers of light in the upper air. ✦

To read more about any of these stories, go to **SkyandTelescope.com** and search for the keyword **SkyTelMar09**.

For astronomy news as it breaks, see SkyandTelescope.com/newsblog.

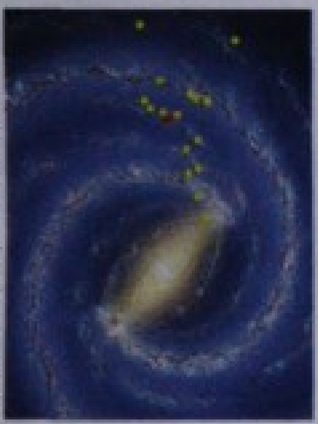
cubic centimeter, for instance — remains the same no matter how greatly space expands. This means that dark energy is somehow associated with empty space *itself*, rather than being some kind of particles or field residing *in* space — which would thin out as space expands, as atoms and galaxies do.

In other words, quips David Spergel (Princeton University), "Even nothing weighs something." And the weight of nothing has a negative value.

The image at the bottom of the facing page shows the galaxy cluster Abell 85 with its diffuse, X-ray-hot gas superposed in purple.

The Milky Way Doubles its Mass

Using a network of 10 radio telescopes worldwide, a group has measured extremely precise parallaxes (distances) of radio sources in 18 of the Milky Way's star-forming regions, as well as their motions in three dimensions. The study provides a new map of the galaxy's rotation independent of most astronomical assumptions. The team finds that the Milky Way rotates 15% faster and thus is twice as massive as previously thought. That puts us on equal footing with the Andromeda Galaxy (M31) masswise, even though the Milky Way has fewer stars.



On the Milky Way map here, the red dot marks the location of the Sun. Yellow dots show the locations of radio masers measured in the study.

Surprising Trove of Gamma-Ray Pulsars

NASA's Fermi Gamma-ray Space Telescope (formerly known as GLAST) has gotten off to a flying start. In January its handlers announced a major new find: the sky is alive with gamma-ray-only pulsars. Fermi spotted 13 of them in its first four months.

Mission Update *Jonathan McDowell*

J-MAPS: Next Step for Astrometry

The U.S. Naval Observatory is leading a new space mission to measure the positions, motions, and distances of tens of millions of stars. The Joint Milli-Arcsecond Pathfinder Survey, funded by the Office of Naval Research, will generate a catalog of star positions to fainter than magnitude 12 — a larger, second-epoch counterpart to Europe's pioneering Hipparcos mission launched in 1989.

J-MAPS will fill in gaps between the Hipparcos and future Gaia star catalogs.

The star positions in the Hipparcos catalog, dating from 1991, are accurate to about a thousandth of an arcsecond (one milliarcsecond). Stars, however, move on the sky: each has its own "proper motion." Hipparcos measured this also, to an accuracy of about 1 milliarcsecond per year. But the Hipparcos catalog will be 20 years old by the time J-MAPS flies in 2012, so the uncertainties in our knowledge of stars' positions, adding up year by year, will be approaching 20 milliarcseconds by then.

The new 1-milliarcsecond catalog of positions from J-MAPS will reset the clock. Even better, the two-decade baseline will give more accurate proper motions as well, so we'll be able to predict precise stellar positions for the rest of the century — and be able to better map the Milky Way's rotation, the motions of star streams, and members of widely dispersed moving groups (disintegrated clusters and associations whose stars were born around the same time and place).

J-MAPS will complement Europe's much more ambitious Gaia mission, expected to launch in December 2011. Gaia will generate an enormous high-precision database of stars down to 20th magnitude, but it will not be able to measure the brightest stars accessible to J-MAPS.

In addition, J-MAPS will observe distant radio-loud quasars as faint as 16th magnitude so that its star positions can be matched with radio astronomy's own highly precise coordinate system.

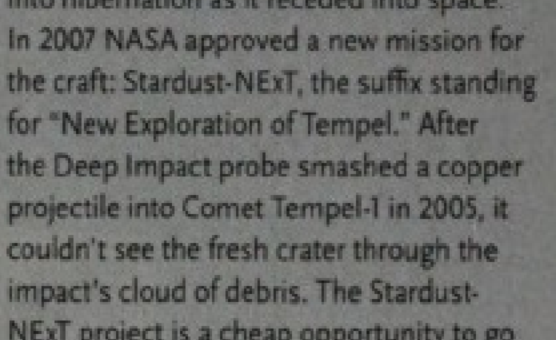
The small, 115-kilogram (254-pound) satellite will be built by the Naval Research Lab. Its star-position catalog is intended for military as well as astronomical purposes.

Stardust Revived

In 2004 NASA's Stardust spacecraft, orbiting the Sun since 1999, flew by Comet Wild-2 and collected a tiny cargo of space dust. In 2006 it sent its sample capsule parachuting to the Utah desert and went into hibernation as it receded into space. In 2007 NASA approved a new mission for the craft: Stardust-NExT, the suffix standing for "New Exploration of Tempel." After the Deep Impact probe smashed a copper projectile into Comet Tempel-1 in 2005, it couldn't see the fresh crater through the impact's cloud of debris. The Stardust-NExT project is a cheap opportunity to go back to Tempel-1 and look.

To help get there, on January 14th Stardust flew only 9,200 kilometers (5,700 miles) above Earth, whose moving gravitational field boosted it into a new orbit that will take it to Tempel-1 in February 2011.

Contributing editor **Jonathan McDowell** *covers more missions at Jonathan's Space Report: www.planet4589.org.*



On January 14th the aging Stardust craft swung by Earth on the way to its next cometary mission.

 Jonathan McDowell

Spirit and Opportunity

The Mars Exploration Rovers landed in enormous Gusev Crater and on the flat Meridiani Plains more than 5 Earth years ago (that's 2½ Martian years), but despite signs of age, Spirit and Opportunity are roving still.

During 2008 Spirit basked in the thin Martian winter sunlight, its dusty solar panels generating just enough electricity to keep the spacecraft healthy but not enough to continue exploring. Spirit began driving again on January 26th, but on January 28th it faced yet another crisis. It refused to obey its daily driving instructions, failed to record its activities, and seemed confused about where it was pointing. Was this, at last, the end?

Not yet! Spirit's handlers still don't understand its memory lapse, but an offset to the rover's accelerometers appeared to fix the orientation error. Three days after the failure, Spirit gingerly moved a third of a meter and successfully resumed operations.

The rover is now 3.5 kilometers (2.2 miles) from its landing site at Columbia Memorial Station on the floor of Gusev.

Meanwhile, Spirit's sister, Opportunity, has been pressing south toward wide, deep Endurance Crater. Its straight-line distance from its Challenger Memorial Station landing site is now 7.5 km (4.7 miles). The odometer reads almost 14 km (8.7 miles), thanks to Opportunity's meandering trail and a year-long tour of Victoria Crater in 2007–08.

As it drives, Opportunity is taking pictures of passing rocks and landforms but without stopping as often as it once did for detailed surveys. Opportunity ran into troubles operating its Rock Abrasion Tool last year, but other instruments are working well.

Dust buildup on the solar panels is a concern for this rover, too, and Opportunity is making regular measurements of the amount of dust on the vehicle and in the atmosphere.

The twin rovers still have another two years to go before they beat the seven-year Martian surface endurance record set by the Viking 1 lander from 1976 to 1982.

Koronas-Foton: From Russia to Watch the Sun

Russia went nine years without launching a major science research mission, but that dry spell ended on January 30th when the Koronas-Foton satellite soared aloft from the Plesetsk spaceport in northern Russia.

Koronas-Foton's primary mission is to study solar flares. Led by the Moscow Engineering Physics Institute, it follows Koronas-I, which worked from 1994 to 1995, and Koronas-F, active from 2001 to 2005.

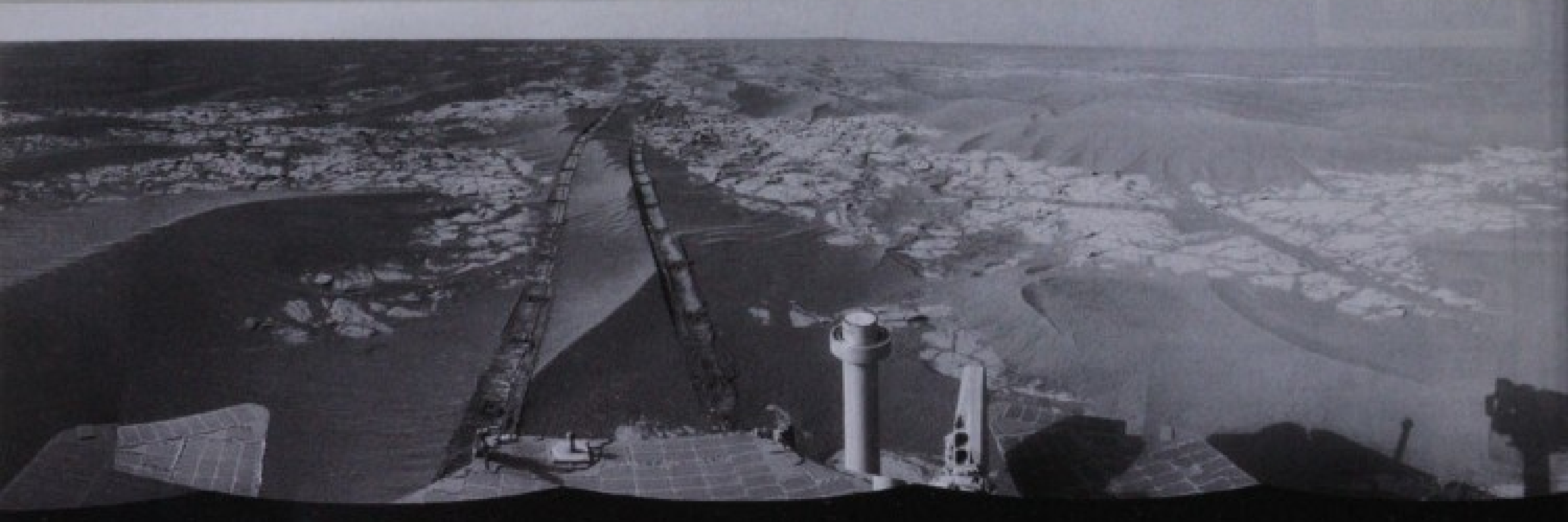
The new probe carries many instruments: a gamma-ray spectrometer, a fast X-ray monitor, an ultraviolet instrument, a gamma-ray-burst detector, and a hard-X-ray polarimeter. In addition to three other Russian instruments and a Ukrainian particle detector, Koronas-Foton includes a Polish full-solar-disk X-ray spectrophotometer and an Indian solar hard-X-ray spectrometer. This last device measures solar flare properties ten times a second in the 15–150 keV energy range.

ROSKOSMOS

The Koronas-Foton satellite was mounted onto its rocket booster at Plesetsk in January.

The Polish instrument will measure the total X-ray output of the Sun in the 0.8–15 keV range. It can detect a much wider range of fluxes than the existing solar-flux monitor on the GOES weather satellite (which is unable to measure the weak X-ray emission at solar minimum), and it has a very fast time resolution of a hundredth of a second. ✦

Contributing editor **Jonathan McDowell** *covers more missions at Jonathan's Space Report: www.planet4589.org.*



After driving 104 meters (341 feet) on January 15th, Opportunity took this panorama looking back north along its tracks. Sand ripples and patches of exposed bedrock are the hallmarks of this portion of the Meridiani Plains, which give new meaning to the word "bleak."

NASA / JPL-CALTECH

Lynch saw similar-looking objects on a TV show about meteorite falls, he took it to the Milwaukee Public Museum and then to Chicago's Field Museum. There scientists got excited. For practically the first time ever, a member of the public had brought in a genuine meteorite. Lynch (at right) learned such a big one might be worth $100,000.

Then the story took a twist. As photos circulated, the meteorite turned out to have been found once before. It was the prized exhibit that had been stolen from the Meteor Crater Visitor Center in Arizona on August 12, 1968.

According to the *Milwaukee Journal Sentinel*, Lynch plans to make a car trip to return it personally and accept a $1,000 reward. "I've got mixed emotions," he admitted to the newspaper. "I'm glad it's going back and a lot of people will be able to see it. And I'm feeling sorry I didn't get $100,000 for it."

No word on how it made its way to the rummage sale.

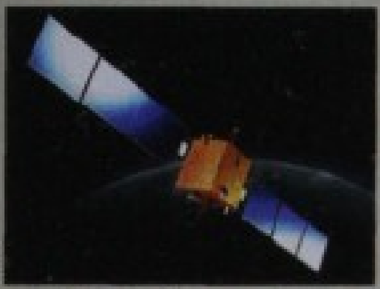
All News Note stories are presented in greater depth, with links to further information, at SkyandTelescope.com; search for the keyword SkyTelJun09.

JEFFREY PHELPS / MILWAUKEE JOURNAL SENTINEL

Mission Update *Jonathan McDowell*

The Life and Death of Chang'e 1

China's first deep-space mission is over. Controllers deliberately crashed the Chang'e 1 lunar probe at a spot near the Moon's equator on March 1st. The impact site (at 1.50° south, 52.36° east) was in Mare Fecunditatis, southeast of the crater Taruntius P. The site was in lunar daylight, and it happened during daytime for China too, with the Moon up in a bright sky. Apparently the China National Space Administration planned no attempt to watch for a spray of dust of other signs of the impact — even though Chang'e 1 was comparable in mass to the Centaur rocket body that NASA plans to crash into the Moon later this year with a global network of observers watching (see page 20). With the mission over, the crash was intended to keep low lunar orbit free of debris.



CNSA

China's Chang'e 1 lunar explorer was a retooled communications satellite.

Launched in October 2007, Chang'e 1 spent a year mapping the Moon from an altitude of 200 km. It was lowered to a 100-km orbit on December 6th and then a 17 × 100-km elliptical orbit on December 18th. Such low orbits around the Moon are very tricky, because "mascons" (mass concentrations) underneath the Moon's impact-basin maria make the lunar gravity field lumpy (see page 15). These gravity anomalies can quickly make a low orbit more elongated until the spacecraft hits a mountain. The Chinese mission controllers, satisfied with their low-altitude flying practice, raised Chang'e 1's orbit back to 100 km after only 30 hours and carried out another two months of scientific studies.

The end of Chang'e leaves only the Indian Chandrayaan–1 and the Japanese Kaguya and Ouna satellites in lunar orbit.

A repeat mission, Chang'e 2, will launch in 2011. It will carry a much-higher-resolution camera and will return an improved lunar map. According to Chinese reports, it will also test soft-landing technologies in preparation for a lander/rover mission in 2012, but it's not clear what these tests entail. The Chinese are also considering a robotic sample return mission for a 2017 launch.

JWST Under Construction

NASA's James Webb Space Telescope (JWST), often billed as the successor to Hubble, is now under construction. It will have an aperture of 6.5 meters compared to Hubble's 2.4 meters, but unlike Hubble it will work almost entirely in the infrared.

In December the first of its 18 hexagonal primary-mirror segments, made of polished beryllium, began cryogenic testing at the NASA/Marshall Space Flight Center in Alabama. The mirror segments will have to be focusable at a temperature of 40 kelvins, with the telescope working behind a sunshield near the Earth-Sun L_2 Lagrangian point a million miles toward midnight.

The complete optical assembly and the JWST's science instruments will be mounted on an optical bench called the Backplane, now being built in Utah by Alliant Techsystems. Receiving infrared light from the mirrors will be Arizona's NIRCam (Near-Infrared Camera), the European Space Agency's NIRSpec (Near-Infrared Spectrograph), the Canadian Tunable Filter Imager, and the internationally developed MIRI (Mid-Infrared Instrument).

NASA / JWST

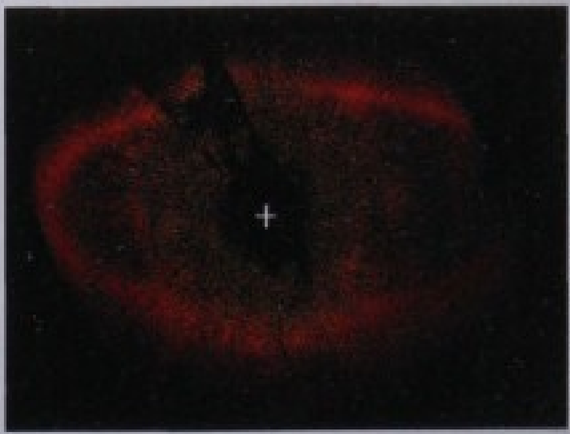
The first hexagonal segment of the JWST's main mirror is delivered for testing.

The entire 6-ton observatory will be assembled beginning in 2011. It should launch on a European Ariane 5 rocket in 2013. ✦

Contributing editor **Jonathan McDowell** *covers more missions at Jonathan's Space Report: www.planet4589.org.*

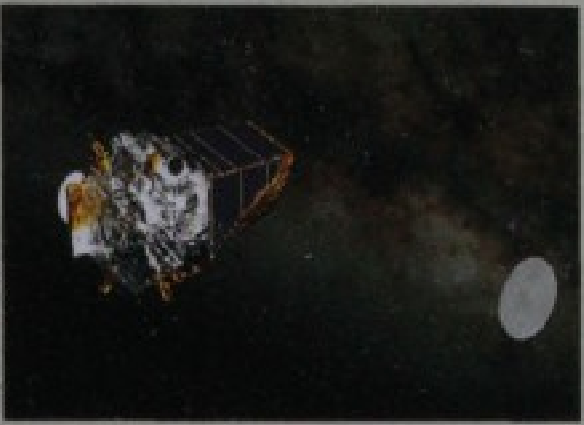
They used long-baseline interferometry, combined with spectroscopy, to determine the rotation axis of the bright star Fomalhaut, 25 light-years away. Fomalhaut has a Kuiper-Belt-like disk of dust and rubble about 140 astronomical units from the star, as seen in the Hubble image at right. And a barely detectable planet, Fomalhaut b, orbits just inside the disk's inner edge (March issue, page 22).

Using the Very Large Telescope interferometer, the European team was able to measure *separately* the radial velocities of different parts of Fomalhaut's rotating surface. From these data, they determined the position of the star's axis of rotation quite accurately. The team finds that Fomalhaut's equator aligns with its far-out rubble disk to within the measurement uncertainty of just 3°.



NASA / ESA / PAUL KALAS ET AL.

Mission Update *Jonathan McDowell*



NASA / KEPLER MISSION

Far from Earth, Kepler ejects its spring-loaded dust cover in this artist's illustration.

Kepler Opens Up

NASA's exoEarth-hunting space telescope is now open to the starry dark. The Kepler spacecraft ejected its dust cover on April 7th as it coasted 3 million kilometers behind Earth in its independent orbit around the Sun. Kepler's 1-meter Schmidt telescope, with a 95-megapixel array of CCDs, will stare for four years at a region of sky between Vega and Deneb. There it will monitor more than 100,000 selected stars (out of at least 4.5 million in view) for tiny dips in brightness caused by planets passing in front of them.

During Kepler's voyage out of the Earth-Moon system, engineers at the control center in Boulder, Colorado, learned to fly it, testing its ability to point in different directions and communicate with NASA's Deep Space Network. Then they fired up the science camera and took dark exposures inside the dust cover to calibrate the sensitivity and stability of each pixel. The detectors were also calibrated on the ground before launch, but they behave differently in space because of the radiation passing through the spacecraft.

On March 23rd Kepler unexpectedly fell into "safe mode" when its software got confused by updated navigation data, but controllers fixed the problem within a week. Kepler took the first test images of its star field on April 8th. Science observations should be under way by the time you read this.

Chandra Going Strong

One of NASA's older telescopes is celebrating its tenth birthday in July. The Chandra X-ray Observatory means a lot to me; I work at the Chandra X-ray Center, which operates it. Tension was high when it was launched in July 1999; we had fresh memories of the disastrous start by its sister "great observatory," Hubble. But the very first focus-test image came back with a science discovery, an unexpected X-ray jet in the quasar PKS 0637–75.

After we corrected some of the wrong minus signs that I had put in the software, the pictures starting coming out right side up, and Chandra quickly began making discoveries in all fields of high-energy astrophysics — from processes in distant quasars to the formation of elements in nearby supernova remnants. All spacecraft have their teething troubles, but the only notable early problem with Chandra was some radiation damage to the detectors when the telescope mirrors accidentally focused protons from Earth's radiation belts onto the CCDs. Since then the detectors have been aging only slightly.

As Chandra passes its decadal milestone, the only other signs of age are minor deterioration of the thermal insulation, which means controllers have to be more careful scheduling where the telescope points at particular times of year. The telescope is as busy as ever, being used by astronomers in many disciplines all over the world. ✦

Contributing editor ***Jonathan McDowell*** *covers more missions at Jonathan's Space Report: www.planet4589.org.*

Chandra's discovery of the "Hand Nebula" in Circinus became an internet sensation last April. In this X-ray image, high-energy wind from the young pulsar PSR B1509–58 interacts with interstellar matter pervaded by a magnetic field. Fingerlike structures extend north (up), apparently energizing knots in the neighboring gas cloud RCW 89 (red). High-energy X-rays are shown as blue, medium energy green, lower energy red. The frame is ⅓°, or about 100 light-years, tall.

NASA / CXC / SAO / PATRICK SLANE ET AL.

Gliese 581e, it's the fourth planet discovered orbiting the red dwarf Gliese 581, located 20.5 light-years away in Libra.

But don't plan on stepping out of your starship and setting up camp. The planet circles just 0.03 astronomical unit (about 3 million miles) from its star, so even the dim dwarf star must roast it to several hundred degrees Celsius.

One of the star's other three planets, Gliese 581d, occupies a more human-friendly temperature niche. But that one is a Neptune-mass world whose surface, if any, is probably deep inside a tremendously massive atmosphere and therefore extremely hot.

ESO / L. CALÇADA

ADAM BLOCK / TIM PUCKETT

Three Free-Floaters

In other exoplanet news, astronomers have identified three planet-mass objects floating loose in the star-forming nebula IC 348 (the blue reflection nebula centered in the image above), about 1,000 light-years away in Perseus. Each body has less than 10 times the mass of Jupiter, below the usual 13-Jupiter lower cutoff for the definition of brown dwarfs. The nebula and cluster are very young, less than about 3 million years old, but the three objects have already cooled to just 600° or 700°C, which means they must be low-mass.

Such free-floaters aren't technically planets because they don't orbit a star. They're called "sub-brown dwarfs" or "planet-mass objects," which is sometimes condensed to "planemos."

What's Going on in Enceladus?

When William Herschel discovered a sixth moon of Saturn in 1789, he named it Enceladus, after one of the Gigantes in Greek mythology. These enormous children of Gaia had, among other things, long, serpentlike lower limbs.

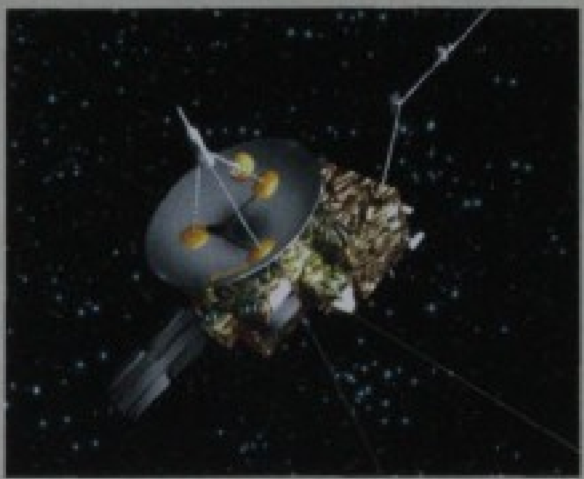
Data from the Cassini probe orbiting

Mission Update *Jonathan McDowell*

Ulysses Takes Its Last Looks at the Sun

Europe's Ulysses solar probe continues its unexpected afterlife. Shortly before its planned demise in July 2008, 18 years after launch, mission scientists found ways to eke out more science from the craft as the Sun continued its unexpectedly long and interesting activity minimum (see page 26). The drastic measures included flowing some hydrazine fuel through the attitude-control system every two hours to keep it from freezing. With less than 1 kg of fuel left, this strategy was expected to keep the mission going until last December at best. But to the astonishment of the spacecraft team, the fuel still had not frozen as of this May.

Multiple attempts to revive the high-power X-band antenna have failed, and science data were being returned through a marginally usable low-gain S-band link at less than 512 bits a second — about a hundred times slower than a household telephone dialup connection. Moreover, data were available only during live sessions monitored by the Deep Space Network (DSN). In February NASA approved extra DSN coverage to double the data rate and activate the onboard tape recorder, but this improvement was interrupted on April 9th when the big DSS-14 dish in California went out of service for a few weeks. On May 4th Ulysses was 4.4 a.u. from Earth at 30° above the ecliptic, Soon the fuel must freeze or run out, Ulysses will no longer be able to point its antenna at Earth, and the mission will really end.



After 19 years and three wide orbits of the Sun, Ulysses is still sending a trickle of data.

Ulysses was originally known as the Out-Of-Ecliptic mission and (before the U.S. dropped out) the International Solar Polar Mission. It orbits the Sun in a wide, 80°-inclination polar orbit, swinging between the orbits of Earth and Jupiter and back every six years.

The Sun isn't losing enough mass to account for it, neither by the solar wind nor the conversion of matter into sunlight. Nor is the gravitational constant *G* changing measurably. Neither the cosmic expansion of space nor the possible influence of dark matter can do the trick.

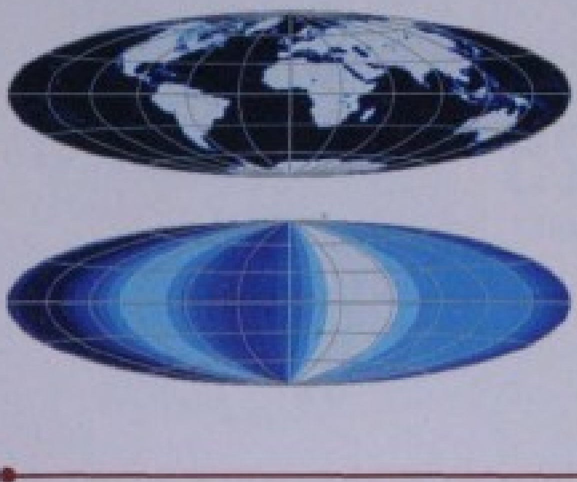
Now three Japanese dynamicists think they have a more mundane answer: tides. They argue that Earth's weak pull should raise tiny tides in the Sun, and a viscous drag by these tides, as the Sun rotates, can transfer a trace of the Sun's rotational energy to Earth's orbit. They find that the Sun's rotation should slow by 3 milliseconds per century due to this effect.

Exoplanet Mapping Tested on Earth

In the hopes that a powerful "Terrestrial Planet Finder" telescope will someday be launched, researchers have tested a way to detect the presence of oceans and clouds on Earth-like planets of far stars.

They aimed the camera on NASA's Deep Impact probe toward Earth in the far distance and monitored our world's total brightness in seven colors as it rotated. To their delight, the scientists found that this method could identify both moving clouds and fixed areas of continents and water, even though crudely. Given a good enough telescope, it would work just as well for planets far outside the solar system.

The rough map of Earth created from the Deep Impact data (shown below) correctly indicates the fraction of land and water in each longitude sector.



NICOLAS COWAN ET AL.

For astronomy news as it breaks, see SkyandTelescope.com/newsblog.

Mission Update *Jonathan McDowell*

Hubble Update

Like camera buffs with a new toy, the Hubble Space Telescope scientists are playing with the settings on their imagers to see what combination gives the best results. Hubble kept making astronomical observations right up to the day before *Atlantis* arrived, but the post-operative recovery period will take awhile.

NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA)

After 16 years of service, Hubble's legendary WFPC2 camera took this final farewell picture before being swapped out. It's of Kohoutek 4–55, a planetary nebula 4,600 light-years away in Cygnus.

The shuttle astronauts released Hubble on May 19th, but the new cameras and spectrographs remained buttoned up tight; it takes several weeks for all traces of Florida air to leak out from new equipment in space. In early June most of the instruments were still taking calibration data with the shutters closed and were testing commands to set up and shut down. Controllers had some tense hours on June 15th when the new data-handling unit locked up and had to be rebooted. The cause of the lockup was unknown.

The repaired Advanced Camera for Surveys will be the first to observe the sky; early-release images, chosen for their "wow" factor, are due out in September.

Spitzer Enters Warm Phase

NASA's infrared Spitzer Space Telescope has ended one phase of its career and embarked on another. On May 15th the liquid helium that kept the telescope's focal plane at only 3°C above absolute zero finally ran out, and the detectors that work in the far-infrared part of the spectrum started to warm up, ending their useful life. Spitzer's "cold phase" had lasted 5.5 years, more than twice the 2.5-year design life.

But Spitzer, behind its Sun shield, is still cold enough to run the two shortest-wavelength channels (3.6 and 4.5 microns) on the Infrared Array Camera (IRAC). So IRAC has all the observing time in Spitzer's new "warm mission." In late May the Spitzer team began a month of recalibrations to find out how IRAC behaves in its new environment at a toasty 31 kelvins (–242°C), before returning the observatory to use.

Spitzer has begun a series of large-scale "Exploration Science" surveys lasting several weeks each. These surveys are intended to remeasure the Hubble constant, study the evolution of galaxies, complete Spitzer's infrared mapping of the Milky Way, and study the atmospheres of extrasolar planets and the properties of near-Earth asteroids. The warm mission is intended to last until 2014, when the much larger James Webb Space Telescope should be ready to take up Spitzer's mantle. ✦

*Contributing editor **Jonathan McDowell** covers more missions at Jonathan's Space Report: www.planet4589.org.*

NASA / JPL-CALTECH / UNIV. OF WISCONSIN

Spitzer's near- and mid-infrared imagers penetrate the dusty Swan Nebula, M17, in northern Sagittarius.

in the whole inner solar system, Earth included. But according to a new study, the tiny refinement imposed by Einstein's theory of gravity (general relativity) lowers this chance to about 1%.

So we're pretty safe from an eventual collision between Venus and Earth, portrayed in the artist's illustration below.

But the chance isn't zero. "The interesting thing is that it can still happen quite a long time after planets have formed," says John Chambers (Carnegie Institution of Washington). "We're sort of changing the idea that planetary systems are formed and then stay the same."

In fact, the solar system is "chaotic" on long timescales. All the planets and smaller bodies gravitationally influence each other, so that any imprecision in today's trajectories becomes multiplied by a factor of ten every 10 million years. Therefore, astronomers will *never* be able to predict the positions of the planets beyond a few hundred million years out — even if the imprecision started out less than a trillionth of a millimeter. In the long run, we only have probabilities. ✦

All News Note stories are presented in greater depth, with links to further information, at SkyandTelescope.com search for the keyword SkyTelOct09.

Mission Update *Jonathan McDowell*

Ultraviolet and X-ray Vision

NASA has selected two new Small Explorer missions, its cheapest scientific satellites.

The first is **IRIS,** the Interface Region Imaging Spectrograph, proposed by a solar research group at Lockheed. Like the group's previous mission, TRACE, the satellite will study the transition region between the Sun's photosphere and corona, but this time in the ultraviolet instead of soft X-rays. IRIS will follow matter flowing through the chromosphere and study how the structure of that layer affects the supply of mass and energy to the corona above, as plasma is heated from 5,000 to more than 1 million kelvin. IRIS's 20-cm telescope will have a slit spectrograph providing both high resolution (0.3 arcsecond) and high cadence (as often as one spectrum per second), as well as a wider-field ultraviolet camera to provide context. IRIS should launch in 2013, near sunspot maximum.

GEMS will study polarization in cosmic X-ray sources to tease apart their inner workings.

The second mission is **GEMS,** the Gravity and Extreme Magnetism SMEX, to be launched in 2014. GEMS is the first mission ever dedicated to measuring X-ray polarization. The only extrasolar object in which X-ray polarization has been measured is the Crab Nebula: by a team using a rocket in 1971 and the Orbiting Solar Observatory 8 in 1976.

GEMS will observe a small number of bright sources for long durations, since polarization measurements pick up only a small fraction of the incoming photons. Scientists hope to measure the spins of black holes in X-ray binary stars — a key topic in current discussions of black-hole evolution — as well as the geometry of neutron stars' intense magnetic fields. Similar studies of supernova remnants will determine whether their fields are smooth or tangled.

For a list of all 12 of the NASA Small Explorer satellites and their purposes, see SkyandTelescope.com/NASASmallExplorers.

Mini Updates

NASA's **LCROSS** and its Centaur rocket are expected to hit the Moon's south polar region on October 9th around 11:30 Universal Time (7:30 a.m. EDT). The time will be refined to within a second by two weeks beforehand. See page 53 for exactly where to watch for the pair of impacts.

Ulysses, the solar polar probe that got an unexpected reprieve a year ago, was finally switched off June 30th after almost 19 years orbiting the Sun.

In early July the **Spirit rover** began its third month stuck in soft ground at the edge of the Home Plate feature in Mars' Gusev Crater region.

Aboard **Hubble,** the rehabbed Space Telescope Imaging Spectrograph began a study of Eta Carinae on July 1st. It was one of Hubble's first science observations since the Shuttle astronauts upgraded it.

The telescope for **WISE,** the Wide-field Infrared Survey Explorer, arrived at Ball Aerospace in May for integration with its spacecraft. WISE is on track for launch at the end of the year.

Contributing editor ***Jonathan McDowell*** *covers more missions at Jonathan's Space Report: www.planet4589.org.*

The WISE telescope's map of the entire infrared sky will become a standard reference for astronomers everywhere.

Meteorite on Mars: A Wayback Machine

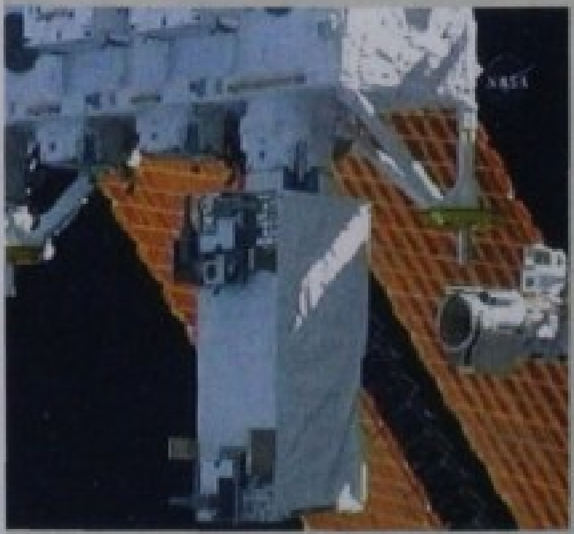
On July 18th the rover Opportunity was rolling across the Martian plains en route to the big crater Endeavour, when it caught sight of a craggy rock about 2 feet across sitting on the ruddy sand. Intrigued, controllers back on Earth had the craft make a U-turn and backtrack some 820 feet (250 meters) for a closer look. The rock turned out to be a nickel-iron meteorite.

Dubbed "Block Island," the meteorite offers exciting hints about Mars's past. Such a large meteorite could not have survived impact unless it fell at a time when Mars had a thicker atmosphere to cushion it, researchers claim. This implies either that enough carbon dioxide is locked up in the Martian polar caps to create a thick atmosphere during periodic warming cycles, or that the meteorite fell billions of years ago in Mars's early history. In the latter case, it probably spent most of its life underground, where it could avoid being weathered away to nothing over the ages. Studies underway of its surface chemistry and weathering may tell new tales of the Martian past. ✦

NASA / JPL / CORNELL UNIVERSITY

For astronomy news as it breaks, visit SkyandTelescope.com/newsblog.

Mission Update *Jonathan McDowell*



NASA TV

The MAXI module (box at lower center) hangs from the newly installed porch of Japan's lab on the International Space Station.

MAXI on the Space Station

During their July visit to the International Space Station, the shuttle *Endeavour's* crew installed a major astronomy experiment. The Japanese MAXI package (Monitor of All-Sky X-ray Image) is designed to supersede the All-Sky Monitor on NASA's aging Rossi X-ray Timing Explorer (RXTE) as an early-warning system for the high-energy sky.

MAXI carries a pair of 1-dimensional slit cameras, which sweep out a view of the sky as the Space Station circles Earth. The main instrument, the Gas Slit Camera, covers a broad range of X-ray energies from 2 to 30 kiloelectron volts (keV). A second instrument, the Solid-state Slit Camera, covers a softer energy range of 0.5 to 10 keV, is less sensitive than the Gas Slit Camera, but has better spectral resolution.

As with RXTE, MAXI will create long-term X-ray light curves of the brightness of every source it sees, so that the flaring behavior of a given object can be studied over a period of many years.

Japan's Venus Climate Orbiter

Japan's next planetary mission is now being built. Assembly and testing of the Venus Climate Orbiter got under way in June at the headquarters of the Japanese Aerospace Exploration Agency (JAXA), southeast of Tokyo. The Venus Climate Orbiter, also called PLANET-C, will be launched in May 2010. It will take up an elliptical orbit going westward around Venus, to follow the westward motion of the upper atmosphere. The mission's main goal is to map the atmospheric circulation. Ultraviolet and infrared cameras will catalog cloud composition, and a high-speed camera will watch for lightning.

The ultraviolet camera will see mostly the cloudtops at 40 miles (65 km) altitude. It will measure sulfur dioxide and other absorbing chemicals. A 2-micron near-infrared camera will see down to the 35–50 km levels and map carbon monoxide. A 1-micron camera will measure the heat of Venus's surface (illustration below) and search for any active volcanoes. An 8–12 micron mid-infrared camera will map the temperatures and altitudes of the cloudtops.

The mission is designed to complement the European Space Agency's Venus Express probe, now orbiting Venus.

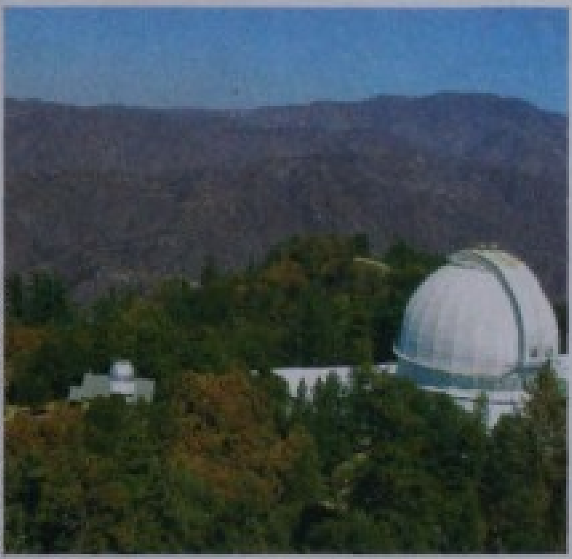
Contributing editor ***Jonathan McDowell*** *covers more missions at Jonathan's Space Report: www.planet4589.org.*

JAXA / PLANET-C TEAM

The Venus Climate Orbiter will monitor layers of the hot planet's atmosphere from the cloudtops down to the ground.

20-inch (0.5-meter) Uppsala Schmidt telescope at Siding Spring Observatory, pictured. Since 1987 McNaught has racked up 38 solo comet discoveries and 12 shared discoveries. His closest competitor is Carolyn Shoemaker, with 32 credited comets.

There's a footnote: those are comets of the night. Rainer Kracht in Germany has identified 242 comet fragments plunging close by the Sun in images from the Solar and Heliospheric Observatory.



UCLA DEPT OF PHYSICS & ASTRONOMY

Observatories Escape Wildfire

Mount Wilson Observatory, with its historic 100-inch and 60-inch telescopes and its state-of-the-art CHARA interferometric array, barely escaped destruction in the wildfire that raged through southern California's Angeles National Forest in September. A massive force of firefighters in airplanes and on the ground held the flames at bay. They also saved an important amateur institution, the Stony Ridge Observatory with its 30-inch telescope, on a different peak five miles away.

In the photo above, greenery saved by firefighters around the Mount Wilson 100-inch dome stands in contrast to the burned mountains beyond.

Wildfires have become an increasing threat to mountain observatories where climates have been turning hotter and drier. The 200-inch Hale Telescope on Palomar Mountain narrowly escaped a forest fire in November 2007, as did Steward Observatory in Arizona in June 2003. Australia's Mount Stromlo Observatory was not so lucky. Founded in 1910, it was destroyed in the record-breaking bush fire of January 2003. ◆

Mission Update *Jonathan McDowell*

Rosetta's Last Visit to Earth

On November 13th, Europe's Rosetta comet probe will make its last flyby of Earth before heading to the outer solar system.

Launched in March 2004, Rosetta circled the Sun once before its first return in March 2005, which boosted its orbit out to meet Mars in February 2007. The Mars flyby sent Rosetta into the inner asteroid belt 1.6 a.u. from the Sun, then back to Earth in November 2007 for a further fling out to 2.2 a.u. and a flyby of the little asteroid 2867 Steins in 2008.

This final Earth flyby will boost Rosetta to Jupiter's distance at 5.1 a.u., where it will rendezvous with Comet 67P/Churyumov-Gerasimenko in 2014 and drop a lander onto its nucleus.

Along the way, on July 10, 2010, Rosetta will also check out the main-belt asteroid 21 Lutetia. With a diameter of 100 km, Lutetia will be by far the largest asteroid yet visited by a space probe.

Planck Maps the Big Bang

On August 24th the European Space Agency's Planck spacecraft began making its long-awaited, newly detailed map of the cosmic microwave background radiation (May issue, page 24). Earlier, test results confirmed that Planck easily sees the well-known "dipole" component in the microwave background, caused by Earth's motion with respect to the absolute standard of rest that the background establishes. Planck also completed a mini-survey of astronomical objects emitting submillimeter-wave radiation.

Mars Orbiter in Intensive Care

NASA's Mars Reconnaisance Orbiter has taken vast swaths of imagery at 1-meter resolution, returning more data than all other Mars missions combined. (Browse 11,000 images at hirise.lpl.arizona.edu). But on August 26th, after a fourth unexplained computer incident in several months, engineers put MRO on hold to study its software. Computer reboots and similar "safe modes" are not normally fatal, but analysts spotted a way that two particular failures in quick succession could kill MRO permanently.

NASA / JPL

Chandrayaan-1's Last Gasp

India's Chandrayaan-1 spacecraft, orbiting the Moon since November 2008, went dead on August 28th. A source of great national pride in India, Chandrayaan-1 spent six months gathering scientific data. But the Indian space agency, ISRO, underestimated the heat the spacecraft would receive in low lunar orbit — and took criticism for keeping the resulting problems under wraps. With Chandrayaan's systems failing, experimenters did manage to carry out a final joint study with NASA's Lunar Reconnaissance Orbiter, using oblique radar to search for lunar surface ice.

An ambitious successor mission, the Chandrayaan-2 lander/rover, is on the books to launch around 2013.

***Jonathan McDowell** covers more missions at www.planet4589.org.*

ESA / LFI & HFI CONSORTIA. BACKGROUND IMAGE: AXEL MELLINGER

This all-sky map, aligned on the plane of the Milky Way, shows a strip of preliminary Planck data circling the sky.

900 feet (300 meters) wide, Apophis would arrive with the energy of several hundred megatons of TNT, roughly 10 times more energy than the largest thermonuclear bomb ever tested. But as soon as its positions were measured over a longer time span (thanks to pre-discovery images being located), an impact in 2029 was ruled out completely. Nevertheless, a 1-in-45,000 chance remained for April 13, 2036.

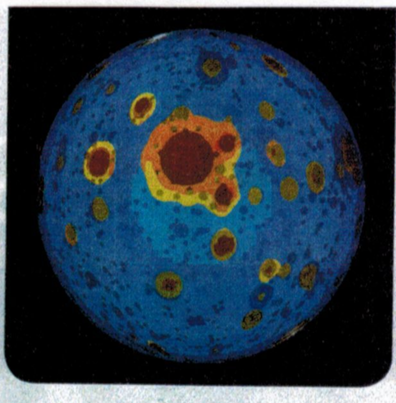
Now, with ever longer orbital tracking, that chance has been downgraded to 1 in 250,000. Another impact possibility has shown up for April 13, 2068, but at only the 1-in-300,000 level.

Do mark your calendar for April 13, 2029, however. Apophis will miss us by only three Earth diameters, and will be visible to the unaided eye creeping across the night sky as bright as 3rd magnitude.

Surviving the Late Heavy Bombardment

Conventional wisdom has been that the solar system's "Late Heavy Bombardment," which pummeled all the inner planets and gave the Moon its biggest impact scars, must have sterilized Earth. The bombardment ended 3.9 billion years ago, so biologists assume that the ancestors of all living things today originated after that. Trace evidence of life exists from 3.83 billion years ago — which implies that life started as soon as it possibly could. That, in turn, would suggest that life arises quickly and easily on suitable planets everywhere.

But a new study finds that bacteria several kilometers deep in Earth's crust (where some microbes live today) could survive even multiple blows severe enough to boil off all of Earth's oceans. These microbes could later recolonize the surface when times improved.



OLEG ABRAMOV / UNIV. OF COLORADO

If so, today's life could have originated *anytime* in Earth's first 800 million years. If life didn't necessarily spring into being as soon as conditions allowed, this weakens the case that life probably gets going easily on every good planet.

The image above is from a temperature simulation of Earth during the bombardment era. ✦

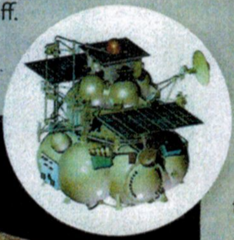
Mission Update

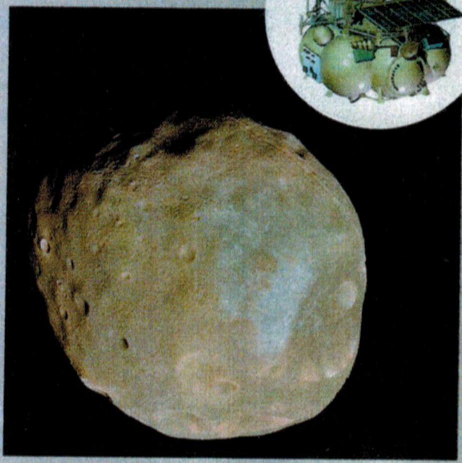
Jonathan McDowell

Fobos-Grunt to Mars: Delayed

Russian space scientists have a long and mostly bitter history with the Red Planet. The occasional technical success (in 1971 Mars-2 was the first human artifact to reach the planet's surface) has been overshadowed by repeated failures. Most recently, in 1996 Russia's first post-Soviet Mars probe crashed in Bolivia soon after takeoff.

Undaunted, Russia's Institute of Space Research began planning an even more ambitious mission, Fobos-Grunt ("Phobos-Sample"). The U.S. has long discussed, but never funded, a sample return from the surface of Mars. Anticipating the Augustine Commission's "stay out of gravity wells" recommendation, Fobos-Grunt would instead return a soil sample from Mars's largest moon.





HIRISE / MRO / LPL / NASA; SPACECRAFT: NPO LAVOCHKIN

Russia insisted that the mission would fly during the October 2009 Mars-launch window. But no one was surprised when in September word came at the last minute that Fobos-Grunt would not launch until 2011. In fact, fundamental design questions remain about the type of soil sampler to be used.

Yinghuo-1 to Mars: Delayed

Also delayed is Fobos-Grunt's Chinese passenger, a microsatellite to study the Martian environment. Hitching a ride to Mars on the Russian spacecraft, the 120-kg Yinghuo-1 would be dropped off in an elliptical orbit. As it passes behind the limb of Mars as seen from Fobos-Grunt, its radio signals will allow scientists to measure Martian ionospheric conditions.

Piggybacking to Venus

The Yinghou-1 mission was to be the first of a new generation of small, cheap spacecraft flying as passengers on expensive planetary missions, but it now looks to be scooped by two Japanese probes. When Japan's Venus Climate Orbiter takes off this May (*S&T:* November 2009, page 16), the second stage of its H-IIA rocket will jettison two small experiments into solar orbit. IKAROS (Interplanetary Kite-Craft Accelerated by Radiation of the Sun) is a 20-meter-wide solar sail covered with photovoltaic cells. The sail will spend several months in a technology demonstration, generating power and using solar radiation pressure to change its orbit.

UNITEC-1, the second passenger, is a 15-kg, 30-cm cube developed by a group of Japanese universities to test on-board computers in the interplanetary radiation environment, as well as deep-space communications and tracking.

Flush with the success of a plethora of student-built 1-kg 'cubesats' in low Earth orbit, other university groups are also looking to interplanetary space for the first time.

*Contributing editor **Jonathan McDowell** covers more missions at Jonathan's Space Report: www.planet4589.org.*

tially crippled by noisy circuitry. As with many internet rumors, there's truth and there's exaggeration. The electronic noise affects three of Kepler's 84 data channels from its 42 imaging chips; the other 81 channels are fine. And mission controllers are storing the data from the faulty three with the expectation that they can write algorithms to clean it up.

Kepler is continuously monitoring 100,000 stars in a 105-square-degree patch of sky between Vega and Deneb for any tiny dips in their light. The positions of Kepler's imaging chips are mapped on the sky photo on page 14. The mission should continue for at least 3½ years. ✦

News Note stories are presented in greater depth, with links to further information, at SkyandTelescope.com; search on SkyTelFeb10.

Mission Update *Jonathan McDowell*

Space Astronomy in 2010

Although 2010 looks to be a fairly light year for launches of new astronomy missions, plenty of science will be done by craft already up. Here are some events to look forward to in the upcoming months:

The year should begin with the exciting WISE infrared sky-survey satellite (December-issue cover story) completing its orbital checkout after a scheduled December 9th launch (good luck, Ned, Pete, and Amy!).

In February the Solar Dynamics Observatory (SDO) will take off to monitor the Sun from geostationary Earth orbit (January issue, page 22).

In May Japan will launch the Venus Climate Orbiter, recently named Akatsuki ("Daybreak").

In June the Japanese Hayabusa probe will return from its seven-year asteroid voyage and land in the Australian desert, perhaps with traces of an asteroid surface sample intact.

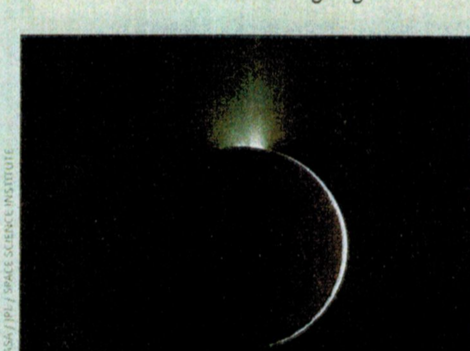
Rosetta, which made its final flyby of Earth in November, will pass the big asteroid 21 Lutetia on July 10th. And EPOXI, the former Deep Impact flyby spacecraft, will whiz past Comet 103P/Hartley-2 on October 11th.

Many more astronomy missions continue their work on a daily basis. An inventory, by location:

- In Earth orbit, the Hubble Space Telescope heads up a small flotilla of visible-light, infrared, and ultraviolet observatories including Canada's MOST, France's COROT planet finder, and Japan's infrared AKARI. The X-ray sky continues to be served by the great Chandra and XMM-Newton observatories, along with Suzaku, the Rossi XTE (nearing the end of its long life), and the MAXI package (in its prime) on the International Space Station. Fermi and Integral continue to survey the gamma-ray sky.

SDO is joined in Sun studies by Koronas-Foton, TRACE, SORCE, RHESSI, and Hinode, as well as the ESA Solar package on the Space Station. IBEX charts the mysterious band of particles emanating from the edge of the solar system. The PAMELA experiment studies positrons aboard the Resurs-DK satellite.

- Around the Earth-Sun L_1 Lagrangian point, the elderly SOHO and ACE sentinels monitor the Sun. Around L_2, WMAP and Planck compete to return the best data on the cosmic microwave background, while Herschel gets down to its program of deep far-infrared observing.
- In lunar orbit, the Lunar Reconnaissance Orbiter continues mapping away; see page 28.
- In orbit around the Sun, Kepler and Spitzer maintain their astronomical observing programs, and STEREO A and B watch at the Sun from their different viewing angles. In addition to Rosetta and EPOXI, Stardust, Dawn, Messenger, and New Horizons continue toward targets they will reach within the next five years.
- At Mars, Opportunity continues to traverse the Martian sands, though its twin rover Spirit may be bogged down for good. In Martian orbit, Mars Odyssey, Mars Express, and Mars Reconnaissance Orbiter look down from above.
- Venus Express orbits Earth's cloudy sister.
- At Saturn, the 13-year-old Cassini spacecraft is extending its hugely productive exploration of the planet, its rings, and especially its many moons.
- Finally, the two Voyagers, launched way back in 1977, are still heading outward, taking readings at the boundary of interstellar space.



NASA / JPL / SPACE SCIENCE INSTITUTE

On November 2nd, the enormously successful Cassini probe made its seventh flyby of Saturn's moon Enceladus — and its deepest plunge yet through the vapor-and-ice plumes jetting from the moon's south polar region. On its way in, Cassini took this image of the plumes backlit by the Sun. Half of Enceladus's night side glows dimly by yellow Saturnshine.

Ave Atque Vale

I started reading this magazine when I was a teenager, and it's been a blast to actually see my name in it each month for the past 16 years. When I began the Mission Update column in 1993, I was a relatively junior scientist and still had free time on evenings and weekends. But, in a little-known cosmological effect, as the universe evolves and expands, one's personal time shrinks.

I have therefore reluctantly decided to lay down my pen (okay, keyboard) and bid farewell to the pages of *Sky & Telescope*. However, you can still keep up with astronomy-from-space happenings in News Notes, which will expand to fill this location. I've promised to send editor-in-chief Bob and his crew hot tips that I come across. And I remain onboard as a Contributing Editor.

I hope you'll also occasionally drop by my ever more irregularly updated Jonathan's Space Report, at **www.planet4589.org**.

—Jonathan McDowell