A Scientific Armada

Space-deployed sensors promise a revolution in science's understanding of the cosmos

by Tim Beardsley, *staff writer*

HUBBLE SPACE TELESCOPE separates from the space shuttle *Discovery* over the Indian Ocean in February 1997, after receiving new instruments. Stunning Hubble images have inspired widespread interest in astrophysical phenomena.

NASA

A decade from now humanity's understanding of the solar system, no less the universe beyond, will have grown vastly more focused and detailed. During the next 10 years, roughly 50 scientific expeditions will blast off from Earth—a veritable armada of missions to visit planets, comets and asteroids, as well as to make sensitive observations of deep space from above Earth's occluding atmosphere. Researchers will very likely resolve some long-standing questions at the same time that they grapple with as yet undreamed of conundrums.

As many as nine spacecraft will intensively survey Mars during the next 10 years, including the Mars Global Surveyor now in orbit. If plans under consideration get the go-ahead, samples from the red planet will return to Earth for analysis sometime after 2005. Missions to Pluto and, perhaps, Mercury and Venus (though not currently scheduled) may advance onto the National Aeronautics and Space Administration's timetable.

Material samples should also arrive at our home planet from remote interplanetary space, from an asteroid and from the tail of a comet. The moon will once again become a familiar destination for robotic spacecraft, including Japanese and European projects. These missions will map the moon's composition and attempt to settle the question—raised by recent radar observations—of whether Earth's orbital companion might harbor water ice near its south pole. In 2005 the Solar Probe mission might even hurtle toward the sun. Farther afield, by 2004, the giant Cassini spacecraft will arrive at Saturn and dispatch its accompanying Huygens probe to investigate the ringed planet's giant moon, Titan. A variety of scheduled missions are also planned to observe from afar the sun's violent outbursts, including Germany and China's Space Solar Tele-

Continued on page 116

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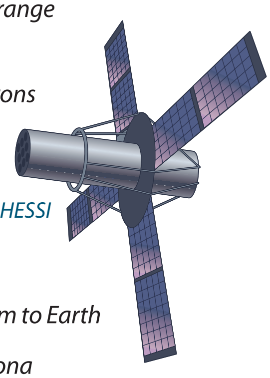
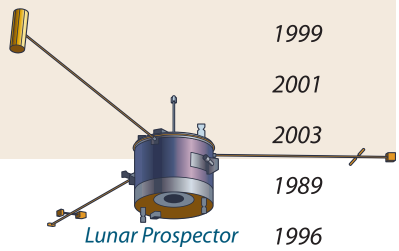
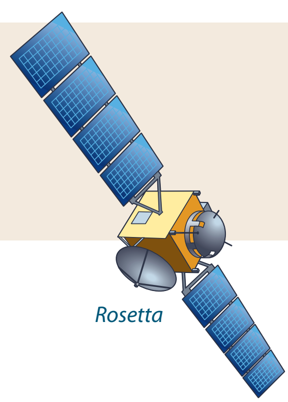
KEY SPACE EXPLORATIONS OF THE NEXT DECADE

	NAME OF MISSION (SPONSOR)	MAIN PURPOSE OF MISSION	LAUNCH DATE
The Sun	*ACE, Advanced Composition Explorer (NASA)*	*Monitor solar atomic particles and the interplanetary environment*	*1997*
	Coronas F (Russia)	*Observe the sun's spectrum during a solar maximum*	*1998*
	TRACE, Transition Region and Coronal Explorer (NASA)	*Photograph the sun's coronal plasmas in the ultraviolet range*	*1998*
	HESSI, High Energy Solar Spectroscopic Imager (NASA)	*Study solar flares through x-rays, gamma rays and neutrons*	*2000*
	Photon (Russia)	*Analyze gamma rays from the sun*	*2000*
	SST, Space Solar Telescope (China and Germany)	*Study the sun's magnetic field*	*2001*
	Genesis (NASA)	*Gather atomic nuclei from the solar wind and return them to Earth*	*2001*
	Solar Probe (NASA)	*Measure particles, fields, x-rays and light in the sun's corona*	*2003*
	Solar B (Japan)	*Study the sun's magnetic field around violent events*	*2004*
The Moon	*Lunar Prospector (NASA)*	*Study the moon's magnetic field and search for evidence of water at its poles*	*1998*
	Lunar A (Japan)	*Analyze the moon's subsurface soil*	*1999*
	Euromoon 2000 (ESA)	*Explore the moon's south pole (under study)*	*2001*
	Selene (Japan)	*Map the moon, studying fields and particles*	*2003*
The Planets	*Galileo (NASA)*	*Explore Jupiter and its moons*	*1989*
	Mars Global Surveyor (NASA)	*Map Mars and relay data from other missions*	*1996*
	Cassini (NASA)	*Explore the Saturn system; Huygens (ESA) will descend to Titan*	*1997*
	Planet B (Japan)	*Study interactions between the solar wind and Mars's atmosphere*	*1998*
	Mars Surveyor '98 (NASA)	*Explore a site near Mars's south pole (two-part mission)*	*1998 and 1999*
	Deep Space II (NASA)	*Analyze Martian subsurface soil*	*1999*
	Mars Surveyor 2001 (NASA)	*Land a rover that will travel many kilometers on Mars (two-part mission)*	*2001*
	Mars Surveyor 2003 (NASA)	*Collect Martian soil samples (two-part mission, under study)*	*2003*
	Mars Express (ESA)	*Analyze Martian soil, using an orbiter and two landers*	*2003*
	Pluto/Kuiper Express (NASA)	*Explore the solar system's only unvisited planet and the Kuiper belt (under study)*	*After 2003*
	Mars Sample Return (NASA)	*Return Martian rock and soil samples to Earth (under study)*	*After 2005*
Comets	*Stardust (NASA)*	*Encounter Comet Wild 2, collect particles from its tail and return the sample to Earth*	*1999*
	CONTOUR, Comet Nucleus Tour (NASA)	*Produce spectral maps of three comet nuclei*	*2002*
	Rosetta (ESA and France)	*Land a probe on Comet Wirtanen's nucleus*	*2003*
Asteroid Belt	*NEAR, Near Earth Asteroid Rendezvous (NASA)*	*Measure the composition, magnetic field and mass distribution of the asteroid Eros*	*1996*
	MUSES C (Japan)	*Return a sample of material from an asteroid*	*2002*







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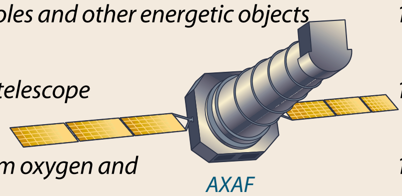
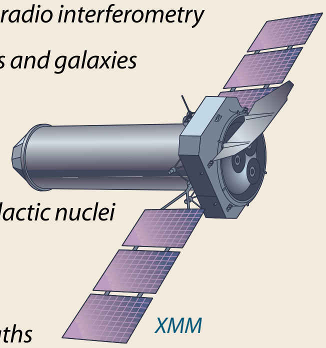
Deep Space

NAME OF MISSION (SPONSOR)	MAIN PURPOSE OF MISSION	LAUNCH DATE
RXTE, Rossi X-ray Timing Explorer (NASA)	Watch x-ray sources change over time	1995
Beppo-SAX (Italy)	Observe x-ray sources over a wide energy range	1996
HALCA (Japan)	Study galactic nuclei and quasars via radio interferometry	1997
FUSE, Far Ultraviolet Spectroscopic Explorer (NASA)	Detect deuterium in interstellar space	1998
AXAF, Advanced X-ray Astrophysics Facility (NASA)	Procure x-ray images and spectra of black holes and other energetic objects	1998
WIRE, Wide-Field Infrared Explorer (NASA)	Observe galaxy formation with a cryogenic telescope	1998
Odin (Sweden)	Detect millimeter-wavelength emissions from oxygen and water in interstellar gas	1998
SWAS, Submillimeter Wave Astronomy Satellite (NASA)	Search for oxygen, water and carbon in interstellar clouds	1999
ABRIXAS, A Broad-band Imaging X-ray All-sky Survey (Germany)	Make a hard x-ray, all-sky survey	1999
Spectrum X-gamma (Russia)	Measure x-ray emissions from pulsars, black holes, supernova remnants and active galactic nuclei	1999
HETE II, High Energy Transient Explorer (NASA)	Study gamma-ray bursters with x-ray and gamma-ray detectors	1999
XMM, High-Throughput X-ray Spectroscopy Mission (ESA)	Observe spectra of cosmic x-ray sources	1999
Astro-E (Japan)	Make high-resolution x-ray observations	2000
MAP, Microwave Anisotropy Probe (NASA)	Study the universe's origin and evolution through the cosmic microwave background	2000
Radioastron (Russia)	Observe quasars and high-energy phenomena via radio interferometry	2000
SIRTF, Space Infrared Telescope Facility (NASA)	Make high-resolution infrared observations of stars and galaxies	2001
Corot (France)	Search for evidence of planets around distant stars	2001
INTEGRAL, International Gamma Ray Astrophysics Lab (ESA)	Obtain spectra of neutron stars, black holes, gamma-ray bursters, x-ray pulsars and active galactic nuclei	2001
GALEX, Galaxy Evolution Explorer (NASA)	Observe stars, galaxies and heavy elements at ultraviolet wavelengths (under study)	2001
Spectrum UV (Russia)	Study astrophysical objects at ultraviolet wavelengths	2001
SIM, Space Interferometry Mission (NASA)	Image stars that may host Earth-like planets (under study)	2004
HTXS, Constellation X-ray Mission (NASA)	Perform high-resolution x-ray spectroscopy (under study)	After 2005
OWL, Orbiting Wide-angle Light collectors (NASA)	Study cosmic-ray effects on Earth's atmosphere (under study)	After 2005
FIRST, Far Infrared Submillimeter Telescope, and Planck (ESA)	Discern the fine structure of the cosmic microwave background (combined mission)	2006
Next Generation Space Telescope (NASA)	View space, near and far, at infrared wavelengths (under study)	2007
TPF, Terrestrial Planet Finder (NASA)	Find planets and protoplanets orbiting nearby stars (under study)	2009





ILLUSTRATIONS BY JARED SCHNEIDMAN DESIGN

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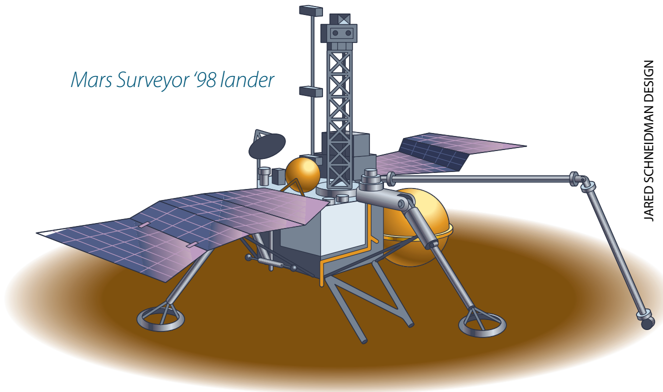
Continued from page 112
scope, Russia's Coronas F and Photon, and Japan's Solar B.

Looking beyond the solar system, an equally impressive fleet of sensitive detectors will soon be launched to make images and analyze radiation and particles emanating from deep space. Although several such observatories have lifted off in recent years, the turn of the century will witness many more launches. These new instruments will vastly outperform their predecessors, because of advances in sensor and computer technology. At least 20 nations will participate in this grand exploration. The great majority of the missions will feature international collaboration at some level—and even a little competition as well.

The U.S., Russia, Japan and the European Space Agency (ESA) stand out as major players, but they are not the only ones. Various smaller explorations are being planned. India and Sweden have observation programs, for example, and France, Germany and Italy run substantial projects aside from their membership in the ESA. Many countries not flying spacecraft will contribute instruments or lend the use of tracking facilities. International collaboration seems likely to increase, especially with expensive endeavors such as the projected Mars Sample Return Mission. Although recently NASA has put an emphasis on low-cost, bare-bones space science missions, a number of costly enterprises lie on its drawing board.

By 2008, gamma-ray bursters may seem less mysterious than they do today, thanks to a squadron of satellites designed to identify and observe these brief but cataclysmic events. Quasars and active galactic nuclei of all kinds—not to mention our own galaxy's center—will come under intense scrutiny at x-ray and gamma-ray wavelengths. Among the most significant of these planned high-energy observatories are INTEGRAL, an ESA project to be launched in 2001 to study gamma-ray sources; the High-Throughput X-ray Spectroscopy Mission, due to be lofted in 1999; and the long-delayed Advanced X-ray Astrophysics Facility (AXAF), scheduled for liftoff in 1998. Radioastronomers, too, will observe such high-energy regions with unprecedented resolution by way of very long baseline interferometry, which combines satellite measurements with those taken with antennae on Earth. HALCA, a Japanese radioastronomy satellite using this technique, is already in operation, and Russia plans to launch a larger one, Radioastron, in 2000. Other specialized sensors, NASA's Microwave Anisotropy Probe (MAP) and the ESA's FIRST/Planck combined mission, will eavesdrop on the cosmic microwave background radiation, a survey that could reveal much about conditions in the universe's first moments.


Mars Surveyor '98 lander

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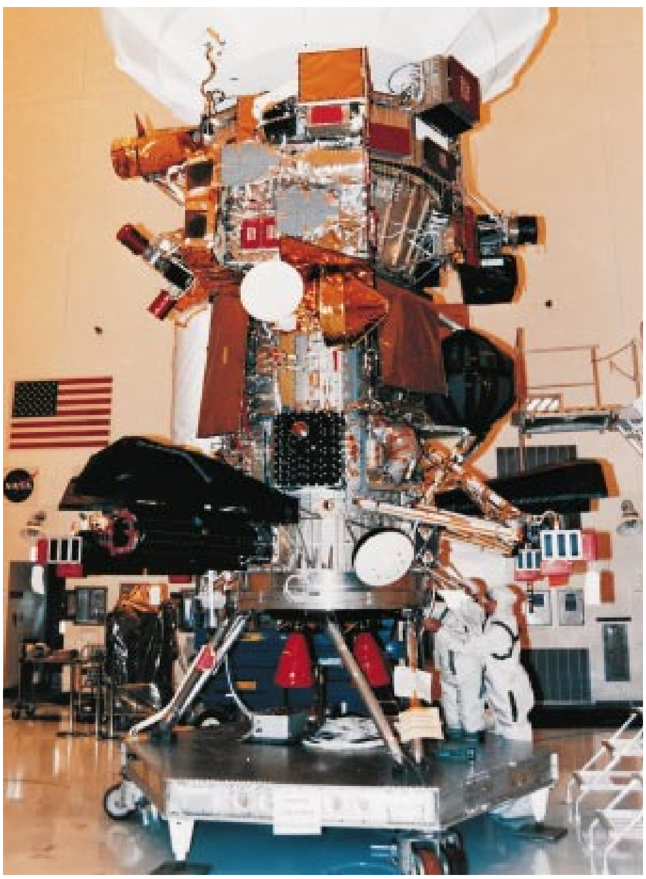
NASA

CASSINI is examined by engineers at the Jet Propulsion Laboratory in Pasadena, Calif. The spacecraft was launched in October 1997 toward Saturn, where it should arrive in 2004.

An important push will come in infrared astronomy, best suited for studying the formation of galaxies, stars and planets. One eagerly anticipated event will arrive with the launch in 2001 of the Space Infrared Telescope Facility (SIRTF). This spacecraft, and some other infrared and submillimeter-wavelength observatories, will extend the capabilities of the ESA's Infrared Space Observatory, which was expected to run out of cryogenic coolant in early 1998.

Although most space-based observatories orbit Earth, infrared observatories benefit from distance. SIRTF will orbit the sun 48 million kilometers (30 million miles) from Earth, whereas some other infrared and submillimeter-wavelength observatories will hover around a gravitationally stable point two million kilometers distant from Earth in the direction away from the sun. The Next Generation Space Telescope, tentatively planned for launch around 2007, will carry a high-resolution infrared observatory—a worthy successor to the Hubble Space Telescope, which will wind down sometime after 2005.

Radioastronomers will not be the only ones using interferometry. The technically daunting challenge of space-based optical interferometry serves as the aim of the Space Interferometry Mission, now under study. Two separate optical telescopes, separated by a 10-meter boom, would combine forces to achieve unprecedented resolution. An even more ambitious mission known as Terrestrial Planet Finder, still in the early planning stage, would employ infrared interferometry to search for Earth-size planets around distant stars—a key component of NASA's theme of studying origins.

All plans and dates for space science missions remain subject to changes. Nevertheless, the size and scope of this scientific armada reveal that human beings have a compelling drive to understand how our universe came to be. SA

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