AERONAUTICS RESEARCH

SCIENCE

EXPLORATION SYSTEMS

SPACE OPERATIONS

National Aeronautics and Space Administration

NASA Headquarters
300 E Street SW
Washington, DC 20546

www.nasa.gov

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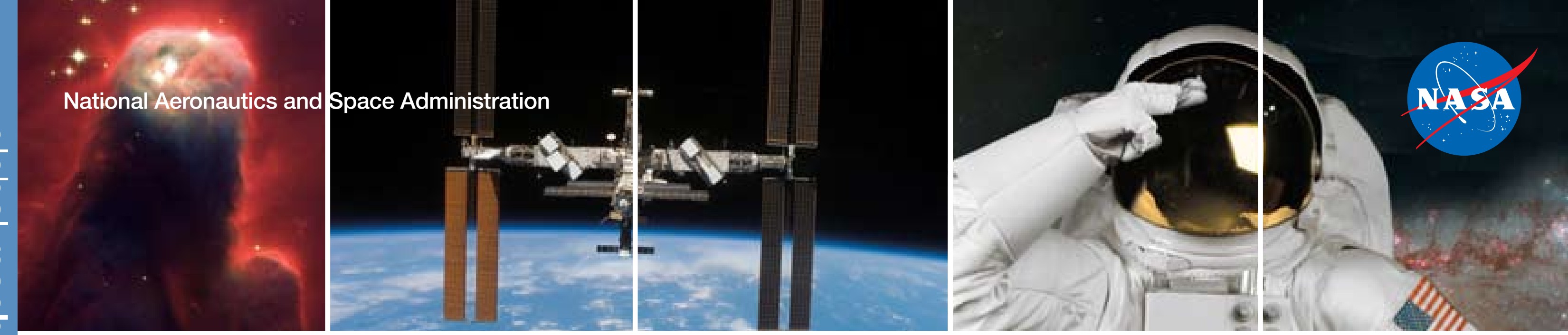
global **reach** A View of NASA's International Cooperation **2008**



National Aeronautics and Space Administration

A View of NASA's International Cooperation

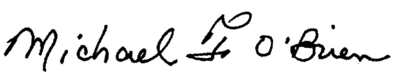
global reach


To learn more about NASA and the Office of External Relations,
please visit NASA's Web site at www.nasa.gov.

To the Reader:

Since the Agency's inception, the National Aeronautics and Space Administration has enjoyed significant benefits to almost all of its programs through some level of international cooperation. As a result of over 4,000 international agreements, NASA and its international partners have successfully shared the risks and the rewards of space exploration for decades. Today, NASA's current international partners share many of our goals for exploration beyond low Earth orbit. In addition, an increasing number of nations are relying on the unique vantage point of space for day-to-day activities such as communications, weather forecasting, and navigation. As a consequence, NASA's international partnerships continue to grow in diversity and importance. This book provides a brief overview of NASA's extensive international cooperation in aeronautics, science, exploration systems, and space operations. I believe that even a casual review of this material will convince you that NASA's international cooperation truly does have a *Global Reach*.

Looking to the future, international cooperation will continue to be fundamentally important to NASA's activities. By direction of the President and Congress, NASA is pursuing a bold agenda that commits the United States to complete assembly of the International Space Station and to develop the next generation of launch systems, vehicles, and other capabilities that will carry humans and robots beyond low Earth orbit as an integral part of a balanced program of aeronautics research and science. As we continue to implement this exciting Vision for U.S. Space Exploration, NASA will seek opportunities for mutually beneficial cooperation around the world.



Michael F. O'Brien
Assistant Administrator for External Relations

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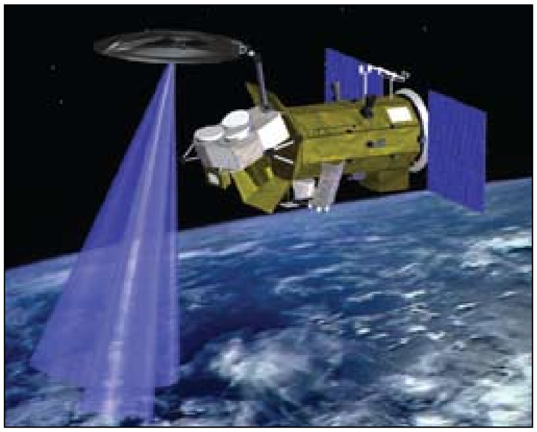
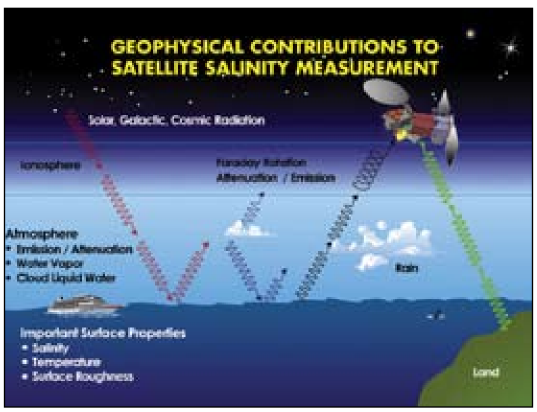
Argentina

Aquarius/SAC-D



Artist concept of the Aquarius/SAC-D satellite above Earth



Among the important geophysical factors that need to be included in the retrieval of salinity from a sensor in space are emission from the atmosphere, Faraday rotation in ionosphere, temperature and roughness (waves) of the ocean surface, and the presence of down-welling radiation from the celestial background that is reflected from the surface into the radiometer. The presence of rain and land within the antenna footprint also needs to be taken into account.

The Argentine Commission on Space Activities (CONAE) and NASA are cooperating on the Aquarius/SAC-D satellite mission scheduled for launch in 2009 onboard a Delta II launch vehicle from Vandenberg Air Force Base (VAFB) California. NASA will provide the Aquarius instrument for the mission, which will be focused on measuring global sea surface salinity, and the launch. CONAE will provide the satellite, a suite of instruments, and a mission operations component. Aquarius/SAC-D has a planned mission life of three years.

The mission will enhance the understanding of the climatic interactions between the global water cycle and ocean circulation by systematically mapping the spatial and temporal variations of sea surface salinity. Aquarius will measure sea surface salinity variability—the key tracer for freshwater input and output to the ocean associated with precipitation, evaporation, ice melting, and river runoff. These measurements, combined with sea surface temperature from other satellites, will assist in determining sea surface density, which controls the formation of water masses and regulates the three-dimensional ocean circulation. The science goals of the mission are to observe and model the processes that relate salinity variations to climatic changes in the global cycling of water in order to understand how these variations influence the general ocean circulation.

Goddard Space Flight Center (GSFC) will build and calibrate the highly accurate radiometers that are crucial for the detection of ocean salinity. Jet Propulsion Laboratory (JPL) will design and build the scatterometer that helps to minimize measurement errors due to sea surface roughness. JPL will manage the mission until launch at which time GSFC will assume this duty. Data processing, dissemination, and archiving tasks will be shared between GSFC and JPL.

Within two months, Aquarius will collect as many sea surface salinity measurements as that of the entire 125-year historical record from ships and buoys. Furthermore, measurements will be taken over the 25 percent of the ocean where previous observations have never been made.

For more information about Aquarius, please see the following URLs: *http://aquarius.gsfc.nasa.gov/and www.conae.gov.ar/eng/satelites/sac-d.html.*

ATM
Air Traffic Management

Australia

Effective Air Traffic Management (ATM) increases the safety and efficiency of civil aviation, decreases delays in airports, and minimizes safety hazards caused by planes occupying the same airspace. NASA is cooperating with Airservices Australia (AsA) in research on ATM decision support automation.

This cooperation enables NASA and AsA to engage in research and development of increasingly safer, secure, and efficient air traffic systems, and combines NASA's ATM research and development expertise and facilities with AsA's ATM testing and validating capabilities.

NASA is testing the Direct-To (D2) decision support tool, the En Route/Descent Advisor (EDA) Decision Support Tool, and Future ATM Concepts Evaluation Tool (FACET) in the Australian airspace environment. AsA is providing the operational testing environment, using AsA ATM facilities and Australian continental and oceanic airspace, for testing and validation of NASA's D2, EDA, and FACET support and evaluation tools. The D2 provides sector controllers with a tactical conflict detection/resolution tool that also advises timesaving direct routing options for aircraft within an en route air traffic control environment. The EDA advises en route controllers on efficiently merging, sequencing, and spacing en route aircraft through congested airspace under flow-rate (metering) restrictions. The FACET permits creation, recording, and playback of various definable air traffic flow and conflict scenarios, including sectorization models while providing the ability to simultaneously simulate multiple airspace constraints. NASA and AsA will cooperatively analyze and document the results of the evaluation of the tools.

NASA and AsA discuss the progress and results of this cooperation annually. Cooperation began in October 2005 and will continue until May 2008.

For more information about ATM, please see the following URL: *http://virtualskies.arc.nasa.gov/main/matm.html.*

A FACET snapshot of air traffic over the United States on July 10, 2006, at 2:45 p.m. EST.

An EDA auxiliary display

Australia

DSN
Deep Space Network

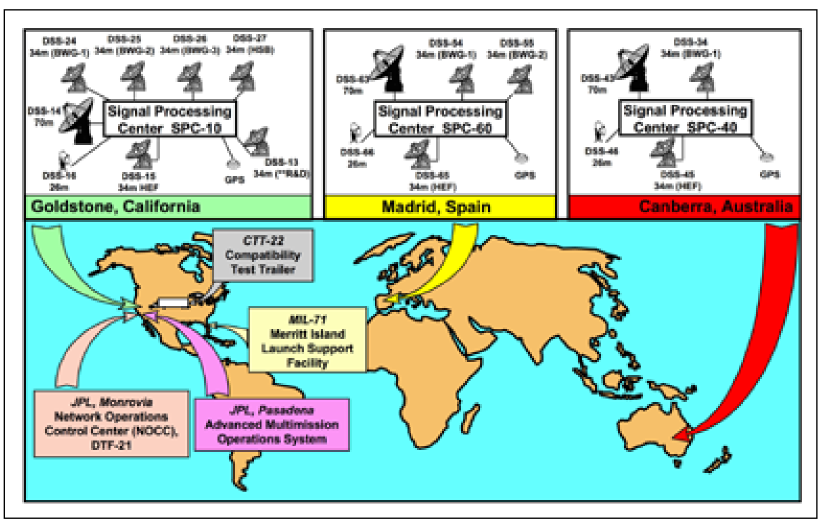
The CDSCC features a number of antennae that are required daily to receive from, and transmit information to, a wide variety of spacecraft.

The Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), on behalf of NASA, manages the Canberra Deep Space Communication Complex (CDSCC), located 40 kilometers southwest of Canberra near the Tidbinbilla Nature Reserve. The CDSCC is one of three deep space facilities that comprise NASA's Deep Space Network (DSN). The United States and Australia have engaged in DSN cooperation since the late 1950s, and the CDSCC was officially opened as a NASA DSN facility in 1965.

NASA's DSN is an international network of antennae that communicates with interplanetary spacecraft missions, is used by radio and radar astronomers to observe the solar system and the universe, and also supports selected Earth-orbiting missions. In addition, the DSN is critical to NASA's mission to explore the Moon, Mars, and beyond.

NASA's three DSN facilities are in the following locations: 1) Goldstone, in the Mojave Desert, California; 2) CDSCC, near Canberra, Australia; and 3) Madrid Deep Space Communications Complex (MDSCC), near Madrid, Spain.

These DSN facilities are located approximately 120 degrees apart around the world, which permits constant observation of spacecraft as the Earth rotates. Each location has an 8-hour to 14-hour viewing period for contact with spacecraft. The DSN provides the two-way communications link that tracks, guides, and controls the spacecraft, and returns telemetry and scientific data collected by the spacecraft. Incoming data to the three DSN facilities are processed and transmitted to NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, for further processing and distribution to science teams over a modern ground communications network.



DSN overview

Each DSN facility consists of at least four deep space stations equipped with ultra-sensitive receiving systems and large parabolic dish antennae. They are:

- 34-meter (111-foot) diameter High Efficiency antenna
- 34-meter Beam Waveguide antenna (three at Goldstone, two at Madrid, and one at Australia)
- 70-meter (230-foot) antenna
- 26-meter (85-foot) antenna

NASA periodically uses CSIRO's 64-meter antenna at Parkes Radio Astronomy Observatory in New South Wales, Australia, to augment NASA's CDSCC. In 2002, this antenna was upgraded by NASA to be compatible with future NASA deep space missions.

For more information about the DSN and CDSCC, please see the following URLs: *http://deepspace.jpl.nasa.gov/dsn/and http://www.cdscc.nasa.gov/.*

THEMIS

Time History of Events and Macroscale Interactions during Substorms

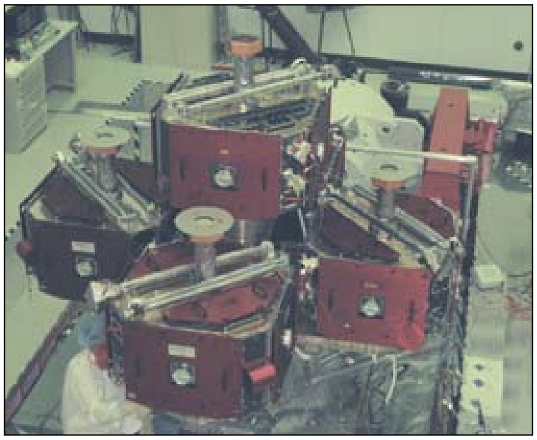
Austria

The Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission is a two-year mission consisting of five identical satellites, each with a suite of five instruments that will study the violent and colorful eruptions in auroras. The mission also incorporates a network of ground-based auroral observatories, many of which are located in Canada. These satellites, or probes, contain subsystems sponsored by the Austrian Space Agency (ASA). THEMIS was launched by NASA on a Delta II launch vehicle from the Kennedy Space Center on February 17, 2007. In addition to ASA, NASA partnered with the Canadian Space Agency, French National Centre for Space Studies, and German Aerospace Center on the mission.

One of the science objectives of THEMIS involves determining what physical processes in near-Earth space initiate the violent eruptions in the Earth's magnetosphere known as substorms. Substorms greatly intensify auroras and create the dramatic "dancing" effects witnessed in auroras. Aligning five identical probes over observatories on the North American continent will allow scientists to collect coordinated measurements along the Earth's magnetic field lines, thereby providing the first comprehensive look at the onset of substorms and the manner in which they trigger auroral eruptions.

ASA and the Space Research Institute of the Austrian Academy of Sciences developed and tested the Fluxgate Magnetometer Electronics, a subsystem of the Fluxgate Magnetometers instrument on all five probes.

For more information about THEMIS, please see the following URL: *http://www.nasa.gov/mission_pages/themis/main/index.html.*

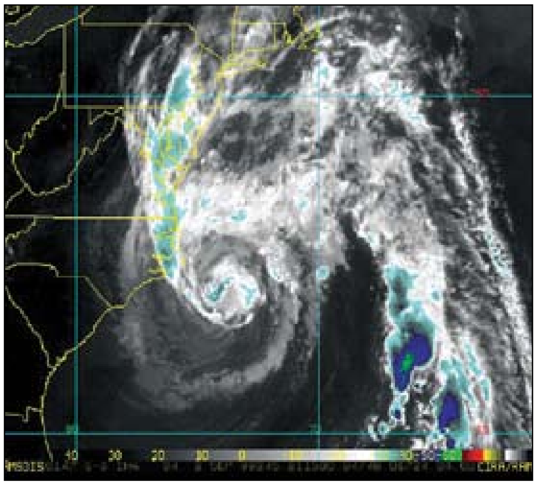


A photo of the THEMIS probes in preparation for launch at the Jet Propulsion Laboratory in California

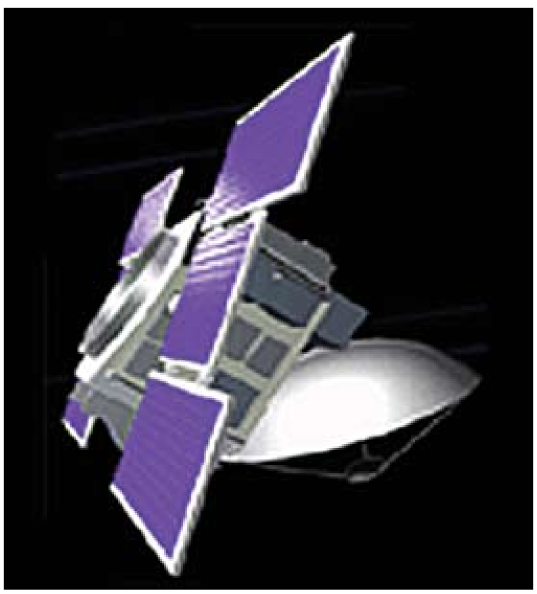
An artist concept of the THEMIS probes in orbit around the Earth

Canada

CloudSat



Existing space-based systems can only observe the uppermost layer of clouds and cannot reliably detect the presence of multiple cloud layers, nor can they determine the cloud water and ice content.



CloudSat satellite

The Canadian Space Agency (CSA) provided the Extended Interaction Klystron for the Cloud Profiling Radar for the CloudSat mission. CloudSat was launched on April 28, 2006, onboard a Delta II launch vehicle from Vandenberg Air Force Base (VAFB), California. CloudSat is an experimental satellite designed to measure the vertical structure of clouds from space. It is the first satellite to fly millimeter-wave radar that is capable of seeing a large fraction of clouds and precipitation, ranging from very thin cirrus clouds to thunderstorms producing heavy precipitation. Cloudsat has a planned mission life to exceed 22 months.

The goal of the CloudSat mission is to furnish data needed to evaluate and improve the way in which clouds are represented in global models, thereby contributing to better predictions of cloud formations and a more detailed understanding into what is currently a poor understanding of their role in both climate change and the cloud-climate feedback.

CloudSat was launched together with the French Centre for Space Studies (CNES) Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO). It is flying in orbital formation as part of a constellation of satellites, including NASA's Aqua and Aura, and CNES's Polarization and Anisotropy of Réflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL). CloudSat maintains a tight formation with CALIPSO in order to overlap measurement footprints at least 50 percent of the time. For the CloudSat mission, NASA provided overall project and mission management, as well as the implementation of the Cloud Profiling Radar instrument.

For more information about CloudSat, please see the following URL: *http://cloudsat.atmos.colostate.edu/*.

Icing Research

Canada

NASA is cooperating on in-flight icing research with the Meteorological Service of Canada (MSC), the French National Aerospace Research Center (ONERA), the Spanish National Institute of Aerospace Technology (INTA), Cranfield University in the United Kingdom, and QinetiQ Limited in the United Kingdom. Aircraft in-flight icing causes multitudes of aircraft accidents. One particular type of in-flight icing hazard, known as Supercooled Liquid Droplets (SLD), can contribute to hazardous ice buildup on unprotected aircraft surfaces, which in turn can lead to a loss of aircraft control. Significant international attention has also focused on icing cloud atmospheric characterization, and on in-situ and remote measurement instrumentation.

NASA is working with its partners from Canada, France, Spain, and the United Kingdom to collect and analyze data to develop a better understanding of the icing environment, improve ice accretion modeling techniques, and refine ice detection instrumentation and measurement systems.

Cooperative icing research includes the following collaborations:

- MSC and NASA are conducting collaborative research related to icing cloud and mixed phase (water droplet and ice crystal clouds) atmospheric definition, in-situ and remote instrumentation development, and data processing and analysis techniques. NASA and MSC are conducting flight tests and remote sensing experiments, and will jointly analyze and publish the resulting data. The collaboration began in April 2004 and will continue through December 2010.
- Collaboration with ONERA began in April 2006 and will continue through September 2008. ONERA and NASA are conducting cooperative research in iced aerodynamics and computational fluid dynamics (CFD) modeling of ice accretions. ONERA is developing a wake rake and providing access to their F-1 pressurized low-speed wind tunnel. ONERA and NASA are planning and supporting wind tunnel testing activities whose resulting data will be jointly analyzed and published.
- INTA and NASA are conducting cooperative activities related to ice-accretion physics and water-film thickness. INTA is conducting experiments whose information and results are then provided to NASA. Together, they will publish a joint report describing the research. The collaboration began in October 2004 and will continue through December 2008.
- NASA and Cranfield University began conducting cooperative research related to SLD formation and effects on aircraft surfaces in January 2004 and will continue through December 2008. They are jointly developing the models for testing, defining test plans, and conducting experiments. They will create a technical report documenting the work.
- NASA and QinetiQ are conducting cooperative research related to SLD icing physics and the development of methods for simulating SLDs in icing research facilities. QinetiQ is developing models, conducting experiments, and analyzing data. The collaboration began in September 2004 and will continue through September 2009.

For more information about icing research, please see the following URLs: *http://icebox.grc.nasa.gov/, http://www.onera.fr/dmph-en/icing/index.php, and http://www.cranfield.ac.uk/soe/ppae/ti-gti/icing_technology.htm.*

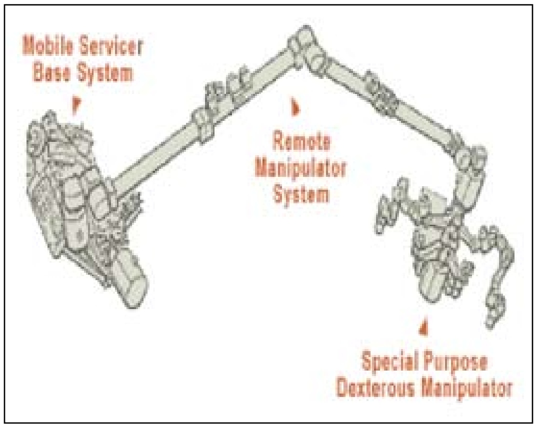
Post-flight image shows ice contamination as a result of encountering SLD conditions near Parkersburg, West Virginia.

Technicians taking measurement of ice accretions after an icing test at Glenn Research Center.

Canada

ISS

International Space Station



The three parts of the MSS, which is CSA's contribution to the ISS

STS-114 Mission Specialist Stephen Robinson attached to a foot restraint on Canadarm2

The Canadian Space Agency's (CSA) primary contribution to the International Space Station (ISS) Program is the Mobile Servicing System (MSS). CSA's MSS Operation Complex, located at CSA Headquarters in Longueuil, Quebec, supports the operation and maintenance of the MSS, and is the main facility for MSS mission planning, equipment monitoring, and training.

NASA's contributions to the ISS Program include overall management, coordination, and integration of the ISS Program, hardware components, and transportation for crew and logistics via the Space Shuttle, and, in the future, the Crew Exploration Vehicle (CEV) and commercial transportation services. Hardware components include the U.S. laboratory module, the Airlock for extravehicular activities (EVA), truss segments to support the U.S. solar arrays and thermal radiators, three connecting nodes, and living quarters.

The ISS Program is a partnership among the space agencies of Canada, Europe, Japan, Russia, and the United States to build an orbiting outpost and research facility at an altitude of approximately 400 kilometers. Construction began in November 1998, and international crews have continuously inhabited the ISS since November 2000. By the time the ISS is completed in 2010, a crew of six will be able to live and work on board, supported by a cadre of international vehicles, control centers, and ground support personnel.

The ISS functions as an orbital microgravity and life sciences laboratory, a testbed for new technologies in areas such as life support and robotics, and a platform for astronomical and Earth observations. The ISS also serves as a unique engineering testbed for flight systems and operations critical to NASA's exploration mission. U.S. research on the ISS will concentrate on the long-term effects of space travel on humans and engineering development activities in support of exploration. Hailed as the most ambitious engineering feat in human history, the ISS is a stepping stone for human exploration and scientific discovery beyond low-Earth orbit.

CSA's MSS plays a key role in both in-orbit construction of the ISS and general ISS operations. The MSS is comprised of three main elements. The Space Station Remote Manipulator System (SSRMS), called Canadarm2, which was delivered to the ISS in April 2001, is a robotic arm, 17 meters in length with seven motorized joints. The Mobile Base System, installed on the ISS in June 2002, is a moveable work platform that transports the Canadarm2 along rails covering the length of the ISS, serves as a storage facility for astronauts during space walks, and can serve as a base for both the Canadarm2 and the Special Purpose Dexterous Manipulator (Dextre) simultaneously. Finally, Dextre, scheduled for delivery to the ISS in 2008, is a smaller two-arm robot 3.5 meters in length, which can perform delicate maintenance and servicing tasks on the exterior of the ISS where precise handling is required.

For more information about CSA's contributions to the ISS, please see the following URLs: *http://www.space.gc.ca/asc/index.html and http://www.nasa. gov/mission_pages/station/main/index.html.*

JWST
James Webb Space Telescope

Canada

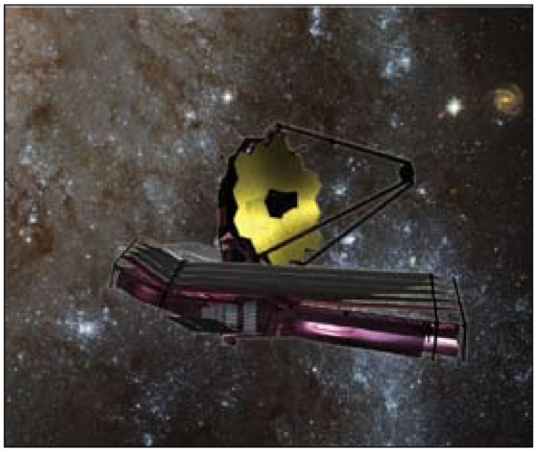
The James Webb Space Telescope (JWST) will be a large infrared telescope with a 6.5-meter primary mirror, and is planned for launch in 2013. It's goal will be to study every phase in the history of our universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems capable of supporting life on Earth-like planets, to the evolution of our own solar system. JWST is an international collaboration between NASA, the Canadian Space Agency (CSA) and the European Space Agency (ESA). CSA is providing the Fine Guidance Sensor/Tunable Filter (FGS/TF) for the telescope.

Referred to as the JWST Observatory, the space-based portion of the JWST system consists of three parts: the Optical Telescope Element (OTE), the Spacecraft Element, and the Integrated Science Instrument Module (ISIM). The OTE is the eye of the JWST, collecting light from space and providing it to scientific instruments. The Spacecraft Element is composed of the spacecraft bus (provides support functions of the observatory) and the sunshield system (separates the observatory into a warm sun-facing side and a cold anti-sun side). The ISIM contains four instruments: Mid-Infrared Instrument (MIRI), Near-Infrared Spectrograph (NIRSpec), Near-Infrared Camera (NIRCam), and the FGS/TF. JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range. It will be sensitive to light from 0.6 to 27 micrometers in wavelength.

Several innovative technologies have been developed for JWST, including a folding, segmented primary mirror adjusted to shape after launch; ultra-lightweight beryllium optics; detectors able to record extremely weak signals; microshutters that enable programmable object selection for the spectrograph; and a cryocooler for cooling the mid-IR detectors to the required 7K operating temperature. The long-lead items, such as the beryllium mirror segments and science instruments, are under construction.

The FGS will provide mission-critical support for the JWST Observatory's attitude control system. The FGS—a very broadband guider camera—is used for both "guide star" acquisition and fine pointing. Its field of view is sufficient to provide a 95 percent probability of acquiring a guide star for any valid pointing direction. The TF is a guide-field, narrow-band camera that provides imagery over a wavelength range of 1.6-4.9 micrometers

For more information about JWST, please see the following URL: *http://jwst.gsfc.nasa.gov/.*



Artist concept of the JWST in orbit

Designed to block solar light and keep the JWST Observatory operating at cryogenic temperature, the five-layer sunshield consists of thin membranes made from a polymer-based film and supporting equipment such as spreader bars, booms, cabling, and containment shells.

Canada

MOPITT/Terra

Measurements of Pollution in the Troposphere/Terra

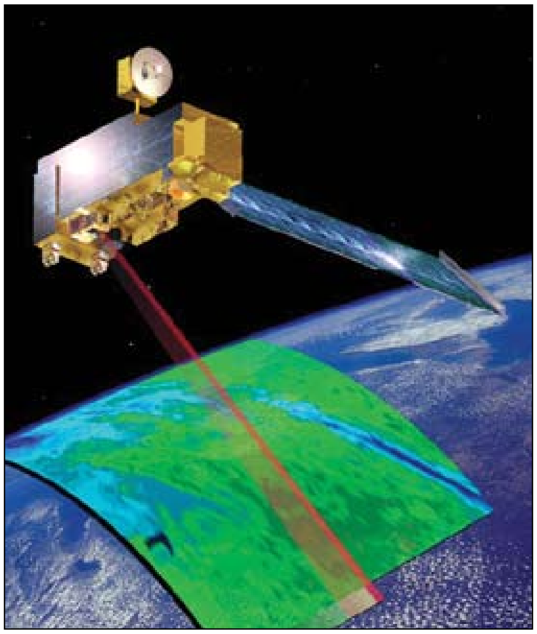


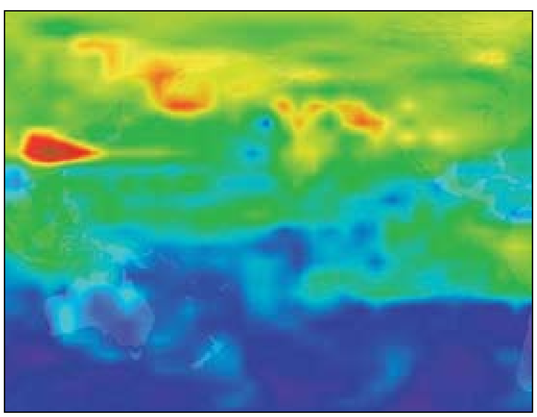
Illustration of how MOPITT scans a swath of Earth's atmosphere

The Canadian Space Agency (CSA) provided the Measurements of Pollution in the Troposphere (MOPITT) instrument on NASA's Terra satellite, which was launched on December 18, 1999, onboard a Delta II launch vehicle from Vandenberg Air Force Base, California. MOPITT measures the pollution of Earth's atmosphere from space using gas correlation spectroscopy. Terra, with a planned mission life of six years, is now operating in extended mission phase.

MOPITT is Canada's first major instrument to measure the pollution of Earth's atmosphere from space, as well as the first satellite sensor to use gas correlation spectroscopy. The sensor measures emitted and reflected radiance from Earth in three spectral bands to determine the concentration of carbon monoxide and methane. MOPITT's spatial resolution is 22 kilometers at nadir, and it views Earth in swaths that are 640 kilometers wide.

MOPITT's continuous scan of the atmosphere below it provides the world with the first long-term global measurements of carbon monoxide and methane gas levels in the atmosphere. This data, together with the other sensor measurements, will help form the first continuing integrated measurements of land, air, water, and life processes. These measurements will be used by scientists to predict the long-term effects of pollution, to understand the increase of ozone in the lower atmosphere, and to guide the evaluation and application of shorter term pollution controls.

For more information about MOPITT, please see the following URLs: *http://terra.nasa.gov, www.atmosp.physics.utoronto.ca/MOPITT/home.html, and www.eos.ucar.edu/mopitt/.*



A MOPITT image of the atmosphere over the Pacific Ocean

MSL

Mars Science Laboratory

Canada

The Canadian Space Agency (CSA) will provide the Alpha Particle X-ray Spectrometer (APXS) on the NASA 2009 Mars Science Laboratory (MSL) mission.

The MSL mission is part of NASA's Mars Exploration Program. Developed by NASA, the MSL mission consists of a long duration rover and mobile scientific laboratory equipped to perform scientific studies of Mars. NASA plans to launch MSL in the fall of 2009 from Cape Canaveral, Florida aboard an Atlas V launch vehicle with an arrival date to Mars of October 2010. The mission is planned to last at least one Martian year (687 Earth days).

The primary scientific objectives, to be carried out during the surface science phase of the MSL mission, will be to assess the biological potential of at least one target area, characterize the local geology and geochemistry, investigate planetary processes relevant to habitability (including the role of water), and to characterize the broad spectrum of surface radiation. The landing site, which has not yet been chosen, will be selected based on an assessment of safety and planetary protection, and an analysis by the scientific community.

The APXS will measure the abundance of chemical elements in rocks and soils. The instrument will be placed in contact with rock and soil samples on Mars in order to expose the material to alpha particles and x-rays emitted during the radioactive decay of the element curium. Scientists will use the APXS to help characterize and select rock and soil samples by examining the interiors of the rocks revealed through abrasion. By analyzing the elemental composition of rocks and soils, scientists hope to understand how the material first formed and if it was later altered by wind, water, or ice. Earlier versions of this APXS flew on NASA's Mars Pathfinder and Mars Exploration Rover missions.

For more information about the MSL mission and the APXS instrument, please see the following URLs: *http://mars.jpl.nasa.gov/msl/ and http://mars.jpl.nasa.gov/msl/mission/sc_instru_apxs.html.*

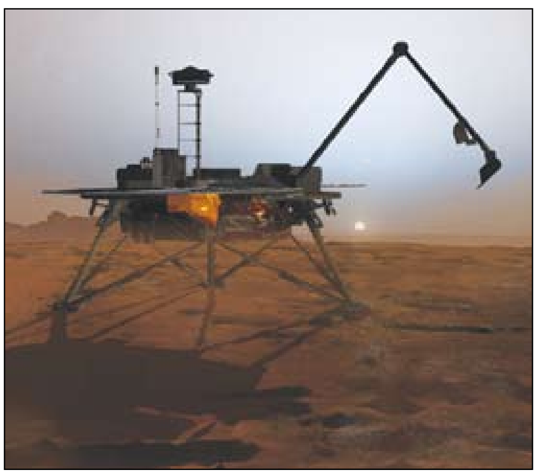
Artist concept of the MSL on the Martian surface

This image indicates the growing wheel size between the various Mars explorers: Pathfinder (left), Mars Exploration Rover, and MSL.

Canada

Phoenix

Artist concept of the Phoenix lander making its descent to the Martian surface



Artist concept of the Phoenix lander beginning work in twilight on the surface of Mars

The Phoenix mission to Mars involves a telerobotic Mars lander, and is the first in NASA's "Scout Program." The Phoenix mission is managed by the Jet Propulsion Laboratory (JPL), with international contributions by the Canadian Space Agency (CSA) and organizations in Denmark, Germany, and Switzerland. NASA provided the satellite and launch for the Phoenix mission, which launched on August 4, 2007, onboard a Delta II launch vehicle from Cape Canaveral, Florida.

Phoenix is studying the history of water and search for complex organic molecules in the ice-rich soil of the Martian arctic. Scheduled to land in May 2008 at the planet's northern polar region, Phoenix will use its robotic arm to dig through the Martian soil and reach the water ice layer underneath, then deliver soil and ice samples to the mission's experiments. Chemical analysis will be provided on the deck, and imaging systems will provide a view of Mars spanning 12 powers of 10 in scale.

The Meteorological Station (MET), built by CSA, will record the daily weather of the Martian northern plains using temperature and pressure sensors, as well as a light detection and ranging (LIDAR) instrument. MET will play a significant role by providing information on the current state of the polar atmosphere and how water is cycled between the solid and gas phases in the Martian arctic. The MET's LIDAR transmits light vertically into the atmosphere, which then reflects off dust and ice particles. By examining this distribution of dust and ice particles, scientists can infer how energy flows within the polar atmosphere—important information for understanding Martian weather. These particles also reveal the formation, duration, and movement of clouds, fog, and dust plumes, improving scientific understanding of Martian atmospheric processes.

For more information about the Phoenix mission, please see the following URLs: *http://solarsystem.nasa.gov/missions/profile.cfm?Sort=Target&Target=Mars&MCode=Phoenix and http://phoenix.lpl.arizona.edu/.*

RADARSAT-1

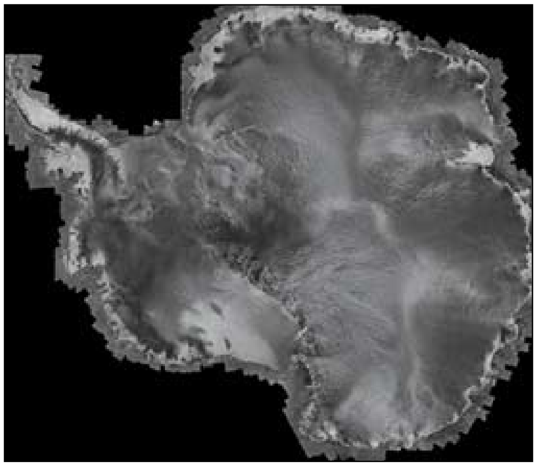
Canada

NASA and the Canadian Space Agency (CSA) continue to cooperate on the RADARSAT-1 satellite, which was launched by NASA in 1995. RADARSAT-1 is an advanced Earth observation satellite system developed by Canada to monitor environmental change and to support resource sustainability. NASA provided a downlink station at the Alaska Satellite Facility. RADARSAT-1 is equipped with a single-frequency SAR (Synthetic Aperture Radar), a powerful microwave instrument that transmits and receives signals to “see” through clouds, haze, smoke, and darkness. SAR is able to obtain high-quality images of Earth’s surface under most weather conditions, day or night.

Canada’s RADARSAT-1 satellite

With this launch, the world has gained access to the first fully operational civilian radar satellite system capable of imaging the entirety of Earth at a very high resolution. The data from the satellite meets the needs of commercial, government, and scientific programs. In addition, RADARSAT-1 provides a reliable source of high-quality radar data.

The Antarctic Mapping Mission (AMM) was conducted using the RADARSAT-1 satellite to collect radar images to produce the first high-resolution mapping of the entire continent of Antarctica. A second mission provided data suitable for interferometric studies of the motion of Antarctic glacier ice.



A RADARSAT image of Antarctica

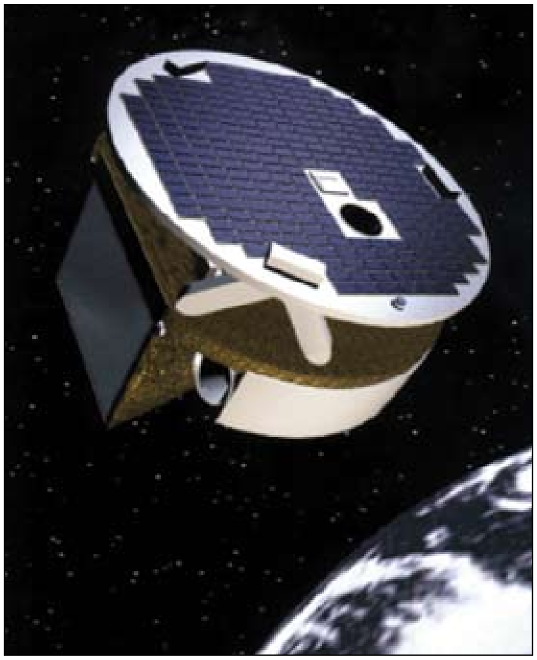
The Application Development Research Program (ADRO) promoted the scientific and technological use of data taken by RADARSAT-1. The ADRO-1 program stimulated the research community to develop new applications and operational programs that use Earth observation data derived from RADARSAT-1. Targeted projects of the ADRO-2 demonstrated the ability of RADARSAT-1 to support disaster assessment or relief efforts.

For more information about RADARSAT-1, please see the following URL: *http://www.space.gc.ca.*

Canada

SCISAT-1

SCISAT-1 Atmospheric Chemistry Experiment (ACE)



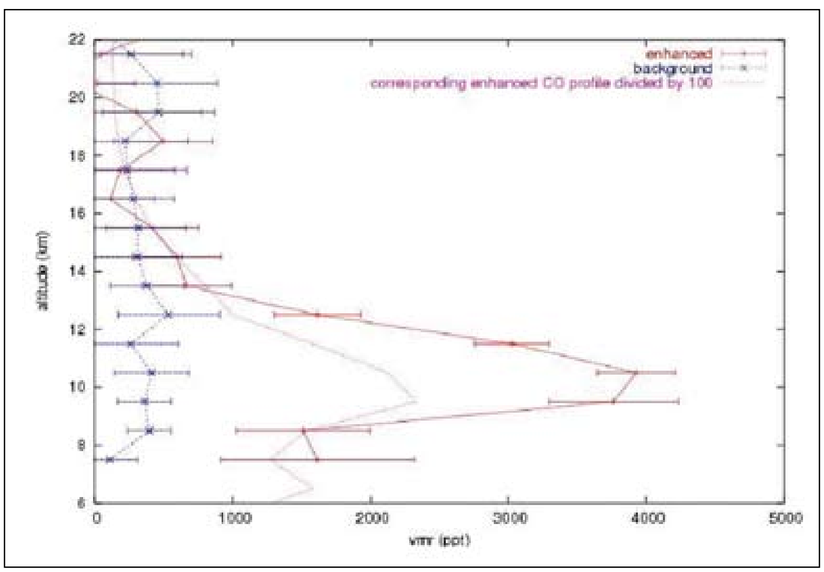
Depicted here is the SCISAT-1 satellite that carries two instruments: the ACE-FTS and the MAESTRO.

NASA and the Canadian Space Agency (CSA) continue to cooperate on the SCISAT-1 Atmospheric Chemistry Experiment (ACE) mission, which was launched on August 12, 2003, from Vandenberg Air Force Base, California. In addition to NASA's contribution of a Pegasus launch, NASA also provided expert design advice on aspects of Canada's Fourier Transform Spectrometer (FTS) instrument, along with science team support and algorithm development for analyzing the data.

The overall objective of the ACE mission is to improve understanding of the depletion of the ozone layer, with close attention to that over Canada and the Arctic. Scientists combined the measurements obtained by the FTS and the Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation (MAESTRO) instruments—also flying on SCISAT-1— with data gathered by ground-based, balloon-based, and other space-based projects in order to predict future trends relating to the chemistry of the ozone layer and its dynamics. SCISAT-1 provides near-global coverage, with observations of gas constituents, aerosols and clouds in the stratosphere, as well as observations in the troposphere. A key capability of the ACE mission—to validate measurements from NASA's Aura mission, which also measures atmospheric composition—is possible because of ACE's high accuracy and fine vertical resolution as it probes the Earth's atmosphere.

In conjunction with other NASA instruments and missions, the European Space Agency and other international partners that also probe the Earth's atmosphere, the SCISAT-1 mission provides important data to better understand the chemistry and dynamics of the atmosphere that affect Earth's protective ozone layer and their relationship to climate change.

For more information about SCISAT-1, please see the following URL: *http://www.space.gc.ca.*

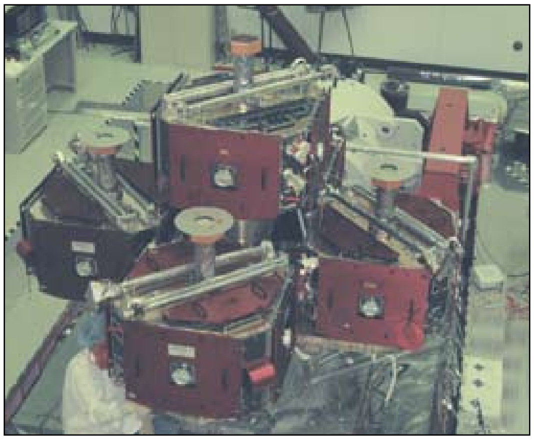


ACE is the first satellite to detect methanol, finding that it is strongly enhanced in pollution plumes produced by biomass burning. Apart from methane, methanol is the most abundant organic molecule in the atmosphere. This chart shows an altitude profile of methanol in a biomass burning plume, the corresponding enhanced profile of carbon monoxide (produced by incomplete combustion in the forest fire), and a typical background methanol profile. ACE has shown that gases from surface fires can reach the upper troposphere and then be transported intercontinental distances. (Credit: Peter Bernath)

THEMIS
Time History of Events and Macroscale Interactions during Substorms

Canada

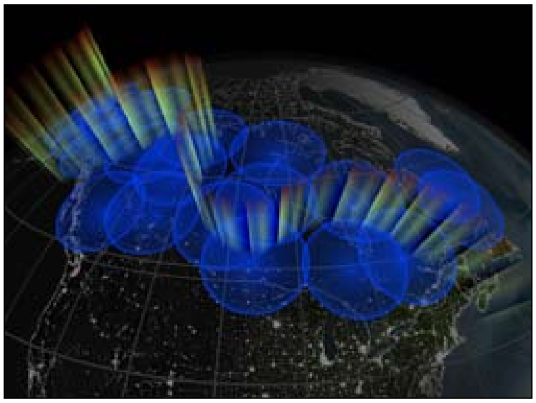
The Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission is a two-year mission consisting of five identical satellites, each with a suite of five instruments that will study the violent and colorful eruptions in auroras. The mission also incorporates a network of ground-based auroral observatories, many of which are located in Canada. These satellites, or probes, contain subsystems sponsored by the Austrian Space Agency (ASA). THEMIS was launched by NASA on a Delta II launch vehicle from the Kennedy Space Center on February 17, 2007. In addition to ASA, NASA partnered with the Canadian Space Agency, French National Centre for Space Studies, and German Aerospace Center on the mission.



A photo of the THEMIS probes in preparation for launch at the Jet Propulsion Laboratory in California

One of the science objectives of THEMIS involves determining what physical processes in near-Earth space initiate the violent eruptions in the Earth's magnetosphere known as substorms. Substorms greatly intensify auroras and create the dramatic "dancing" effects witnessed in auroras. Aligning five identical probes over observatories on the North American continent will allow scientists to collect coordinated measurements along the Earth's magnetic field lines, thereby providing the first comprehensive look at the onset of substorms and the manner in which they trigger auroral eruptions.

CSA, working with the University of Calgary, has deployed across the Arctic Circle a network of ground-based observatories (GBOs) to measure the substorms from underneath while the THEMIS satellites measure the substorms in space. CSA-sponsored activities will operate the GBO network, collect the massive amounts of data produced, and distribute the data to the THEMIS investigators.



This visualization shows the 20 THEMIS ground station locations across the Northern American continent.

For more information about THEMIS, please see the following URL: *http://www.nasa.gov/mission_pages/themis/main/index.html.*

Denmark

MER

Mars Exploration Rovers—Spirit and Oppportunity

Artist concept of a MER on the Martian surface

This image was taken by Spirit on January 15, 2004, as it rolled off its lander platform onto the Martian soil.

The Niels Bohr Institute for Astronomy, Physics, and Geophysics (NBI) of the University of Copenhagen provided the permanent magnet arrays for the Athena Payload on the Mars Exploration Rover (MER) mission. Athena is MER's science payload, consisting of a package of science instruments that includes two instruments for surveying the landing site and three instruments located on each rover's arm for close-up study of rocks. Each rover has three sets of permanent magnet arrays that work in conjunction with the science instruments and collect airborne dust for analysis. A periodic examination of this dust can reveal clues about their mineralogy and the planet's geological history.

The MER mission, involving two robotic geologists—Spirit and Opportunity—is part of NASA's Mars Exploration Program, a long-term robotic exploration of the Red Planet. Both rovers were launched aboard Delta II launch vehicles from Cape Canaveral, Florida. The first rover was launched on June 10, 2003, and landed on Mars on January 3, 2004. The second rover was launched on July 7, 2003, and landed in a different area of Mars on January 24, 2004.

Primary among the MER mission's scientific goals is to search for and characterize a wide range of rocks and soils that hold clues to past water activity. The MER mission seeks to determine where conditions may once have been favorable to life by analyzing the climate and water histories at sites on Mars. Each rover is equipped with the Athena science payload used to read the geological record at each site, investigate what role water played there, and determine how suitable the conditions would have been for life.

Spirit and Opportunity have worked on Mars for more than ten times their originally planned three-month missions, and both continue to send data downlinks to Earth. Within two months after landing on Mars in early 2004, Opportunity found geological evidence of an environment that was once wet. On October 7, 2006, Spirit set a new milestone by exploring Mars for 1,000 consecutive Martian days.

The rovers are two of five active robotic missions at Mars, including NASA's Mars Odyssey and Mars Reconnaissance orbiters and the European Space Agency's Mars Express orbiter. The orbiters and surface missions complement each other in many ways. Observations by the rovers provide ground-level understanding for interpreting global observations by the orbiters. In addition to their own science missions, the orbiters relay data from the Mars rovers.

For more information about MER, please see the following URLs: *http://marsrovers.nasa.gov/home/index.html and http://athena.cornell.edu/the_mission.*

Cassini-Huygens

Cassini-Huygens—a joint mission by NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI), to explore Saturn, Titan, and the other moons of the Saturnian system—has two distinct elements: ESA's Huygens Probe and NASA's Cassini orbiter. ASI provided the High-Gain Antenna for the Cassini orbiter. In addition, scientists from the United States and Europe contributed to and participated in the science teams that designed and developed several of the scientific instruments for Cassini and the Huygens Probe.

The Cassini-Huygens mission was launched on October 15, 1997, onboard a Titan IVB-Centaur from Cape Canaveral, Florida. In July 2004, seven years after launch, the Cassini-Huygens spacecraft entered the Saturnian system and began its four-year mission of making 75 orbits around Saturn and its moons. On December 25, 2004, the Huygens probe was jettisoned from the Cassini orbiter and successfully completed its 20-day mission to enter the atmosphere and land on the surface of Titan.

Cassini-Huygens is a three-axis stabilized spacecraft equipped to thoroughly investigate all the important elements of Saturn, its rings, and its orbiting moons. The Huygens Probe explored the atmosphere and surface of Titan. The Cassini orbiter has 12 scientific instruments, and the Huygens probe had six scientific instruments.

Additionally, the following European space entities cooperated with NASA on Cassini's scientific instruments and two of the Huygens scientific instruments, either through provision of hardware or sponsorship of scientists on instrument science teams with responsibility for design, development, testing, integration, and post-launch operation of the instruments:

- Austrian Space Agency
- British National Space Centre
- British Science and Engineering Research Council
- Technical Research Centre of Finland
- University of Oulu, Finland
- French National Centre for Space Studies
- German Aerospace Center
- Technical University of Braunschweig, Germany
- Hungarian Space Office
- Norwegian Space Centre
- Swedish National Space Board

A total of seventeen nations contributed to building Cassini-Huygens, and nearly 300 scientists from the United States and Europe study the several gigabytes of data generated by the spacecraft on a daily basis.

For more information about the Huygens Probe and the Cassini-Huygens mission, please see the following URLs: *http://www.esa.int/SPECIALS/Cassini-Huygens, http://saturn.jpl.nasa.gov/, and http://www.nasa.gov/cassini.*

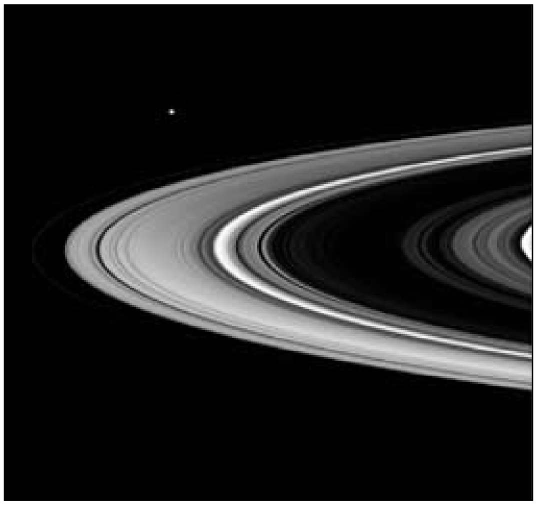
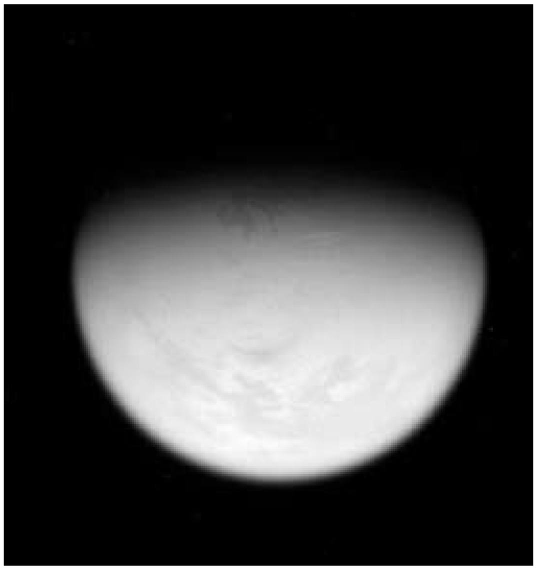


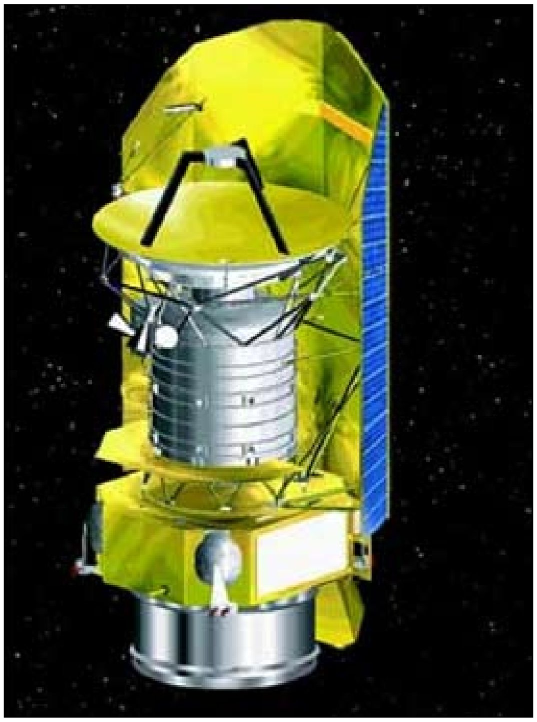
Photo of Saturn's rings taken by Cassini during a ring plane crossing, an event that occurs twice during every orbit



An image of Saturn's moon Titan, taken by Cassini, indicates the presence of a large lake-like feature in Titan's North Polar Region.

Europe

Herschel

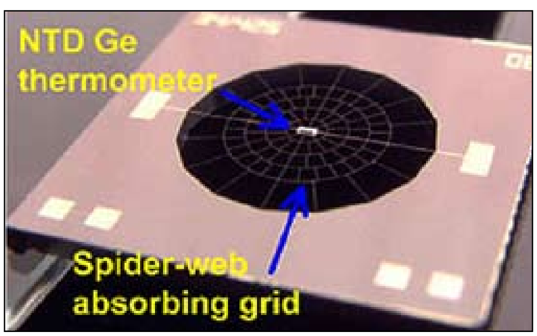


Artist concept of the Herschel Space Observatory in orbit

The Herschel Space Observatory is a space-based telescope that will use the light of the far-infrared and submillimeter portions of the spectrum to study the universe. It is expected to reveal new information about the earliest, most distant stars and galaxies, as well as those closer to home in space and time. Herschel will contain the largest mirror ever built for a space telescope. Hershel is also the fourth cornerstone mission in the European Space Agency's (ESA) Horizon 2000 program.

Led by ESA, the Hershel mission is planned for launch in 2008 on an Ariane-5 rocket from Kourou, French Guiana. ESA's Planck spacecraft will also launch aboard the same rocket, and the two spacecraft will share the same 4-month journey to independently enter their orbits between the Sun and the Earth. ESA, the Space Research Organization Netherlands (SRON), and the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom are providing support for many of the instruments aboard Herschel. The observatory is expected to remain active for at least three years.

The telescope will focus light onto three instruments: the Spectral and Photometric Imaging Receiver (SPIRE), the Heterodyne Instrument for the Far-Infrared (HIFI), and the Photoconductor Array Camera and Spectrometer (PACS). SPIRE has two main components: a low-to-medium resolution spectrometer and a photometer. It will detect protons directly through a web-like bolometer—an instrument that can detect very small amounts of energy and convert these to electrical signals. The PPARC is providing the majority of the design, development, and calibration of the SPIRE instrument. HIFI is a very high resolution heterodyne spectrometer. Rather than producing pictures of stars and galaxies, HIFI will provide extremely detailed spectra of their atoms and molecules. SRON is providing a majority of the support to the HIFI instrument.



Through the Jet Propulsion Laboratory, NASA is contributing key technology to two of Herschel's three detector instruments: SPIRE (pictured above) and HIFI.

One of the main instrument contributions of ESA is the PACS instrument, a photometer and medium resolution spectrometer. PACS will observe wavelengths from 60 to 210 microns, a range optimal for studying young, distant, dusty, star-forming galaxies. Overall, PACS combines the photometric sensitivity needed to survey over a large dynamic range with the spectroscopic sensitivity and resolution needed to identify and characterize the discovered objects.

For more information about the Herschel Space Observatory, please see the following URLs: *http://herschel.jpl.nasa.gov/index.shtml and http://sci.esa.int/science-e/www/area/index.cfm?fareaid=16.*

Mars Express

Europe

Mars Express, named because of the rapid and streamlined development time, marks the European Space Agency's (ESA) first visit to another planet in the solar system. Borrowing technology from the failed Russia Mars 96 mission and ESA's Rosetta mission, Mars Express is helping to answer fundamental questions about the geology, atmosphere, surface environment, history of water, and potential for life on Mars.

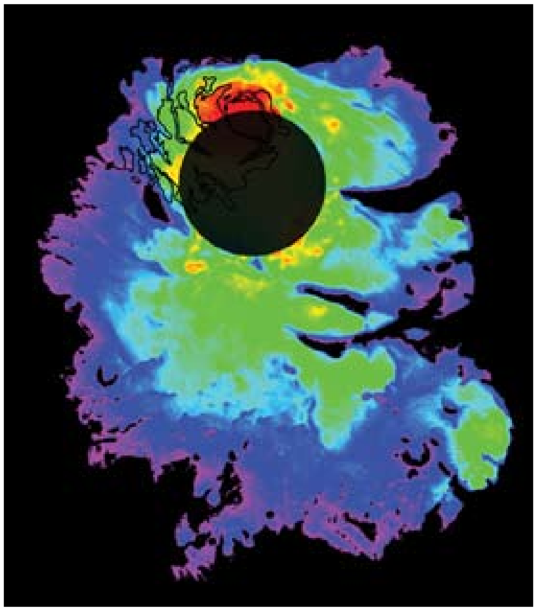
The ESA-led Mars Express mission was launched on June 2, 2003, aboard a Soyuz-Fregat launch vehicle. The mission consists of an orbiter with seven experiments and a lander called Beagle 2. The orbiter has been a huge scientific success since it entered orbit in December 2003, including recently having its second mission extension approved to carry it through May 2009. Once released from the orbiter, the Beagle 2 lander was never heard from again, but its loss has not discouraged ESA from planning for future attempts to land on Mars.

Working with ESA, NASA provided scientific and engineering support to the mission as a whole, as well as significant deep space network communications coverage for the mission. NASA also participated bilaterally on each of the seven experiments on the orbiter, as well as on the Beagle 2 lander. For the orbiter, NASA's main hardware contributions involved the joint development of the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) instrument with the Italian Space Agency (ASI) and the Analyzer of Space Plasmas and Energetic Atoms version 3 (ASPERA-3) instrument with the Swedish Institute of Space Physics. NASA also contributed to the following instruments: the German Aerospace Center-provided High Resolution Stereo Camera (HRSC) and Mars Radio Science Experiment (MaRS); the ASI-provided Planetary Fourier Spectrometer (PFS); and the French National Centre for Space Studies-provided Visible and Infrared Mineralogical Mapping Spectrometer (OMEGA) and Ultraviolet and Infrared Mars Atmospheric Spectrometer (SPICAM).

Mars Express is revolutionizing our view of the Red Planet. The MARSIS instrument recently made new measurements of Mars' south polar region that may indicate the presence of extensive frozen water—enough to cover the whole planet in a liquid layer approximately 11 meters (36 feet) deep. MARSIS also found evidence of buried impact basins ranging in diameter from about 130 kilometer to 470 kilometer over 14 percent of the northern lowlands. The SPICAM instrument discovered an aurora around Mars, and the OMEGA instrument observed that the polar caps on Mars consist chiefly of CO_2 and exhibit seasonal variations in their coverage.

For more information about ESA's Mars Express mission, please see the following URLs: *http://www.esa.int/SPECIALS/Mars_Express/index.html and http://mars.jpl.nasa.gov/express/.*

Artist concept of the Mars Express in orbit around the Red Planet

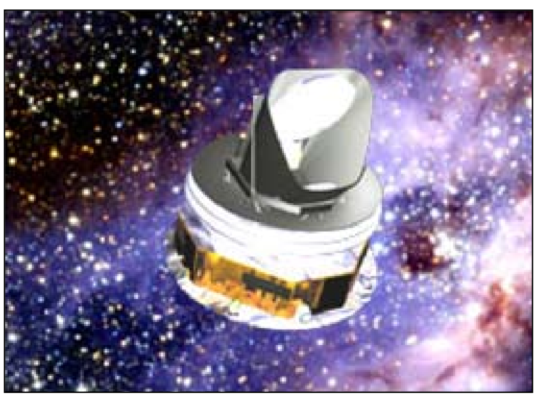


This map shows the thickness of layered deposits at the south polar of Mars, an ice-rich geologic unit that was probed by MARSIS.

Europe

Planck

Planck is the third Medium-Sized Mission of ESA's Horizon 2000 Scientific Program. The spacecraft will take 6 months to reach the L2 Lagrange point from where it will map the full sky in another 6 months.



Artist concept of the Planck spacecraft

Scheduled for launch in 2008, the Planck spacecraft will measure both minute temperature fluctuations and the polarization of the Cosmic Microwave Background (CMB), which will lead to a better understanding of the large-scale structure and history of the universe. Planck will be the third space satellite to measure the CMB across nearly the full sky, following the highly successful Cosmic Background Explorer and Wilkinson Microwave Anisotropy Probe missions. With its improved precision, Planck will extract essentially all of the cosmological information contained within the temperature map of the CMB. In addition, its map of the CMB polarization will provide further insights into the evolution of the universe.

The Planck mission is a product of international cooperation between NASA, the European Space Agency (ESA), the French National Center for Space Studies (CNES), the Italian Space Agency (ASI), and the Particle Physics and Astronomy Research Council (PPARC) in the United Kingdom. Planck will be launched with the Herschel spacecraft aboard an Ariane-5 rocket from the Guiana Space Centre in Kourou, French Guiana, and is scheduled to have a mission lifetime of 21 months. The Planck spacecraft consists of the telescope and two instruments—the High Frequency Instrument (HFI) and the Low Frequency Instrument (LFI)—which will measure neighboring bands of the CMB spectrum.

CNES, NASA, and PPARC are the primary collaborators on the design, construction, and integration of the HFI. ASI, NASA, PPARC, and the Finland National Technology Agency are the principal parties in the construction and integration of the LFI. In addition to the launch, ESA (with the Danish Space Research Institute) is providing the telescope for the Planck spacecraft. Most of the other ESA member nations are also providing contributions to Plank.

For more information about the Planck mission, please visit the following URL: *http://sci.esa.int/planck.*

STEREO
Solar TErrestrial Relations Observatory

Europe

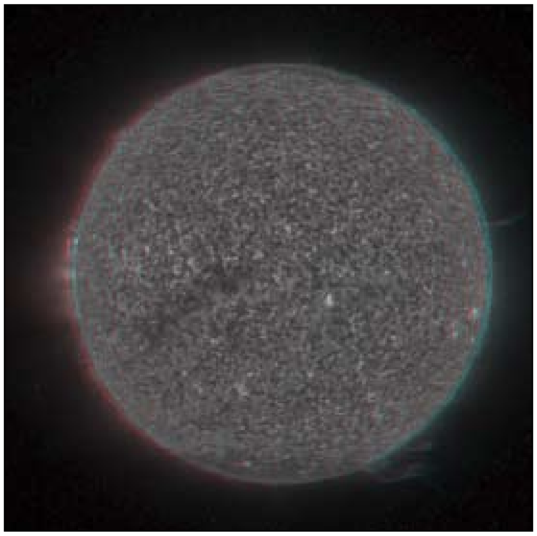
STEREO (Solar TErrestrial RElations Observatory) is a two-year mission to provide a unique and revolutionary view of the Sun-Earth System. The STEREO observatories have been returning data and images since December 2006. The European Space Agency (ESA), French Centre for Space Studies (CNES), German Aerospace Center (DLR), Hungarian Space Office (HSO), Swiss Space Office (SSO), and the Particle Physics and Astronomy Research Council (PPARC), United Kingdom, are all providing support for this mission. The STEREO observatories were launched from Kennedy Space Center on October 25, 2006, aboard a Delta II launch vehicle.


An artist concept drawing shows a coronal mass ejection sweeping past one of the STEREO satellite observatories.

The two nearly identical spacecraft observatories—one ahead of Earth in its solar orbit, the other trailing behind—will trace the flow of energy and matter from the Sun to Earth. They will also reveal the three-dimensional structure of coronal mass ejections (CME), helping us understand why they happen. CMEs travel away from the Sun at speeds of approximately one million mph (1.6 million kph). Furthermore, they can create major disturbances in the interplanetary medium and trigger severe magnetic storms when they collide with Earth's magnetosphere. The new information from STEREO will greatly improve the ability to forecast the arrival time of severe space weather.

Each spacecraft has four suites of instruments—three led by U.S. scientists and one led by the French.

- STEREO/WAVES (SWAVES) is an interplanetary radio burst tracker that will trace the generation and evolution of traveling radio disturbances from the Sun to the orbit of Earth. CNES is sponsoring the Principal Investigator and provided this instrument suite.
- In-situ Measurements of Particles and CME Transients (IMPACT) will sample the three-dimensional distribution of these solar energetic particles. Provide plasma characteristics of them, and measure the local vector magnetic field. ESA, CNES, DLR, HSO, and SSO contributed to IMPACT.
- Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI)—consisting of an extreme ultraviolet imager, two white-light coronagraphs, and a heliospheric imager—will study the three-dimensional evolution of CMEs from birth at the Sun's surface through the corona and interplanetary medium to its eventual impact at Earth. CNES, DLR, and PPARC contributed to SECCHI.
- PLAsma and SupraThermal Ion Composition (PLASTIC) will provide key diagnostic measurements on the form of mass and charge state composition of heavy ions and characterize the CME plasma from ambient coronal plasma. DLR, HSO, and SSO contributed to PLASTIC.


NASA's STEREO satellites have provided the first three-dimensional images of the Sun. This new view will greatly enhance scientific understanding solar physics, thereby improving space weather forecasting. To view this correctly, you must have three-dimensional glasses.

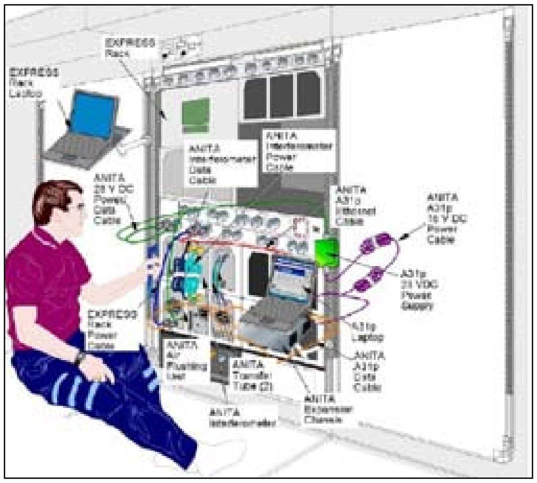
With the second lunar swing-by of the Behind spacecraft on January 22, 2007, the STEREO mission entered into the main science phase of the mission. The two spacecraft have now escaped from Earth orbit and are in orbit around the Sun. On April 23, 2007, the SECCHI team released the first three-dimensional views of the Sun.

For more information about STEREO, please see the following URL: *http://www.nasa.gov/stereo.*

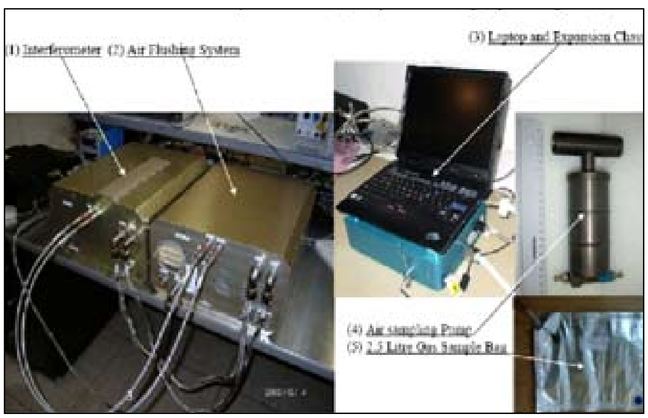
European Space Agency

ANITA

Analyzing Interferometer for Ambient Air



The diagram above depicts the placement of the ANITA components in the EXPRESS Rack.



Pictured above are the different components used in the ANITA experiment.

The Analyzing Interferometer for Ambient Air (ANITA) experiment will be the first of its kind to optically monitor the air within the International Space Station (ISS) for 32 potentially gaseous contaminants. With a Principal Investigator at the European Space Research and Technology Center, in Noordwijk, the Netherlands, and development by the European Space Agency (ESA), ANITA represents an important European contribution to crew health and safety in space. ANITA launched to the ISS onboard the STS-118 mission. NASA's contribution to this cooperation included launch of ANITA to the ISS, integration of ANITA into the U.S. Destiny Laboratory, and operation of ANITA on board the ISS.

ANITA will remain in orbit for six months, with an initial commissioning and science phase of ten days known as the "Baseline Experiment." After completing the Baseline Experiment, ANITA will continue to operate onboard the ISS for a period of six months for the "Extended Experiment" in which ANITA will collect additional baseline data and aid in further developmental activities.

The experiment is a trace gas optical monitoring system based on Fourier Transform Infrared (FTIR) technology. The initial flight of ANITA will test the accuracy and reliability of the FTIR technology as a potential next- generation atmosphere trace gas monitoring system for the ISS. The FTIR is calibrated to detect low parts per million levels in the cabin atmosphere—everything from formaldehyde to ammonia and carbon monoxide.

ANITA consists of two ISS locker-sized units, the Air Flushing Unit and the Interferometer, which will be installed into pre-integrated lockers in a continuously powered EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Rack in the U.S. Destiny Laboratory. ANITA also requires a dedicated experiment laptop, Expansion Chassis, Personal Computer Memory Card International Association (PCMCIA) cards, and an Ultrabay adapter with Hard Drive. The software load on the ANITA hard drive allows the operator to initiate continuous measurements following hardware setup. An ANITA kit will also contain the hardware required to collect samples from different locations on the ISS.

ANITA not only provides rapid detection of air quality, but also allows immediate initiation of countermeasures to mitigate the air contamination. On Earth, the ANITA application of FTIR technology provides an improved multi-component gas measurement system for purposes like workplace monitoring (including airplanes and submarines), environmental monitoring, and control of industrial processes.

For more information on ANITA, please see the following URL: *http://exploration.nasa.gov/programs/station/ANITA.html.*

European Space Agency

Cluster

Composed of a fleet of four identical satellites, the Cluster mission is designed to provide details of how particles from the Sun interact with the magnetic field of the Earth. Launched aboard two Russian Soyuz-Fregat rockets, the first two satellites were launched on July 16, 2000, and the second two satellites were launched on August 9, 2000. The mission is expected to be operational through the end of 2009. The Cluster mission is one of six current cooperative heliophysics projects between the European Space Agency (ESA) and NASA.

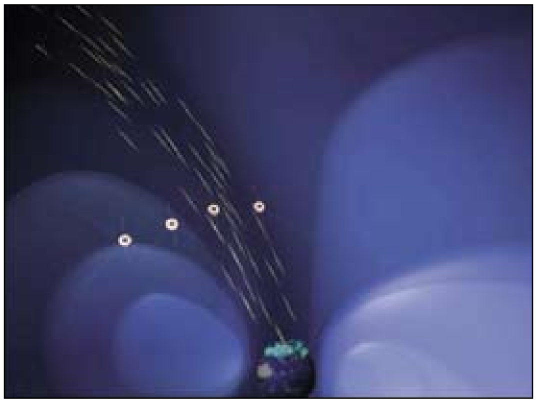
After being launched into an elliptical polar orbit, the four Cluster satellites have taken measurements of the Earth's magnetic field and high altitude particle environment. Each spacecraft carries an identical suite of 11 scientific instruments, and the cluster of satellites are positioned in orbit to form the four points of a pyramid. This arrangement allows for the collection of data to generate three-dimensional structures in both the magnetosphere and solar wind.

As a cooperative science project, ESA and NASA are working closely together throughout the mission. ESA is providing the management of the satellites and the science operations, while NASA-sponsored investigators are participating in the operation of the scientific instruments, data processing, and analyses of Cluster's scientific data.

On December 29, 2006, the four Cluster satellites completed their 1,000th orbit around the Earth. Since being launched, the Cluster mission has provided a detailed three-dimensional map of the magnetosphere. Additionally, the data has been used to study magnetic reconnection—a physical process that can cause the ejection of solar plasma jets towards Earth, affecting Global Positioning System and radio communications. On a grander scale, magnetic reconnection plays an important role in star formations and solar explosions; understanding the phenomena in our own backyard can lead to insights in the larger systems.

For more information about the Cluster mission, please see the following URL: *http://sci.esa.int/science-e/www/area/index.cfm?fareaid=8.*

An artist concept image of the Cluster satellites (Credit: ESA)



This image shows Cluster probing the sources of aurorae. (Credit: ESA)

European Space Agency

HST
Hubble Space Telescope

This 1995 photo of eerie, dark pillar-like structures has appeared on magazine covers, postcards, and computer desktops worldwide. The pillars are actually columns of cool interstellar hydrogen gas and dust that serve as incubators for new stars.

This photo of the HST was taken from Space Shuttle Columbia in 2002 during the STS-109 mission.

The European Space Agency (ESA) joined NASA in developing the Hubble Space Telescope (HST) in 1977. HST was launched aboard the Space Shuttle on April 24, 1990, and was deployed into low-Earth orbit the following day. ESA provided the Faint Object Camera (FOC), an instrument for high resolution imagery in the ultraviolet, visual, and near infrared portions of the spectrum. ESA also provided the two 12-meter solar arrays to provide power for HST that were originally launched with it. The solar arrays convert the Sun's energy into electricity, which runs the telescope's scientific instruments, computers, and radio transmitters. ESA also provided the second set of solar arrays that replaced the first set. These were installed during Servicing Mission 1 in December 1993, and operated for over eight years. The second solar arrays were replaced with more robust solar arrays during Servicing Mission 3B in March 2002.

ESA was represented on the HST Science Working Group, which was the principal mechanism for scientific input to the HST Project Office during the development of HST. ESA provided post-launch operational support, with experts located at the HST Project Office and the science operations facility. European astronomers receive approximately 15 percent of HST viewing time.

Over its 16-year history, HST has completed the following:

- taken many hundreds of images that have expanded our knowledge of the universe
- enabled the image of the face-on spiral galaxy, Messier 101 (M101), which is the largest and most detailed photo of a spiral galaxy ever released. The M101 galaxy is 170,000 light-years across, or nearly twice the diameter of the Milky Way, and is estimated to contain at least one trillion stars
- completed an eight-year effort measuring the expansion of the universe. with a preliminary result that, if confirmed, will be one of the most important scientific discoveries of our time—that universe is expanding at an accelerating rate and driven by an unknown force
- provided convincing proof of a black hole several billion times the mass of the Sun in the early 90s, and found evidence that supermassive black holes are at the core of most, if not all, galaxies
- discovered 16 extrasolar planet candidates orbiting a variety of distant stars in the central region of our Milky Way galaxy
- confirmed the presence of two moons around the distant planet Pluto
- captured the best view of Mars ever obtained from Earth with details as small as 10 miles across

For more information about HST, please see the following URLs: *http:/hubble.nasa.gov and http://www.spacetelescope.org/about/index.html.*

INTEGRAL

The International Gamma-Ray Astrophysics Laboratory

From the International Gamma-Ray Astrophysics Laboratory (INTEGRAL) launched in October 2002 aboard a Russian Proton rocket, new insight is arising into the most violent and exotic objects of the universe, such as neutron stars, active galactic nuclei, and supernovae. INTEGRAL is also producing data on processes such as the formation of new chemical elements and the mysterious bursts of gamma rays—the most energetic phenomena in the universe.

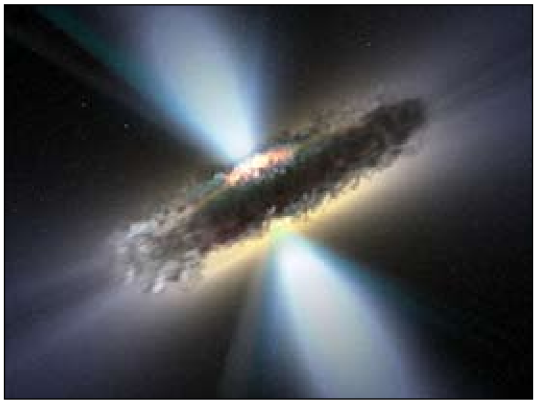
A project of the European Space Agency (ESA), INTEGRAL is an example of international cooperation. Scientists from ESA member countries led the development and implementation of all four of INTEGRAL's instruments. ESA also provides ground stations while NASA provides Deep Space Network (DSN) support from its DSN Goldstone station to track and keep in contact with the INTEGRAL spacecraft.

INTEGRAL consists of four main instruments: the Spectrometer on INTEGRAL (SPI), Imager on Board the INTEGRAL Satellite (IBIS), the Joint European X-ray Monitor (JEM-X), and the Optical Monitoring Camera (OMC). The SPI performs spectral analysis of gamma-ray point sources and extended regions, while the IBIS provides diagnostic capabilities of fine imaging, source identification, and spectral sensitivity. The JEM-X supplements the main INTEGRAL instruments (the SPI and IBIS) and plays a crucial role in the detection and identification of the gamma-ray sources and in the analysis and scientific interpretation of gamma-ray data. The OMC consists of a passively cooled charge-coupled device (2048 by 1024 pixels, imaging area: 1024 by 1024 pixels) tasked with recording the optical emissions from the target subjects.

INTEGRAL continues to fly smoothly and return data from its orbit 40,000 kilometers above Earth and completed its fifth year in orbit in October 2007.

For more information about INTEGRAL, please see the following URLs: *http://integral.gsfc.nasa.gov/ and http://www.esa.int/SPECIALS/Integral/SEME2V0XDYD_0.html.*

Artist concept of the INTEGRAL spacecraft (Credit: ESA)



The picture shows an artist rendering of a dust torus surrounding a supermassive black hole and an accretion disk. In this case, the thick torus will block the optical light emitted from the center, but hard x-rays and gamma-rays will mostly be able to pass through the torus. (Credit: ESA)

European Space Agency

ISS
International Space Station

Columbus is a multifunctional pressurized laboratory to carry out experiments in materials science, fluid physics, and biosciences, as well as to perform technological applications.

The ATV is an autonomous logistical resupply vehicle designed to dock to the ISS and provide the crew with dry cargo, atmospheric gas, water, and propellant.

The European Space Agency's (ESA) primary contributions to the International Space Station (ISS) Program are the Columbus Research Laboratory, Nodes 2 and 3, the Automated Transfer Vehicle (ATV), the Cupola, and the European Robotic Arm (ERA).

NASA's contributions to the ISS Program include overall management, coordination, and integration of the ISS Program, hardware components, and transportation for crew and logistics via the Space Shuttle, and, in the future, the Crew Exploration Vehicle (CEV) and commercial transportation services. Hardware components include the U.S. laboratory module, the Airlock for extravehicular activities (EVA), truss segments to support the U.S. solar arrays and thermal radiators, three connecting nodes, and living quarters.

The ISS Program is a partnership among the space agencies of Canada, Europe, Japan, Russia and the United States to build an orbiting outpost and research facility at an altitude of approximately 400 kilometers. Construction began in November 1998, and international crews have continuously inhabited the ISS since November 2000. By the time the ISS is completed in 2010, a crew of six will be able to live and work on board, supported by a cadre of international vehicles, control centers and ground support personnel.

The ISS functions as an orbital microgravity and life sciences laboratory, a testbed for new technologies in areas such as life support and robotics, and a platform for astronomical and Earth observations. The ISS also serves as a unique engineering testbed for flight systems and operations critical to NASA's exploration mission. U.S. research on the ISS will concentrate on the long-term effects of space travel on humans and engineering development activities in support of exploration. Hailed as the most ambitious engineering feat in human history, the ISS is a stepping stone for human exploration and scientific discovery beyond low-Earth orbit.

ESA's Columbus Research Laboratory, currently scheduled to launch on the Space Shuttle to the ISS in 2008, is a multifunctional pressurized laboratory that will house one-third of the ISS research facilities for experiments in life and materials science, fluid physics, and biosciences, as well as technological applications. Node 2, built by ESA for NASA and launched to the ISS in 2007, connects the U.S., European, and Japanese laboratories and provides utilities essential to support life on the ISS. Node 3, still in development, will be attached to the U.S.-provided Node 1 and provide additional habitation functions.

ESA's ATV is a logistical resupply vehicle designed to dock to the ISS and provide dry cargo, atmospheric gas, water, and propellant. The ATV is scheduled to make its inaugural flight to the ISS atop an Ariane 5 to the ISS in 2008. ESA will provide five ATVs for the ISS.

The Cupola, also built for NASA, is a pressurized observation and control tower for the ISS with windows that provide a panoramic view through which crew members can observe and guide operations on the outside of the ISS. The launch of Cupola to the ISS is currently planned for 2010.

For more information about the ISS and ESA's contributions, please see the following URLs: *http://www.nasa.gov/mission_pages/station/structure/elements/, http://www.esa.int/esa HS/index.html, and http://www.nasa.gov/mission_pages/station/main/index.html.*

European Space Agency

ISS Early Utilization

International Space Station Early Utilization

Recognizing the mutual NASA and European Space Agency (ESA) interest in International Space Station (ISS) utilization during early phases of the program, the agencies initiated cooperative activities to ensure early research opportunities. This cooperation permits the location and operation of hardware and experiments in the U.S. Laboratory Module (Destiny) prior to delivery of the European Columbus Research Laboratory. It also provides flight opportunities for two ESA astronauts. ESA contributed a broad range of hardware, including the Microgravity Science Glovebox (MSG), Minus 80C Laboratory Freezer for ISS (MELFI), and the European Modular Cultivation System (EMCS).

The MSG is a sealed container with built-in gloves and provides an enclosed workspace for investigations conducted in the unique microgravity environment of the ISS. It was launched on STS-111 and will be relocated to the Columbus Laboratory. It provides a safe environment for research with liquids, flames, and particles used as a part of everyday research in ground-based facilities on Earth. Without the MSG, many types of hands-on investigations on the ISS would be impossible or severely restricted.

The MELFI was launched on STS-121. It is a rack-size facility designed to provide the ISS with refrigerated volume for the storage and fast freezing of life science and biological samples.

The EMCS was also launched on STS-121. It is a combination centrifuge/growth chamber, and is designed to carry out plant growth experiments in controlled partial gravity and microgravity conditions. EMCS experiments contribute to food production research that may benefit astronauts on long-term missions, such as that of an expedition to Mars. These experiments can also be used for research on insects, amphibians, and invertebrates, as well as studies with cell and tissue cultures. Furthermore, plant cell root and physiology experiments can provide knowledge about the growth processes in plants with the potential of improving food production techniques in space and on the Earth.

Also intended for the Destiny Laboratory, the Materials Science Research Rack-1 (MSRR-1) is the primary facility for U.S.-sponsored materials science research on the ISS, contained in an International Standard Payload Rack (ISPR) equipped with the Active Rack Isolation System (ARIS) for the best possible microgravity environment. The MSRR-1 will accommodate dual experiment modules and provide simultaneous on-orbit processing operations capability. The first integral experiment module for the MSRR-1, the Materials Science Laboratory, is also a cooperative activity between NASA and ESA.

For more information, please see the European Users Guide to Low Gravity Platforms at the following URL: *http://www.spaceflight.esa.int/users/index.htm.*

Mary Etta Wright, the MSG Integration and Test Engineer at NASA Marshall Space Flight Center's Microgravity Development Laboratory, demonstrates the roomy interior of the MSG.

Astronaut Michael E. Lopez-Alegria, Expedition 14 commander and NASA ISS science officer, performs the EMCS experiment container replacement in the Destiny Laboratory of the ISS.

European Space Agency

ISS HRF-EPM

ISS Human Research Facility-European Physiology Module

Astronaut Donald R. Pettit, Expedition Six NASA ISS science officer, works to set up pulmonary function inflight hardware in preparation for an HRF experiment in the ISS Destiny Laboratory.

Astronaut William S. McArthur, Jr.—Expedition 12 commander and NASA ISS science officer—and cosmonaut Valery I. Tokarev—ISS flight engineer representing the Russian Federal Space Agency—participate in HRF Rack Percutaneous Electrical Muscle Stimulator 2 training in the ISS Destiny Laboratory mockup/trainer at NASA Johnson Space Center.

The European Space Agency (ESA) and NASA are cooperating on the ESA European Physiology Module (EPM) and the NASA Human Research Facility (HRF). ESA is providing the EPM, a single-rack multi-user facility launched on STS-122 for the Columbus Laboratory on the International Space Station (ISS). The Columbus Laboratory module is ESA's most-significant contribution to the ISS.

The EPM and other components will support neuroscience research, as well as investigations of respiratory and cardiovascular conditions, hormonal and body fluid shift, and bone demineralization. The experiment results will also contribute to researchers' knowledge of terrestrial health problems, such as the aging process, osteoporosis, balance disorders, and muscle wastage.

Built in Bremen, Germany, the EPM contains the following containers for science experiments: ESA's Multi-Electrode Electroencephalography Module for neurologic scans of the brain, ESA's Samples Collection Kit for collection of different medical instruments and boxes for biologic probes and the German/French Cardiolab for scanning of the cardiovascular system. The EPM has a potential lifespan of ten years.

NASA's HRF in conjunction with the EPM will support the needs of the science community by providing the instrumentation and capabilities needed to collect and distribute data gained through human life science research in space. NASA and ESA have reviewed each other's plans for development of research hardware to minimize duplication and reduce costs, while establishing a research capability that will meet the requirements of both agencies for biomedical research.

The HRF provides a space for experiments and instruments, along with the means to access ISS services and utilities such as electrical power, command and data handling, cooling air and water, pressurized gases, and vacuum. Specifically, it delivers ESA's Photo-acoustic Analyzer Module/Pulmonary Function Module and NASA capabilities such as:

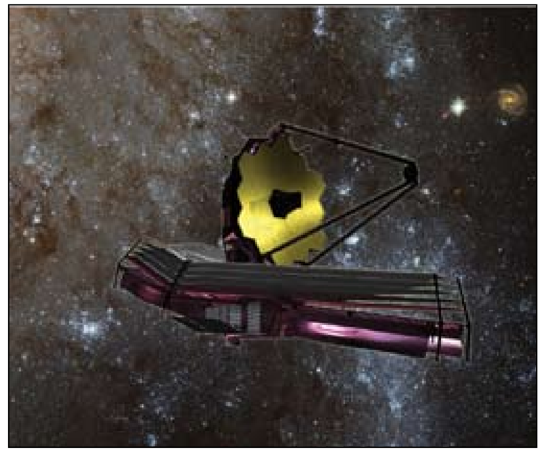
- Refrigerated Centrifuge
- Space Linear Acceleration Mass Measurement Device
- Rack 2 Workstation
- Gas Delivery System

For more information about the HRF and EPM, please see the following URLs: *http://www.esa.int/esaHS/ESA44I0VMOC_iss_0.html, http://stationpayloads.jsc.nasa.gov/F-facilities/f2.html, and http://www.esa.int/esaHS/ESAFRG0VMOC_iss_0.html.*

European Space Agency

JWST
James Webb Space Telescope

The James Webb Space Telescope (JWST) will be a large infrared telescope with a 6.5-meter primary mirror, and is planned for launch in 2013. It's goal will be to study every phase in the history of our universe, ranging from the first luminous glows after the Big Bang, to the formation of solar systems capable of supporting life on Earth-like planets, to the evolution of our own solar system. JWST is an international collaboration between NASA, the Canadian Space Agency (CSA) and the European Space Agency (ESA). CSA is providing the Fine Guidance Sensor/Tunable Filter (FGS/TF) for the telescope.



Artist concept of the JWST in orbit

Referred to as the JWST Observatory, the space-based portion of the JWST system consists of three parts: the Optical Telescope Element (OTE), the Spacecraft Element, and the Integrated Science Instrument Module (ISIM) . The OTE is the eye of the JWST, collecting light from space and providing it to scientific instruments. The Spacecraft Element is composed of the spacecraft bus (provides support functions of the observatory) and the sunshield system (separates the observatory into a warm sun-facing side and a cold anti-sun side). The ISIM contains four instruments: Mid-Infrared Instrument (MIRI), Near-Infrared Spectrograph (NIRSpec), Near-Infrared Camera (NIRCam), and the FGS/TF. JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range. It will be sensitive to light from 0.6 to 27 micrometers in wavelength.

Designed to block solar light and keep the JWST Observatory operating at cryogenic temperature, the five-layer sunshield consists of thin membranes made from a polymer-based film and supporting equipment such as spreader bars, booms, cabling, and containment shells.

Several innovative technologies have been developed for JWST, including a folding, segmented primary mirror adjusted to shape after launch; ultra-lightweight beryllium optics; detectors able to record extremely weak signals; microshutters that enable programmable object selection for the spectrograph; and a cryocooler for cooling the mid-IR detectors to the required 7K operating temperature. The long-lead items, such as the beryllium mirror segments and science instruments, are under construction.

The NIRSpec enables scientists to obtain simultaneous spectra of more than 100 objects in a 9-square-arcminute field of view. This instrument provides medium-resolution spectroscopy over a wavelength range of 1 to 5 micrometers, and lower-resolution spectroscopy from 0.6 to 5 micrometers. The MIRI is an imager/spectrograph that covers the wavelength range of 5 to 27 micrometers.

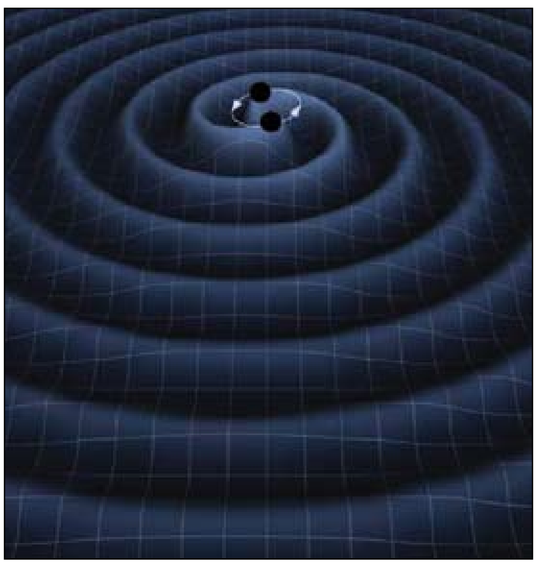
For more information about JWST, please see the following URL: *http://jwst.gsfc.nasa.gov/.*

European Space Agency

LISA Pathfinder

Laser Interferometer Space Antenna Pathfinder

Artist concept of the LISA Pathfinder spacecraft (Credit: ESA)



Artist concept of the gravitational waves that cause a variable strain of space-time, resulting in changes in the distance between points with the size of the changes proportional to the distance between the points.

The Laser Interferometer Space Antenna (LISA) Pathfinder mission (known as the Space Technology 7 within NASA) is a technology precursor mission to the planned LISA mission. The LISA Pathfinder aims to validate the performance of technologies for precise spacecraft control. Scheduled to launch in 2009, the LISA Pathfinder mission is a collaborative mission between NASA and the European Space Agency (ESA). In addition to providing some of the instruments, ESA will construct the LISA Pathfinder spacecraft and operate the instruments after launch.

The LISA mission, if launched, would be the first dedicated space-based gravitational wave observatory. It would use an advanced system of laser interferometry and the most delicate measuring instruments ever made to directly detect gravitational waves. Consisting of three spacecraft positioned in the form of a large equilateral triangle, the LISA mission is tentatively scheduled for launch in 2015 with a planned mission length of five years.

The LISA spacecraft will rely on sensors to measure the gravitational waves. Each sensor will contain the test masses—two cubes allowed to float freely within the spacecraft. These cubes—highly polished to enable them to reflect laser light—will be shielded from external and internal disturbances so that they detect only the force of gravity. To measure the gravitational waves, light from the central spacecraft is sent out to the other two spacecraft. The freely floating test masses act as mirrors and reflect the light back to the source spacecraft where it hits a detector causing an interference pattern. The relative motion of these cubes will detect passing gravitational waves.

The LISA Pathfinder mission consists of two test packages: the LISA Technology Package (LTP) provided by ESA, and the Disturbance Reduction System (DRS) provided by NASA. The LTP is designed to comprise one gravitational sensor, an optical bench, and related optical metrology system. The LTP sensors are used to monitor the position of the spacecraft with respect to a freely floating test mass. The DRS is designed to include micro-propulsion thrusters, supporting electronics, housekeeping avionics, data handling, and drag-free attitude control software. It is planned that the thrusters will be used to adjust the position of the spacecraft to keep it centered on the test mass. Both of these test packages lay important groundwork for the potential LISA mission itself.

For more information about the LISA Pathfinder mission, please see the following URLs: *http://nmp.jpl.nasa.gov/st7/ABOUT/About_index.html and http://sci.esa.int/science-e/www/area/index.cfm?fareaid=40.*

European Space Agency

Rosetta

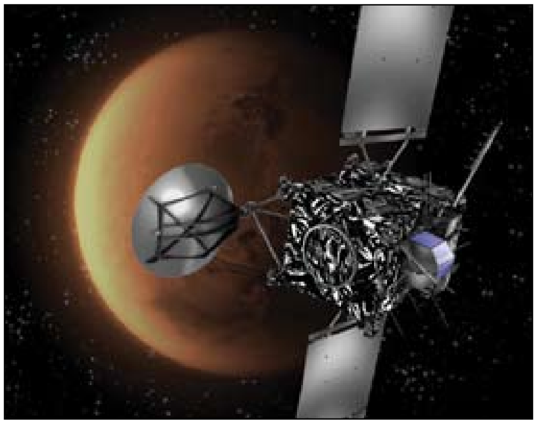
The European Space Agency's (ESA) Rosetta spacecraft will be the first to undertake the long-term exploration of a comet at close quarters. The mission is comprised of a large orbiter designed to operate for a decade at large distances from the Sun, and a small lander called Philae. Each of these carries a large complement of scientific experiments designed to complete the most detailed study of a comet ever attempted.

Rosetta was launched on March 2, 2004, by an Ariane-5G rocket from Kourou, French Guiana, to begin the 10-year mission required to reach its destination, Comet 67P/Churyumov-Gerasimenko. The journey will include gravity assists from Earth and Mars and flybys of main belt asteroids. After entering orbit around Comet 67P/Churyumov-Gerasimenko in 2014, the spacecraft will release its small lander onto the icy nucleus, then spend the next two years orbiting the comet as it heads towards the Sun.

In addition to providing mission operations and Deep Space Network communications support to the Rosetta mission as a whole, NASA also developed and supports the Alice Ultraviolet Spectrometer, the Microwave Instrument for the Rosetta Orbiter (MIRO), and the Rosetta Plasma Consortium/Ion Electron Spectrometer (RPC/IES). NASA contributed to the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA).

Rosetta mission highlights so far include participation in the observation campaign of NASA's Deep Impact encounter with Comet Temple 1 on July 4, 2005, and completion of a flyby of the planet Mars. Rosetta also recently completed a co-observing session of the Planet Jupiter with NASA's New Horizons mission.

For more information about ESA's Rosetta mission, please see the following URL: *http://rosetta.jpl.nasa.gov/.*



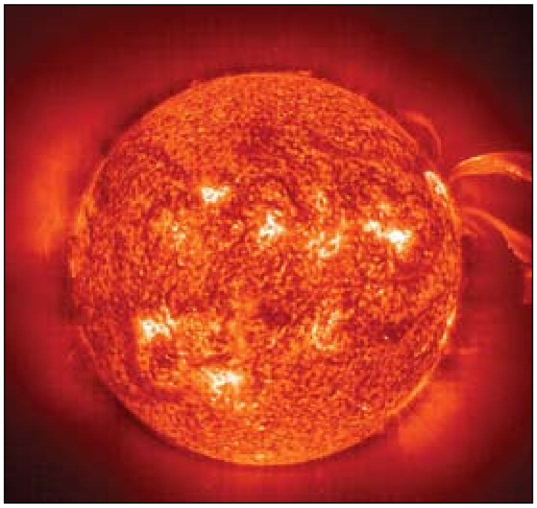
Artist concept of the Rosetta spacecraft with Mars in the background

Artist concept of Rosetta's small lander on the surface of the Comet 67P/Churyumov-Gerasimenko

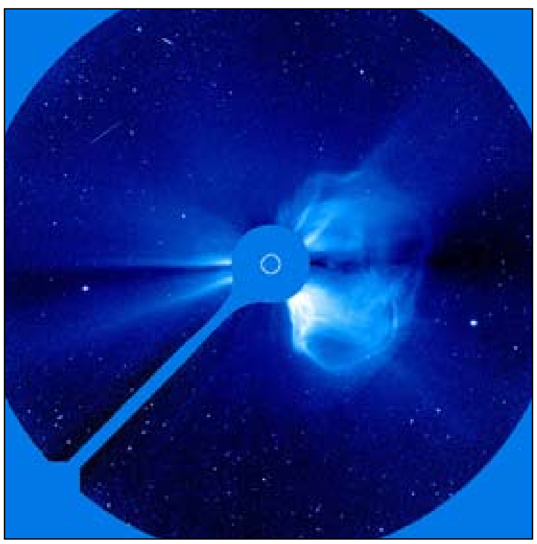
European Space Agency

SOHO

Solar and Heliospheric Observatory



SOHO captured an image of a pair of curving erupting prominences from the Sun in the summer of 2000. Prominences are huge clouds of relatively cool dense plasma suspended in the Sun's hot, thin corona.



LASCO image of a large coronal mass ejection was taken on April 20, 1998. The dark disk blocks the Sun so that the LASCO instrument can observe the structures of the corona in visible light. The white circle represents the size and position of the Sun.

The Solar and Heliospheric Observatory (SOHO) is a project of international cooperation between the European Space Agency (ESA) and NASA to study the Sun—from its deep core to its outer corona and solar winds. Since SOHO's launch on December 2, 1995, on an Atlas II-AS rocket from Cape Canaveral, Florida, the observatory has been providing a vast amount of images and data regarding the Sun and the heliosphere. Originally designed for a two-year mission, SOHO was extended numerous times through December 2009 to study a full 11-year Sun cycle.

The twelve instruments onboard SOHO were provided by teams of European and American scientists who continue to operate the instruments and process the data. The instruments take images of the solar surface, the dynamic layers of the solar atmosphere, and the corona—observable only in ultraviolet light. By special processing of the solar white light data, scientists can measure the magnetic fields around sunspots and look deep into the interior of the Sun. Other instruments measure the pulse and total light output of the Sun and the speed, density, and composition of solar wind as it flows past SOHO.

ESA managed the construction, integration, and testing of the SOHO spacecraft, and a team of ESA scientists have been resident at NASA's Goddard Space Flight Center orchestrating science observation planning. In addition to providing for the launch of SOHO, NASA operates the spacecraft and tracks it with the Deep Space Network.

From its position (about 1.5 million kilometers from Earth), SOHO is providing detailed measurements of the Sun's temperature structure, interior rotation, and gas flow. It also serves as a space weather forecaster, providing advance notice of solar disturbances that are directed towards Earth. In addition to providing valuable information regarding the Sun, amateur astronomers worldwide, using images from the SOHO's Large Angle and Spectrometric Coronograph Experiment (LASCO) instrument, have discovered more than 1000 comets.

For more information about the SOHO mission, please see the following URL: *http://sohowww.nascom.nasa.gov/.*

European Space Agency

Ulysses

The European Space Agency (ESA) and NASA cooperated jointly on the Ulysses mission, the only probe so far to explore the polar regions of the Sun and the heliosphere. ESA provided the Ulysses spacecraft. NASA provided the Radioisotope Thermoelectric Generator (RTG) that supplies the electrical power for Ulysses, the launch service, and the two upper stages—the Inertial Upper Stage (IUS) and a Payload Assist Module-S (PAM-S). The upper stages, combined with a Jovian gravity assist, propelled Ulysses onto a path toward high, out-of-ecliptic latitudes. The scientific instruments and data analysis for Ulysses were developed by U.S. and European Science Teams. Spacecraft operations are performed at the Jet Propulsion Laboratory (JPL) by a joint ESA/JPL team.

Depicted here is an artist concept of Ulysses after deployment from the Space Shuttle cargo bay. Ulysses is a combined upper-stage vehicle, consisting of an Inertial Upper Stage and a Payload Assist Module, both of which propelled Ulysses away from the Earth toward Jupiter.

Ulysses was launched on October 6, 1990, aboard the Space Shuttle Mission STS-41. During the spacecraft's current 17-year journey, exploring the three-dimensional structure of the heliosphere has served as its mission science focus. Furthermore, Ulysses closely encountered the Jupiter system on February 8, 1992, and later again during a distant encounter in 2003 and 2004 in which the spacecraft was separated from the planet by 0.8 astronomical units. Three chance encounters of comet tails have occurred: Hyakutake (1996), NcNaught-Hartley (2000), and McNaught (2007), making this mission the record holder in comet encounters. Since 1992, Ulysses has been in its planned, highly inclined orbit about the Sun. In near solar minimum conditions of 1994, Ulysses reached 79 degrees heliographic latitude over the Sun's south pole for the first time. At that time, and a year later over the north pole, Ulysses was fully embedded in fast solar wind streaming out of the Sun's polar coronal holes. No previous spacecraft had reached latitudes higher than 32 degrees. Three other polar passes have occurred since: during solar maximum in 2000 and 2001, and during the declining phase of the solar cycle in February 2007. Ulysses' mission has been extended until at least March 2008, enabling it to fly over the Sun's north pole for a third time in 2008.

The Ulysses spacecraft undergoing tests at the European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands, in 1985

Ulysses has returned a wealth of data that has led to a much broader understanding of the global structure of the Sun's heliosphere, including in regards to solar wind, the magnetic field, transient disturbances, and the propagation of energetic particles. As the only spacecraft out of the ecliptic with a gamma-ray instrument, Ulysses is part of the InterPlanetary Network (IPN), a network of spacecraft equipped with gamma ray burst detectors.

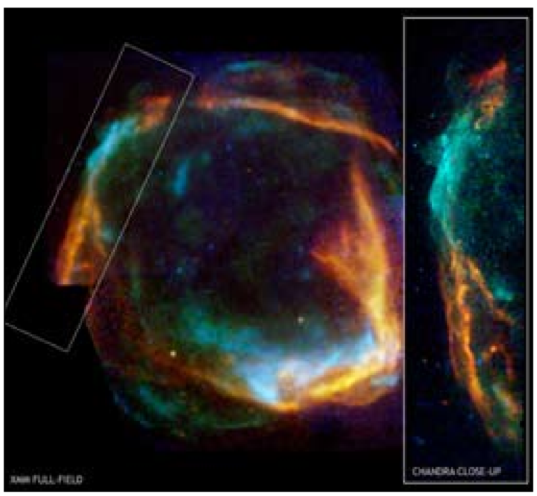
For more information about Ulysses, please see the following URL: *http://ulysses.jpl.nasa.gov/index.html.*

European Space Agency

XMM-Newton

X-ray Multi-Mirror—Newton

The XMM-Newton mission is one of the cornerstones of ESA's Horizon 2000 Program of ESA. XMM-Newton was launched on December 10, 1999. (Credit: ESA)



The oldest-recorded supernova, unveiled by XMM-Newton and Chandra. (Credit: ESA)

X-ray Multi-Mirror (XMM)-Newton is an x-ray satellite launched into Earth orbit on December 10, 1999, by the European Space Agency (ESA). XMM-Newton is a fully-functioning observatory, carrying three advanced x-ray telescopes. Each telescope contains 58 high-precision concentric mirrors, nested to offer the largest collecting area possible to catch x-rays. Additionally, its detectors are much more sensitive, allowing fainter objects to be observed. XMM-Newton has a planned operational lifetime of up to 10 years.

XMM-Newton uses an unusual technique to focus x-rays onto the different detectors. An optical telescope works by reflecting and focusing light; however, x-rays have such high energy that they pass through most materials, making reflection impossible. Therefore, in the case of an x-ray telescope, the mirrors are arranged so that incoming x-rays graze off of the mirrors. The shape and highly-polished surfaces of the mirrors focus the incoming x-rays into a beam when they enter the detectors.

The XMM-Newton spacecraft consists of three main instruments. The European Photon Imaging Camera—the main camera onboard XMM-Newton—can perform both x-ray imaging and spectroscopy. Actually three cameras in one, it employs three different detectors to view the x-rays. The second instrument is a Reflection Grating Spectrometer, which is similar to an optical prism in that it spreads out the incoming light according to the wavelength of the photon. The third instrument is the Optical/Ultraviolet Monitor, which has a 30-centimeter-wide mirror designed to focus optical and ultraviolet light coming from the same direction as the x-rays observed by the other instruments on XMM-Newton. Occurring for the first time from the same spacecraft, this process allows for the simultaneous observations of a target in the optical/ultraviolet and x-ray regions of the electromagnetic spectrum.

ESA designed and built the XMM-Newton spacecraft, along with the three main instruments aboard the spacecraft. ESA also controls spacecraft operations. NASA provides access to the mission for U.S. astronomers through the Guest Observer facility at the Goddard Space Flight Center.

For more information about XMM-Newton, please see the following URLs: *http://xmm.gsfc.nasa.gov/ and http://xmm.sonoma.edu/index.html.*

CALIPSO

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations

France

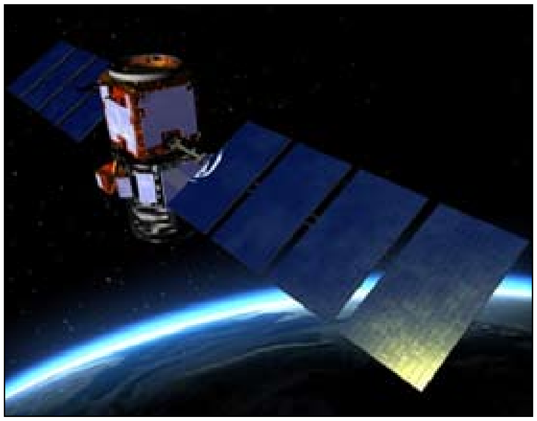
For the Cloud-Aerosol LiDAR (light detection and ranging) and Infrared Pathfinder Satellite Observations (CALIPSO) satellite, the French Centre for Space Studies (CNES) provided the PROTEUS platform, satellite engineering and operations, the Imaging Infrared Radiometer (IIR), algorithm development for the IIR, and a data site for the mission. CALIPSO launched on April 28, 2006, onboard a Delta II launch vehicle from Vandenberg Air Force Base, California. CALIPSO has a planned mission life of three years.

CALIPSO was launched with NASA's CloudSat satellite. It will fly in orbital formation as part of a constellation of satellites including NASA's Aqua and Aura and CNES's Polarization and Anisotropy of Réflectances for Atmospheric Sciences coupled with Observations from a LiDAR (PARASOL). CALIPSO will maintain a tight formation with CloudSat in order to overlap measurement footprints at least 50 percent of the time.

Scientists have received from CALIPSO vertically resolved identification of cloud ice/water phase and, together with the cloud profiling radar on CloudSat, will provide comprehensive observations of cloud vertical structure on a global scale. CALIPSO will provide a unique 3-year coincident set of global data on aerosol and cloud properties, radiative fluxes, and atmospheric state. From this data will come an improved understanding of the role aerosols and clouds play in regulating the Earth's climate, in particular, how aerosols and clouds interact with one another.

CALIPSO's data will greatly improve predictions of the regional impacts of long-term climate change, ensuring a scientific basis for understanding and assessing the impact of climate change. The scientific advances enabled by this coincident data set will also improve short-term (days) weather forecasts, as well as forecasts on seasonal-to-interannual time scales. CALIPSO will augment the capabilities of the civilian operational Earth-observing satellite used by the National Weather Service, offering a unique capability to monitor volcanic plumes and the long-range transport of pollutants that impact air quality and visibility.

For more information about CALIPSO, please see the following URL: *http://www.nasa.gov/mission_pages/calipso/main/.*

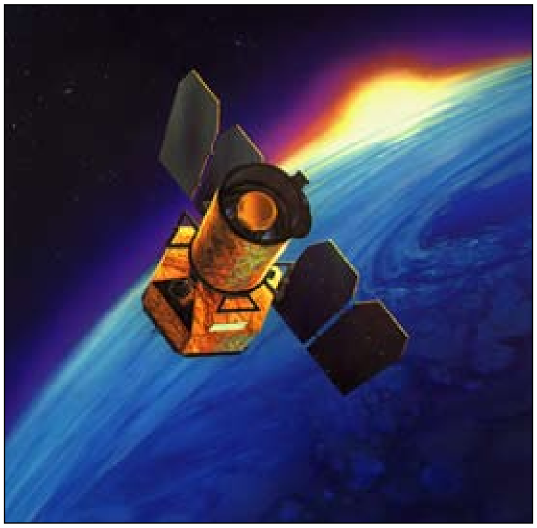


Artist concept of the CALIPSO satellite over Earth

Photo of the Delta II launch of the CALIPSO satellite

France

GALEX
Galaxy Evolution Explorer



Artist's concept of the GALEX spacecraft

This image of the nearby spiral galaxy M101, better known as the Pinwheel Galaxy, is a three-color combination of images from the GALEX spacecraft.

The Galaxy Evolution Explorer (GALEX) is a Small Explorer Mission (SMEX) studying ultraviolet astrophysics. GALEX is an orbiting ultraviolet space telescope mapping the celestial sky in the ultraviolet. The data from GALEX will reach across the last ten billion years—80 percent of the way back to the Big Bang—to determine the history of star formation in the universe. The French National Centre for Space Studies (CNES) contributed to the ultraviolet telescope. GALEX was launched on April 28, 2003, aboard a Pegasus XL launch vehicle from Cape Canaveral, Florida.

GALEX is surveying the entire sky at ultraviolet wavelengths for clues as to how the earliest galaxies evolved into mature galaxies like that of the Milky Way. To detect these faint early galaxies, specialized cameras allow the arrival of each photon of ultraviolet light to be timed with the precision of about a microsecond. In addition to studying galaxies, GALEX has also proved useful in observing flares and bursts from stars and streaks from asteroids. The satellite has observed over 84 bonus astrophysical events that were not originally planned.

CNES provided the following for the ultraviolet telescope: Optics Design, the Back Focal Assembly Optics, the Imaging Window, the Grism, and the Asphere Corrector Plate Substrate. CNES also sponsored the French members of the GALEX science team to conduct data analysis and calibration.

Originally planned for a 28-month duration, GALEX is currently still active and providing ultraviolet data about galaxy formations and other astrophysical events. On March 7, 2007, GALEX data was used to determine that double star systems can produce full-blown explosions, as well as smaller aftershock-like bursts. Following the first large explosion, GALEX data proved that there was enough matter and pressure to form smaller explosions.

For more information about the GALEX, please see the following URLs: *http://galexgi.gsfc.nasa.gov/ and http://www.nasa.gov/mission_pages/galex/index.html.*

GLAST
Gamma-ray Large Area Space Telescope

France

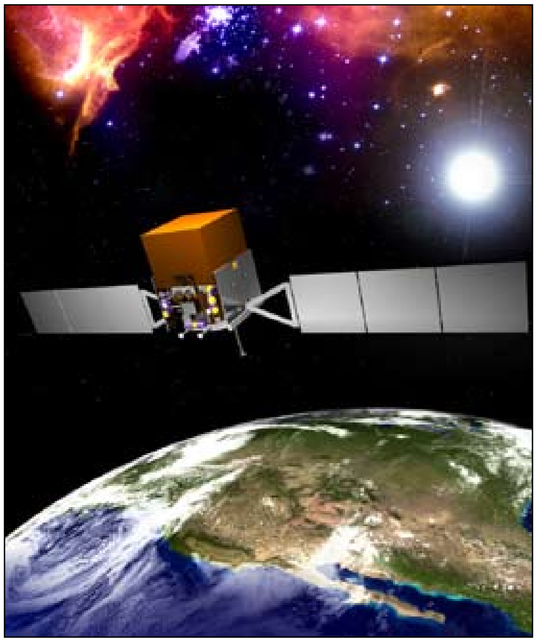
The Gamma-ray Large Area Space Telescope (GLAST) is a spacecraft with the ability to detect gamma rays created by the most energetic objects and phenomena in the universe. Among topics of cosmological interest to be studied by the mission will be the periods of star and galaxy formation in the early universe and on dark matter. Planned for launch in 2008 from Cape Canaveral, Florida, GLAST is designed for a mission lifetime of five years, with a goal of 10 years of operations. NASA is working with the French National Centre for Space Studies (CNES) on the GLAST mission.

Because of their tremendous energy, gamma rays travel through the universe largely unobstructed. This means GLAST will be able to observe gamma-ray sources near the edge of the visible universe. Gamma rays detected by GLAST will originate near the otherwise obscured central regions of exotic objects like supermassive black holes, pulsars, and gamma-ray bursts.

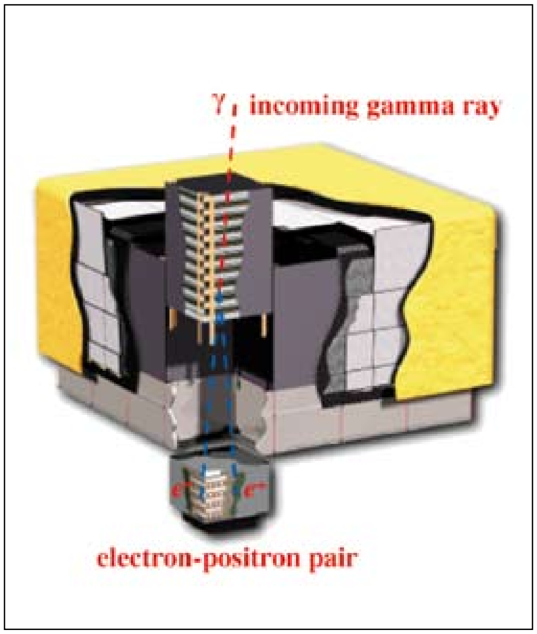
In order to study these high energy waves, two main instruments will be used: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The LAT will detect gamma rays by using a technique known as pair-conversion in which a gamma ray slams into a layer of tungsten in the detector, creating a pair of subatomic particles. These particles in turn hit another, deeper layer of tungsten, each creating further particles, and so on. The direction of the incoming gamma ray is determined by tracking the direction of these cascading particles back to their source using high-precision silicon detectors. A separate detector counts up the total energy of all the particles created. The GBM is designed to observe gamma ray bursts, which are sudden, brief flashes of gamma rays that are detectable once or twice a day at random positions across the sky. The sources of these flashes are a mystery, but they are among the most powerful explosions in the universe.

For the GLAST mission, CNES provided support in the development of the LAT, specifically on the detector that will calculate the amount of energy from the gamma rays. Along with CNES and NASA, the following are also cooperating on the GLAST mission: the German Aerospace Center, Italian Space Agency, Japan Aerospace Exploration Agency, and Royal Institute of Technology in Sweden.

For more information about the GLAST mission, please see the following URL: *http://glast.gsfc.nasa.gov/.*



Artist concept image of the GLAST spacecraft above Earth (Credit: General Dynamics C4 Systems)



Artist concept image of the LAT instrument (Credit: LAT Collaboration)

France

Human Factors Research

Human Fators Research includes analyzing and measuring prospective memory demands on pilots in the cockpit

The Intelligent Spacecraft Interface Systems Lab contains a reconfigurable cockpit simulator, which is used to gather human performance data for current and future vehicle display designs.

NASA is cooperating with the French National Aerospace Research Center (ONERA) on Human Factors Research. This research pertains to the human component of aircraft performance and air safety, including human performance, technology design, and human-computer interaction. Annually, 60 percent to 80 percent of aviation accidents are attributed to human factors.

NASA and ONERA are evaluating methodologies to highlight links between various accidents and reveal precursors or characteristics that could indicate potential safety hazards.

With sufficient flight-recorded numerical data, NASA's automated tools and techniques assist in identifying systemic problems that relate to human factors. ONERA has acquired access to flight-recorded numerical data, and has developed analytical techniques similar to NASA's. ONERA will apply NASA- and European-developed analytical methodologies to analyze their set of available flight-recorded numerical data. ONERA will then process the flight-recorded data into a format that is compatible with NASA's Aviation Performance Measuring System (APMS). NASA and ONERA will compare and assess analyses using APMS with other methods available to ONERA, and will follow up with jointly written reports reviewing and commenting on the methodologies used for analyzing flight and incident-report data.

This cooperation began in June 2005 and will continue until July 2008.

For more information about Human Factors Research, please see the following URLs: *http://human-factors.arc.nasa.gov/ and http://www.onera.fr/english.php.*

Icing Research

France

NASA is cooperating on in-flight icing research with the Meteorological Service of Canada (MSC), the French National Aerospace Research Center (ONERA), the Spanish National Institute of Aerospace Technology (INTA), Cranfield University in the United Kingdom, and QinetiQ Limited in the United Kingdom. Aircraft in-flight icing causes multitudes of aircraft accidents. One particular type of in-flight icing hazard, known as Supercooled Liquid Droplets (SLD), can contribute to hazardous ice buildup on unprotected aircraft surfaces, which in turn can lead to a loss of aircraft control. Significant international attention has also focused on icing cloud atmospheric characterization, and on in-situ and remote measurement instrumentation.

NASA is working with its partners from Canada, France, Spain, and the United Kingdom to collect and analyze data to develop a better understanding of the icing environment, improve ice accretion modeling techniques, and refine ice detection instrumentation and measurement systems.

Cooperative icing research includes the following collaborations:

- MSC and NASA are conducting collaborative research related to icing cloud and mixed phase (water droplet and ice crystal clouds) atmospheric definition, in-situ and remote instrumentation development, and data processing and analysis techniques. NASA and MSC are conducting flight tests and remote sensing experiments, and will jointly analyze and publish the resulting data. The collaboration began in April 2004 and will continue through December 2010.
- Collaboration with ONERA began in April 2006 and will continue through September 2008. ONERA and NASA are conducting cooperative research in iced aerodynamics and computational fluid dynamics (CFD) modeling of ice accretions. ONERA is developing a wake rake and providing access to their F-1 pressurized low-speed wind tunnel. ONERA and NASA are planning and supporting wind tunnel testing activities whose resulting data will be jointly analyzed and published.
- INTA and NASA are conducting cooperative activities related to ice-accretion physics and water-film thickness. INTA is conducting experiments whose information and results are then provided to NASA. Together, they will publish a joint report describing the research. The collaboration began in October 2004 and will continue through December 2008.
- NASA and Cranfield University began conducting cooperative research related to SLD formation and effects on aircraft surfaces in January 2004 and will continue through December 2008. They are jointly developing the models for testing, defining test plans, and conducting experiments. They will create a technical report documenting the work.
- NASA and QinetiQ are conducting cooperative research related to SLD icing physics and the development of methods for simulating SLDs in icing research facilities. QinetiQ is developing models, conducting experiments, and analyzing data. The collaboration began in September 2004 and will continue through September 2009.

For more information about icing research, please see the following URLs: *http://icebox.grc.nasa.gov/, http://www.onera.fr/dmph-en/icing/index.php, and http://www.cranfield.ac.uk/soe/ppae/ti-gti/icing_technology.htm.*

Post-flight image shows ice contamination as a result of encountering SLD conditions near Parkersburg, West Virginia.

Technicians measure ice accretions after an icing test at Glenn Research Center.

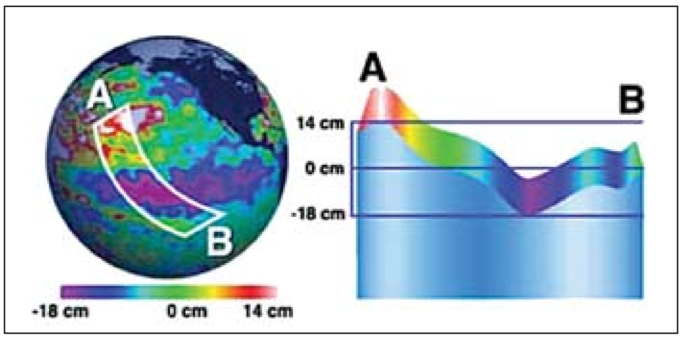
France

Jason-1

Depiction of Jason-1 in space

Jason-1 is a joint project between NASA and the French National Centre for Space Studies (CNES). The Jason-1 satellite monitors global ocean circulation and researches the role of oceans in Earth's climate. Jason-1 is a follow-on mission to the highly successful U.S./French TOPography Experiment (TOPEX)/Poseidon mission that measured ocean surface topography to an accuracy of better than 3.3 centimeters and enabled scientists to forecast the 1997–1998 El Niño. Jason-1 was launched on December 7, 2001, on a Delta II launch vehicle from Vandenberg Air Force Base, California.

The primary requirement for Jason-1 is to provide a continuation of the TOPEX/Poseidon mission's high-accuracy radar altimetry measurements. A secondary requirement is to provide near-real-time data for operational marine nowcasting and numerical prediction of sea state, ocean circulation, and weather.



These images show sea surface height anomalies with the seasonal cycle (the effects of summer, fall, winter, and spring) removed. The differences between what we see and what is normal for different times and regions are called anomalies, or residuals. When oceanographers and climatologists view these anomalies, they can identify unusual patterns and tell how heat is being stored in the ocean to influence future planetary climate events.

The Jason-1 satellite carries both U.S. and French instruments. CNES provided the satellite bus (PROTEUS), the Poseidon-2 Altimeter (C- and Ku-band), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), a Doppler tracking antenna that receives ground signals for precise orbit deter-mination, satellite tracking, and ionospheric correction data for the CNES altimeter. NASA provided the microwave radiometer, the BlackJack Global Positioning System receiver, and the laser retroreflector array. NASA also provided the launch vehicle, launch services, and continuing mission operations. Jason-1's radar altimeter measures the precise distance between the satellite and the sea surface by determining the round-trip travel time of microwave pulses bounced from the spacecraft to the sea surface and back to the spacecraft.

In December 2006, Jason-1 completed its 5th year on orbit. With this milestone, Jason-1 surpassed both its primary and extended mission phases and continues to collect valuable ocean data for researchers and operational users worldwide. Jason-1 was launched into the same orbit as TOPEX/Poseidon where they made virtually simultaneous measurements for 6 months to assure calibration and consistency of the two mission's time series of ocean surface topography. Following that, TOPEX/Poseidon was moved to an interleaved orbit with Jason-1 to provide double spatial coverage of the ocean as a tandem mission. Three full years of Tandem mission data were collected before the TOPEX mission terminated in October 2005. Jason-1 has now replaced TOPEX/Poseidon in gathering important ocean altimetry data.

For more information about Jason-1, please see the following URL: *http://sealevel.jpl.nasa.gov/mission/jason-1.html.*

Mars Odyssey

France

The French National Centre for Space Studies (CNES), as a member of the Gamma Ray Spectrometer (GRS) Science Team, provided four Germanium detectors for the GRS instrument suite and science support for NASA's 2001 Mars Odyssey mission. The Mars Odyssey was launched on April 7, 2001, on a Delta II launch vehicle from Cape Canaveral, Florida.

For the first time the amount and distribution of chemical elements and minerals that make up the Martian surface was mapped. The spacecraft globally mapped many elements, and the maps of hydrogen distribution led scientists to discover vast amounts of water ice in the polar regions buried just beneath the surface. Odyssey recorded the radiation environment in low-Mars orbit to determine the radiation-related risk to future human explorers who may one day go to Mars.

The GRS instrument suite—one of three primary instrument packages on the Mars Odyssey—has studied the elemental distribution at the surface of Mars and searched for water across the planet. Specifically, this instrument suite detects and counts gamma rays and neutrons from the Martian surface. By associating the spectral distribution of the gamma rays with known nuclear transitions lines, it is possible to calculate the ratio of elemental abundances on the surface. By counting the number of neutrons as a function of energy, it is possible to calculate the hydrogen abundance, thus inferring the presence of water.

Odyssey is one of five active robotic missions at Mars, which include NASA's Mars Reconnaissance Orbiter and Mars Exploration Rovers (Spirit and Opportunity) and the European Space Agency's Mars Express orbiter. The orbiters and surface missions complement each other in many ways. Observations by the rovers provide ground-level understanding for interpreting global observations by the orbiters. In addition to their own science missions, the orbiters relay data from the Mars Rovers.

For more information about Mars Odyssey, please see the following URL: *http://marsprogram.jpl.nasa.gov/odyssey/overview/.*

Artist concept of the 2001 Mars Odyssey in orbit above Mars

This mosaic image of Valles Marineris canyon—colored to resemble the Martian surface—comes from the Thermal Emission Imaging System (THEMIS), a visible-light and infrared-sensing camera on the Mars Odyssey orbiter.

France

MSL
Mars Science Laboratory

Artist concept of the MSL on the Martian surface

This image indicates the growing wheel size between the various Mars explorers: Pathfinder, Mars Exploration Rover, and MSL.

On the NASA 2009 Mars Science Laboratory (MSL) mission, the French National Centre for Space Studies (CNES) will provide significant hardware for two of the instrument suites—the Laser-Induced Remote Sensing for Chemistry and Micro-Imaging (ChemCam) and the Sample Analysis at Mars (SAM).

The MSL mission is part of NASA's Mars Exploration Program. Developed by NASA, the MSL mission consists of a long duration rover and mobile scientific laboratory equipped to perform scientific studies of Mars. NASA plans to launch MSL in the fall of 2009 from Cape Canaveral, Florida aboard an Atlas V launch vehicle with an arrival date to Mars of October 2010. The mission is planned to last at least one Martian year (687 Earth days).

The primary scientific objectives, to be carried out during the surface science phase of the MSL mission, will be to assess the biological potential of at least one target area, characterize the local geology and geochemistry, investigate planetary processes relevant to habitability (including the role of water), and to characterize the broad spectrum of surface radiation. The landing site, which has not yet been chosen, will be selected based on an assessment of safety and planetary protection, and an analysis by the scientific community.

The ChemCam instrument suite will be provided by NASA with CNES providing the ChemCam Mast Unit, including the laser, telescope, camera, and front-end electronics. The ChemCam instrument suite will be used to characterize the geology of the Mars landing region, investigate planetary processes relevant to past habitability, assess the biological potential of a target environment, and look for toxic materials. Looking at rocks and soils from a distance, ChemCam will fire a laser and analyze the elemental composition of vaporized materials from areas smaller than 1 millimeter on the surface of Martian rocks and soils. An onboard spectrograph will provide unprecedented detail about minerals and microstructures in rocks by measuring the composition of the resulting plasma, a visible brief glow of ionized material.

The SAM instrument suite will be provided by NASA's Goddard Space Flight Center, with CNES providing the Gas Chromatograph portion of the suite. SAM will be used to study geochemical conditions that are directly relevant to the larger goal of assessing the habitability of Mars. SAM will also search for compounds of the element carbon, including methane, which are associated with life and explore ways in which they are generated and destroyed in the Martian ecosphere.

For more information about the MSL mission and the ChemCam and SAM instrument suites, please see the following URLs: *http://mars.jpl.nasa.gov/msl/, http://mars.jpl.nasa.gov/msl/mission/sc_instru_chemcam.html, and http://mars.jpl.nasa.gov/msl/mission/sc_instru_sam.html.*

OSTM

Ocean Surface Topography Mission

France

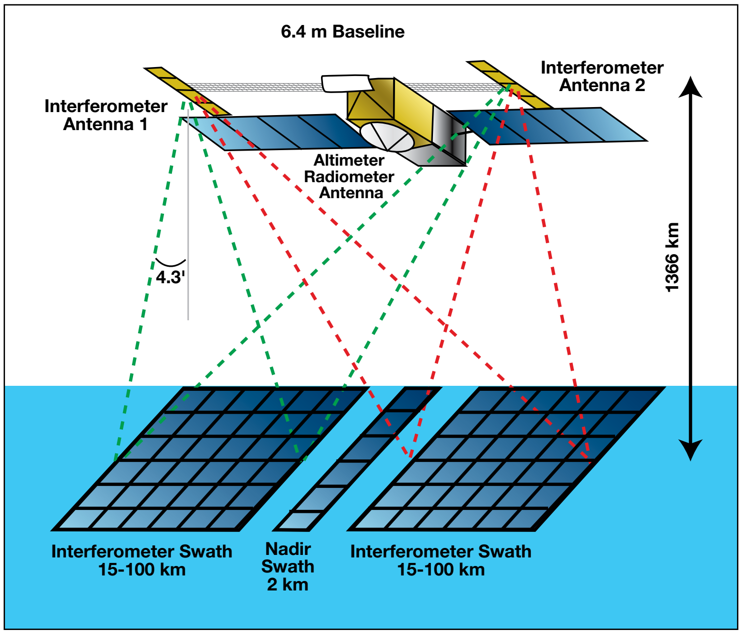
The Ocean Surface Topography Mission (OSTM) will provide continuity of ocean topography measurements beyond Topex/POSEIDON and Jason-1 for determining ocean circulation, climate change, sea level rise, and societal applications (e.g. El Niño, hurricane forecasting,). The French National Centre for Space Studies (CNES) is providing the PROTEUS platform and payload module, a Poseidon-3 dual frequency radar altimeter, the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) receiver package, and DORIS auxiliary instruments. OSTM is scheduled to launch in 2008 on a Delta II launch vehicle and has a planned mission life of three years, with a five-year goal.

Computer simulation of the Ocean Surface Topography Mission Satellite

OSTM will function as a bridge to an operational mission for the continuation of multi-decadal ocean topography measurements. OSTM features two new operational partners—the European Meteorological Satellite Organization (EUMETSAT) and the National Oceanic and Atmospheric Administration (NOAA)—and is a joint project among CNES, NASA, NOAA, and EUMETSAT. This mission intends to illustrate a clear transition from research and development agencies to operational agencies for ocean surface topography measurements in both Europe and the United States.

NASA and CNES will jointly provide the payload instruments. NASA will provide a microwave radiometer, a laser retroreflector, a GPS receiver package, and launch services for the satellite. The two operational partners—EUMETSAT and NOAA—will furnish ground system elements and support operations for the satellite. NOAA will establish an Operations Control Center, along with communication and data acquisition stations, and will operate and control the OSTM satellite after CNES hands over this responsibility. In addition, NOAA will provide operational data processing, distribution, and archiving. EUMETSAT will provide an Earth terminal, operational data processing, and distribution to European users.

For more information about OSTM, please see the following URL: *http://sealevel.jpl.nasa.gov/mission/ostm.html; and www.aviso.oceanobs.com.*



Wide-Swath Ocean Altimeter (WSOA) is an altimeter/interferometer project. Several altimeters mounted on masts will acquire measurements simultaneously, thus providing continuous single- or multi-altimeter wide-area coverage. WSOA could be flown on a Jason-1 satellite.

France

TAL Sites

Transoceanic Abort Landing Sites for the Space Shuttle

NASA's TAL sites are located almost directly across the Atlantic Ocean from the Space Shuttle launch pad at the Kennedy Space Center in Florida.

Landing convoys such as these at KSC would provide support to the Space Shuttle crew in the event of a landing at a TAL site.

NASA maintains three Transoceanic Abort Landing (TAL) sites for the Space Shuttle. One is in the South of France, near Marseille, and the other two are in Zaragoza and Moron in Spain.

The three current TAL sites were chosen because of their location near the high-inclination launch path of Space Shuttle missions to the International Space Station (ISS). Other factors, such as runway length, the state of infrastructure and facilities, and local climate, were also considered in choosing these sites.

The TAL site in France is at the Istres French Air Force (FAF) Base 125, which was activated during the post-Columbia, return-to-flight preparations in 2005 to provide another TAL site for high-inclination launches of the Shuttle. The Istres Air Base houses a French Air Force Base and French civilian aviation companies. This TAL site has a single runway, 197 feet wide and 11,303 feet long, which is equipped with shuttle-unique visual landing aids and a Microwave Landing System (MLS), a Tactical Air Control and Navigation (TACAN) system, and a remote weather tower.

The TAL site in Zaragoza, Spain, is the primary TAL site for high-inclination launches of the Space Shuttle to the ISS. The TAL site in Moron serves as a weather alternate TAL site for both low- and high-inclination launches of the Space Shuttle; and the TAL site in Istres serves as a weather alternate TAL site for high-inclination launches of the Space Shuttle to the ISS.

TAL sites provide the capability for an emergency landing during ascent to an augmented site that has been specifically modified and staffed to receive the Space Shuttle. Such a landing would typically be attempted if an emergency were declared roughly between 2 ½ minutes and 8 ½ minutes after liftoff from Kennedy Space Center (KSC), and if the Space Shuttle could not safely enter into orbit or return to the launch site. During a TAL abort, the Space Shuttle would continue on a trajectory across the Atlantic to a predetermined runway at one of the TAL sites.

There is a flight rule indicating that at least one TAL site must be available in order to proceed with launching the Space Shuttle. The combination of three available TAL sites in a geographic configuration that mitigates the risk of adverse weather decreases the likelihood of postponing the launch as a result of a violation of that rule.

For more information about NASA's TAL sites and the TAL site in France, please see the following URLs: *http://www.pao.ksc.nasa.gov/nasafact/tal.htm, http://www.nasa.gov/mission_pages/shuttle/behindscenes/tal_sites.html, and http://www.nasa.gov/returntoflight/main/talsite.html.*

THEMIS

Time History of Events and Macroscale Interactions during Substorms

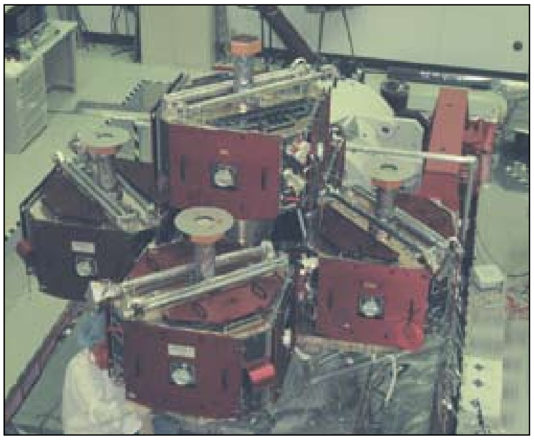
France

The Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission is a two-year mission consisting of five identical satellites, each with a suite of five instruments that will study the violent, colorful eruptions in auroras. The French National Center for Space Studies (CNES) sponsored the Search Coil Magnetometer (SCM) instrument, which is present on each satellite. The mission also incorporates a network of ground-based auroral observatories, many of which are located in Canada. THEMIS was launched by NASA on a Delta II launch vehicle from the Kennedy Space Center on February 17, 2007. In addition to CNES, NASA partnered with the Austrian Space Agency, Canadian Space Agency, and German Aerospace Center on the mission.

One of the science objectives of THEMIS involves determining what physical processes in near-Earth space initiate the violent eruptions in the Earth's magnetosphere known as substorms. Substorms greatly intensify auroras and create the dramatic "dancing" effects witnessed in auroras. Aligning five identical probes over observatories on the North American continent will allow scientists to collect coordinated measurements along the Earth's magnetic field lines, thereby providing the first comprehensive look at the onset of substorms and the manner in which they trigger auroral eruptions.

CNES and the French Centre for the Study of Terrestrial and Planetary Environments developed and tested the SCM instrument. The SCM measures low-frequency magnetic field fluctuations and waves in three directions in Earth's magnetosphere.

For more information about THEMIS, please see the following URL: *http://www.nasa.gov/mission_pages/themis/main/index.html.*

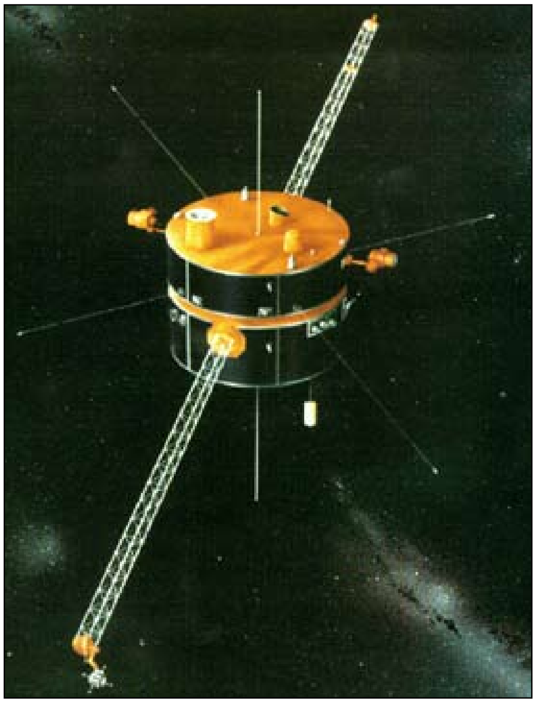


A photo of the THEMIS probes in preparation for launch at the Jet Propulsion Laboratory in California

An artist concept of the THEMIS probes once in orbit around the Earth

France

Wind/WAVES



Artist concept of the Wind spacecraft

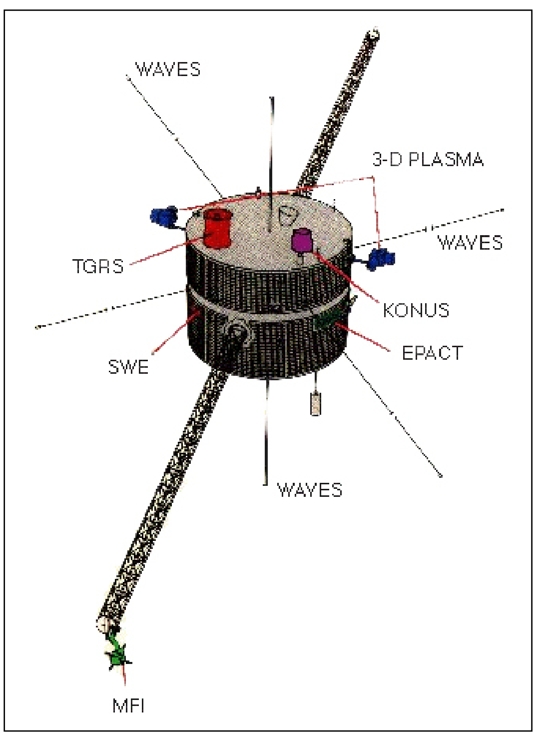


Diagram of the Wind spacecraft and instruments

Launched on November 1, 1994, Wind was the first of two NASA spacecraft in the Global Geospace Science Program and part of the International Solar-Terrestrial Physics (ISTP) Science Initiative. The French National Centre for Space Studies (CNES) and NASA jointly cooperated on the Wind/Radio and Plasma Wave Experiment (WAVES) instrument. CNES sponsored the French Principal Investigator and Co-Investigators in contributing to the design and development of this instrument, mission operations, and data analysis. The joint WAVES instrument is a forerunner to the SWAVES experiment now flying on the two STEREO spacecraft.

NASA's Wind satellite took up a vantage point between the Sun and the Earth, giving scientists a unique opportunity to study the enormous flow of energy and momentum known as the solar wind. The main scientific goal of the mission is to measure the mass, momentum, and energy of the solar wind that is transferred into the space environment toward the Earth.

The WAVES instrument provides comprehensive measurements of the radio and plasma wave phenomena that occur in the solar wind upstream of the Earth's magnetosphere and in key regions of the magnetosphere. In situ measurements of different modes of plasma waves are providing key information on the generation and transport of coronal mass ejections—the large eruptions of solar material that intercept the Earth's magnetosphere. WAVES observes the local processes and couplings that lead to space plasma instabilities: magneto-acoustic waves, ion cyclotron waves, whistler waves, electron plasma oscillations, electron burst noise, and other types of electrostatic or electromagnetic waves.

NASA's Wind satellite remains in operation at the sunward Sun-Earth equilibrium point (L-1).

For more information about Wind/WAVES, please see the following URLs: *http://pwg.gsfc.nasa.gov/wind.shtml and www-istp.gsfc.nasa.gov/istp/wind/.*

Chandra X-ray Observatory

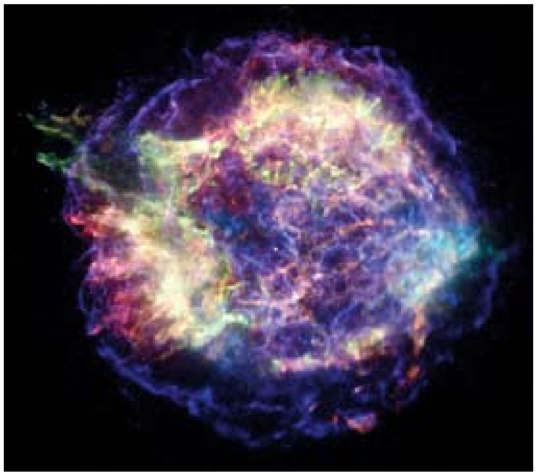
Germany

The Chandra X-ray Observatory is part of NASA's fleet of "Great Observatories" along with the Hubble Space Telescope and the Spitzer Space Telescope. Chandra allows scientists from around the world to obtain unprecedented x-ray images of exotic environments in order to help understand the structure and evolution of the universe. Having already surpassed its originally-planned five-year lifetime, Chandra's observations are rewriting textbooks and helping advance technology. The German Aerospace Center (DLR) is cooperating with NASA on Chandra through the Electron, Proton, Helium Instrument (EPHIN) and the Low Energy Transmission Grating for Cosmic X-ray Spectrometer (LETGS).

The Chandra telescope system consists of four pairs of mirrors and their support structure. x-ray telescopes function differently from optical telescopes in that high energy x-ray photons penetrate into a mirror much as bullets slam into a wall, then the photons ricochet off the mirrors. The shape of the mirrors direct the photons to one spot where the four scientific instruments then analyze information from these photons. The Chandra X-ray Observatory was launched on July 23, 1999, aboard the Space Shuttle.

DLR provided the EPHIN detector, which monitors the local charged particle environment as part of the scheme to protect the two focal-plane science instruments (i.e., the High-Resolution Camera (HRC) and the Advance Charge-Coupled Devices (CCD) Imaging Spectrometer (ACIS)) from particle radiation. DLR also sponsored the participation of the German scientist for the EPHIN cooperation.

For more information about Chandra, please see the following URLs: *http://www.nasa.gov/mission_pages/chandra/main/ and http://chandra.harvard.edu.*



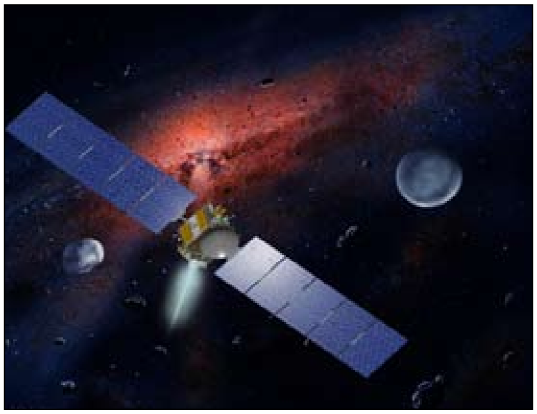
This Chandra image shows Cassiopeia A, the youngest supernova remnant in the Milky Way. New analysis shows that this supernova remnant acts like a relativistic pinball machine by accelerating electrons to enormous energies.

Chandra observations of the massive spiral galaxy NGC 5746 revealed a large halo of hot gas (blue) surrounding the optical disk of the galaxy (white). The halo extends more than 60,000 light years on either side of the disk of the galaxy.

Germany

Dawn

Asteroid Rendezvous Mission



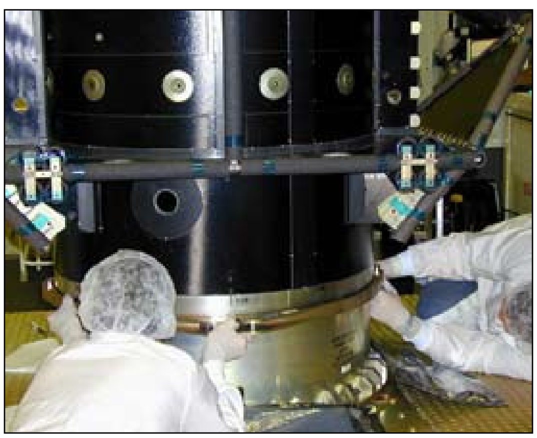
Artist concept of the Dawn spacecraft (Credit: UCLA)

Led by NASA, the Dawn Mission is sending an orbiting space probe to examine the dwarf planet Ceres and the asteroid Vesta, two of the most massive members of the asteroid belt. This is the first science mission to make use of ion propulsion and will also be the first mission to visit and go into orbit around two distinct bodies other than the Earth and the Moon. Dawn launched on September 27, 2007, on a Delta II launch vehicle.

Dawn's goal is to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets that have remained relatively intact since their formations. Ceres and Vesta reside in the extensive zone between Mars and Jupiter, together with many other smaller bodies, called the asteroid belt. Each has followed a very different evolutionary path, constrained by the diversity of processes that operated during the first few million years of solar system evolution.

The German Aerospace Center (DLR) developed, supported, and integrated the two Framing Cameras (FC) that will provide scientific imagery for the Dawn mission.

For more information on the Dawn mission, please see the following URL: *http://dawn.jpl.nasa.gov/mission/index.asp.*

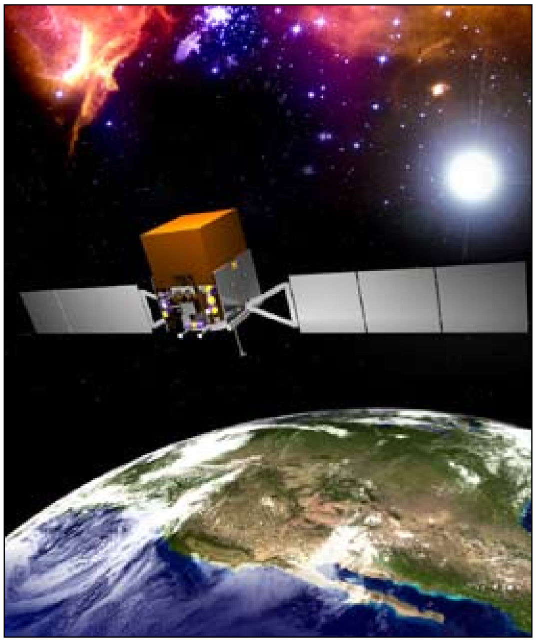


Scientists at the Jet Propulsion Laboratory in California inspect the Dawn spacecraft.

GLAST
Gamma-ray Large Area Space Telescope

Germany

The Gamma-ray Large Area Space Telescope (GLAST) is a spacecraft with the ability to detect gamma rays created by the most energetic objects and phenomena in the universe. Among topics of cosmological interest to be studied by the mission will be the periods of star and galaxy formation in the early universe and on dark matter. Planned for launch in 2008 from Cape Canaveral, Florida, GLAST is designed for a mission lifetime of five years, with a goal of 10 years of operations. NASA is working with the French National Centre for Space Studies (CNES) on the GLAST mission.


Artist concept image of the GLAST spacecraft above Earth (Credit: General Dynamics C4 Systems)

Because of their tremendous energy, gamma rays travel through the universe largely unobstructed. This means GLAST will be able to observe gamma-ray sources near the edge of the visible universe. Gamma rays detected by GLAST will originate near the otherwise obscured central regions of exotic objects like supermassive black holes, pulsars, and gamma-ray bursts.

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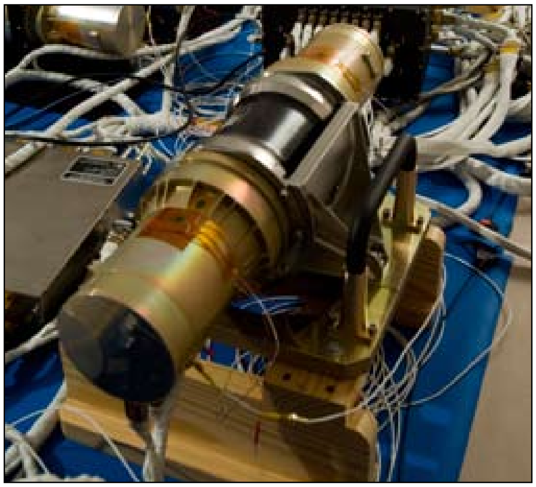


Photo of one of the GBM instruments

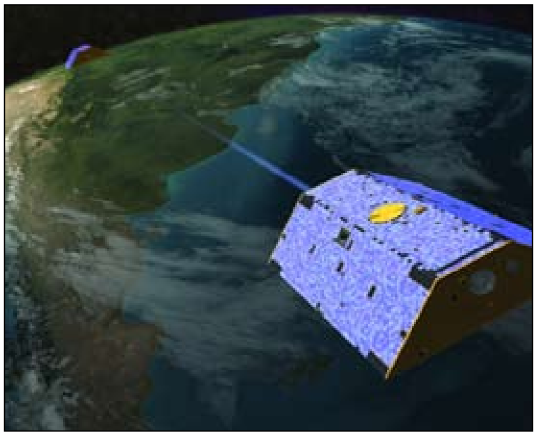
For the GLAST mission, the German Aerospace Center (DLR) provided the GBM instrument detectors. Along with DLR and NASA, the following are cooperating on the GLAST mission: the French National Centre for Space Studies, the Italian Space Agency, the Japan Aerospace Exploration Agency, and the Royal Institute of Technology in Sweden.

For more information about the GLAST mission, please see the following URL: *http://glast.gsfc.nasa.gov/.*

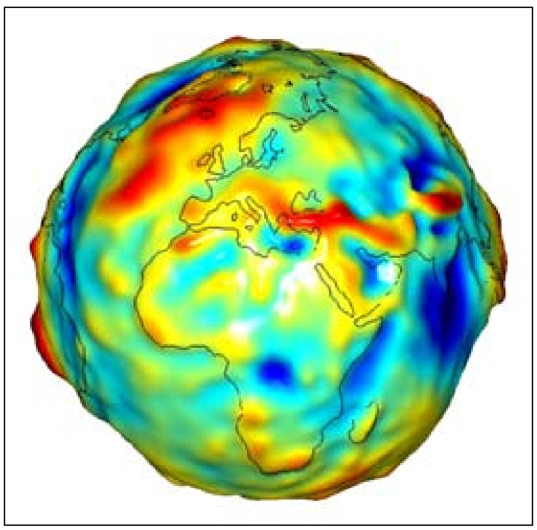
Germany

GRACE

Gravity Recovery and Climate Experiment



Artist concept image of the GRACE satellites in orbit over Earth.



A gravity model of Africa and Europe prepared using data from the GRACE satellites.

The Gravity Recovery and Climate Experiment (GRACE) is a NASA Earth System Science Pathfinder mission supported through a partnership with the German Aerospace Center (DLR). DLR provided the rocket launch vehicle and all launch services for the satellite, and DLR's German Space Operations Center is providing mission operations, controlling the satellite flight operations, and providing data downlink and archive facilities. GRACE was launched on March 17, 2002, on board a Russian rocket vehicle from Plesetsk Cosmodrome in Russia.

GRACE consists of a pair of identical satellites in coplanar formation flight whose relative velocities are measured with submicron/sec velocities over a range of more than 200 kilometers. This tandem formation provides spatial and temporal gravity field measurements of a few micrograms (a few parts per billion) to measure the transport of mass with the Earth system. The two satellites and instruments were provided by NASA's Jet Propulsion Laboratory (JPL). Currently, GRACE is in an extended period of operations beyond its planned mission life of 5 years.

In 2003, using only 111 days of GRACE satellite data, the GRACE science team released a preliminary model of Earth's gravity field 10 to 100 times more accurate than the previous model constructed from decades of geodetic data. GRACE improvements to the gravity field have advanced numerous fields of endeavor, from the observation of the Lense-Thirring effect of general relativity to improvements in continental scale leveling for mapping and development projects.

GRACE time variable gravity data is yielding crucial information about the distribution and movement of mass within the solid Earth and its fluid surroundings. The gravity field of Earth varies both in space and time according to movement of mass due to tectonic forces, ocean and atmospheric circulation, and changing hydrology from weather and climate changes.

GRACE is the newest tool helping oceanographers unlock the secrets of ocean circulation and its effect on climate. Research scientists using GRACE time variable gravity data have estimated post glacial rebound rates, changes in the polar ice sheets and mountain glaciers, changes in water distribution within the world's major drainage basins, changes in deep ocean circulation, and, finally, the relative contributions of ocean warming and water mass distribution to sea level change. The changes in crustal mass distribution caused by the Great Sumatran Earthquake of December 2004 were measured in the GRACE satellite gravity field, yielding new insights into the physics of major earthquakes.

For more information about GRACE, please see the following URLs: *http://www.csr.utexas.edu/grace/ and http://www.dlr.de.*

MER

Mars Exploration Rovers—Spirit and Opportunity

Germany

The German Aerospace Center (DLR) provided two science instruments for the Athena Payload on the Mars Exploration Rover (MER) mission. Athena is MER's science payload, consisting of a package of science instruments that includes two instruments for surveying the landing site and three instruments located on each rover's arm for close-up study of rocks. DLR provided the following two science instruments:

- the Alpha Particle X-ray Spectrometer (APXS) that determines the elemental composition of rocks and soils provides scientists with information about crustal formation and weathering processes
- the Mössbauer Spectrometer (MB) that determines the composition and abundance of iron-bearing minerals and examines the magnetic properties of surface materials provides information about early Martian environmental conditions and possible fossil evidence

DLR also sponsored three German scientists for the MER Science Team, who are conducting the following scientific investigations using MER data: research on soil composition at both global and local scales, an investigation of Martian dust, and research on Martian soil mechanics, including soil perturbations and soil characteristics.

The MER mission, involving two robotic geologists—Spirit and Opportunity—is part of NASA's Mars Exploration Program, a long-term robotic exploration of the Red Planet. Both rovers were launched aboard Delta II launch vehicles from Cape Canaveral, Florida. The first rover was launched on June 10, 2003, and landed on Mars on January 3, 2004. The second rover was launched on July 7, 2003, and landed in a different area of Mars on January 24, 2004.

Primary among the MER mission's scientific goals is to search for and characterize a wide range of rocks and soils that hold clues to past water activity. The MER mission seeks to determine where conditions may once have been favorable to life by analyzing the climate and water histories at sites on Mars. Each rover is equipped with the Athena science payload used to read the geological record at each site, investigate what role water played there, and determine how suitable the conditions would have been for life.

Spirit and Opportunity have worked on Mars for more than ten times their originally planned three-month missions, and both continue to send data downlinks to Earth. Within two months after landing on Mars in early 2004, Opportunity found geological evidence of an environment that was once wet. On October 7, 2006, Spirit set a new milestone by exploring Mars for 1,000 consecutive Martian days.

The rovers are two of five active robotic missions at Mars, including NASA's Mars Odyssey and Mars Reconnaissance orbiters and the European Space Agency's Mars Express orbiter. The orbiters and surface missions complement each other in many ways. Observations by the rovers provide ground-level understanding for interpreting global observations by the orbiters. In addition to their own science missions, the orbiters relay data from the Mars rovers.

For more information about MER, please see the following URLs: *http://marsrovers.nasa.gov/home/index.html and http://athena.cornell.edu/the_mission.*

Artist concept of one of the Mars Exploration Rovers on the Martian surface

This image was taken by Spirit on January 15, 2004, as it rolled from its lander platform onto the Martian soil.

Germany

MSL
Mars Science Laboratory

Artist concept of the MSL on the Martian surface

This image indicates the growing wheel size between the various Mars explorers: Pathfinder, Mars Exploration Rover, and MSL.

The German Aerospace Center (DLR) will provide significant input to the Radiation Assessment Detector (RAD) on the NASA 2009 Mars Science Laboratory (MSL) mission.

The MSL mission is part of NASA's Mars Exploration Program. Developed by NASA, the MSL mission consists of a long duration rover and mobile scientific laboratory equipped to perform scientific studies of Mars. NASA plans to launch MSL in the fall of 2009 from Cape Canaveral, Florida aboard an Atlas V launch vehicle with an arrival date to Mars of October 2010. The mission is planned to last at least one Martian year (687 Earth days).

The primary scientific objectives, to be carried out during the surface science phase of the MSL mission, will be to assess the biological potential of at least one target area, characterize the local geology and geochemistry, investigate planetary processes relevant to habitability (including the role of water), and to characterize the broad spectrum of surface radiation. The landing site, which has not yet been chosen, will be selected based on an assessment of safety and planetary protection, and an analysis by the scientific community.

The RAD will be provided by NASA. DLR will contribute components of the RAD Sensor Head (RSH), including the solid-state-detectors and the scintillator core. The RAD will characterize the broad spectrum of radiation at the surface of Mars, an essential precursor to human exploration of the planet. The RAD will also measure and identify all high-energy radiation on the Martian surface, such as protons, energetic ions of various elements, neutrons, and gamma rays. Included here are not only direct radiation from space, but also secondary radiation produced by the interaction of space radiation with the Martian atmosphere and surface rocks and soils.

For more information about the MSL mission and the RAD instrument, please see the following URLs: *http://mars.jpl.nasa.gov/msl/ and http://marsprogram.jpl.nasa.gov/msl/mission/sc_instru_rad.html.*

Phoenix

Germany

The Phoenix mission to Mars is a telerobotic Mars lander and the first in NASA's "Scout Program." The Phoenix mission is managed by the Jet Propulsion Laboratory (JPL), with international contributions by the Max Planck Institute for Solar System Research (MPS) in Germany, and organizations in Canada, Denmark, and Switzerland. NASA provided the satellite and launch for the Phoenix mission, which was launched on August 4, 2007, onboard a Delta II launch vehicle from Cape Canaveral, Florida.

Phoenix is studying the history of water and search for complex organic molecules in the ice-rich soil of the Martian arctic. Scheduled to land in May 2008 at the planet's northern polar region, Phoenix will use its robotic arm to dig through the Martian soil and reach the water ice layer underneath, then deliver soil and ice samples to the mission's experiments. Chemical analysis will be provided on the deck, and imaging systems will provide a view of Mars spanning 12 powers of 10 in scale.

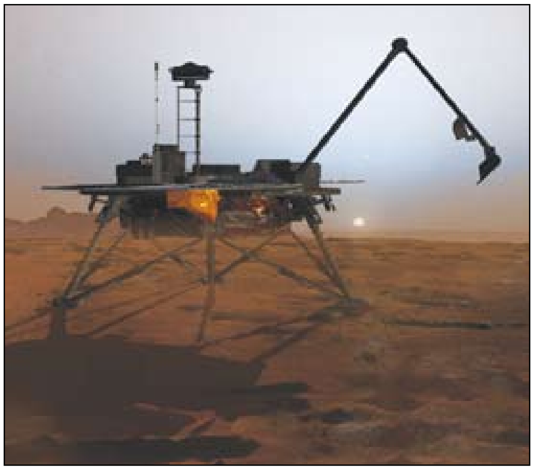
The Robotic Arm Camera (RAC), provided by the University of Arizona and MPS, is mounted on the Robotic Arm (RA) of the Phoenix lander and provides close-up, full-color images of:

- the Martian surface in the vicinity of the lander
- prospective soil and water ice samples in the trench dug by the RA
- verification of collected samples in the scoop prior to analysis
- the floor and side-walls of the trench to examine fine-scale texturing and layering

By examining the color and grain size of scoop samples, scientists will better understand the nature of the soil and water-ice in the trench being dug by the RA.

For more information about the Phoenix Mission, please see the following URLs: *http://solarsystem.nasa.gov/missions/profile.cfm?Sort=Target&Target=Mars&MCode=Phoenix and http://phoenix.lpl.arizona.edu/.*

Artist concept of the Phoenix lander making its descent to the Martian surface



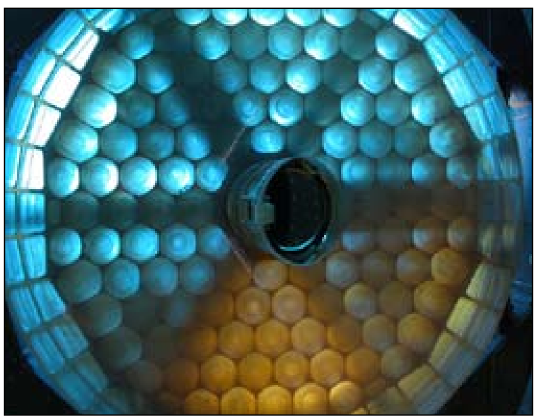
Artist concept of the Phoenix lander beginning work in twilight on the surface of Mars

Germany

SOFIA

Stratospheric Observatory For Infrared Astronomy

The SOFIA aircraft completed its first flight test on April 26, 2007.



Sunlight can be seen through SOFIA's 2.7-meter mirror prior to the addition of the opaque aluminum coating. Once the coating is added, the view will no longer be possible due to the reflective nature of the aluminum coating.

NASA and the German Aerospace Center (DLR) are collaborating on the Stratospheric Observatory For Infrared Astronomy (SOFIA). Unlike its counterpart telescopes in space, SOFIA will consist of a 2.5-meter telescope aboard a modified Boeing 747SP. Not only will it be able to study the universe in the infrared and sub-millimeter spectrum, but SOFIA will also be integral in the development of new observation techniques and instrumentations.

As a flying observatory, SOFIA consists of two main sections: the modified Boeing 747SP and the telescope. This Boeing 747SP was used commercially through 1995. The "SP" indicates that the body of the plane was constructed with a special short-body, as compared to the standard 747. This shorter body allows for longer flight times. The plane was purchased in 1997 by NASA and has been undergoing large modifications since 1998 to transform it into a flying observatory.

The telescope consists of three main mirrors—the largest is a 2.7-meter concave mirror that initially captures the light. After reflecting off the other two mirrors, the image is focused on the focal point, where the instruments will record and analyze the images. Currently, there are nine first light instruments that are in development for SOFIA, including cameras, spectrometers, and photometers that will utilize varying infrared wavelengths. Once the information is gathered, sciences can use it to analyze the birth and death of stars, the formation of solar systems, black holes, and various other space phenomena.

DLR is contributing the telescope, along with two of the planned first light instruments. DLR will also provide additional operation support during the course of the resulting flights.

On April 26, 2007, the SOFIA aircraft completed one of its major milestones: its first flight test. This was the first time the airplane had been airborne since modifications began in 1998.

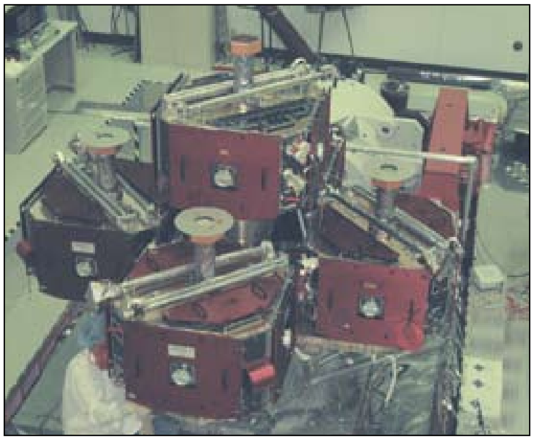
For more information about SOFIA, please see the following URL: *http://www.sofia.usra.edu/index.html.*

THEMIS

Time History of Events and Macroscale Interactions during Substorms

Germany

The Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission is a two-year mission consisting of five identical satellites, each with a suite of five instruments that will study the violent, colorful eruptions in auroras. The German Aerospace Center (DLR) sponsored the Fluxgate Magnetometer (FGM) instrument, which is present on each probe. The mission also incorporates a network of ground-based auroral observatories, many in Canada. THEMIS was launched by NASA on a Delta II launch vehicle from the Kennedy Space Center on February 17, 2007. In addition to DLR, NASA partnered with the Austrian Space Agency, Canadian Space Agency, and French National Centre for Space Studies on the mission.



A photo of the THEMIS probes in preparation for launch at the Jet Propulsion Laboratory in California

One of the science objectives of THEMIS involves determining what physical processes in near-Earth space initiate the violent eruptions in the Earth's magnetosphere known as substorms. Substorms greatly intensify auroras and create the dramatic "dancing" effects witnessed in auroras. Aligning five identical probes over observatories on the North American continent will allow scientists to collect coordinated measurements along the Earth's magnetic field lines, thereby providing the first comprehensive look at the onset of substorms and the manner in which they trigger auroral eruptions.

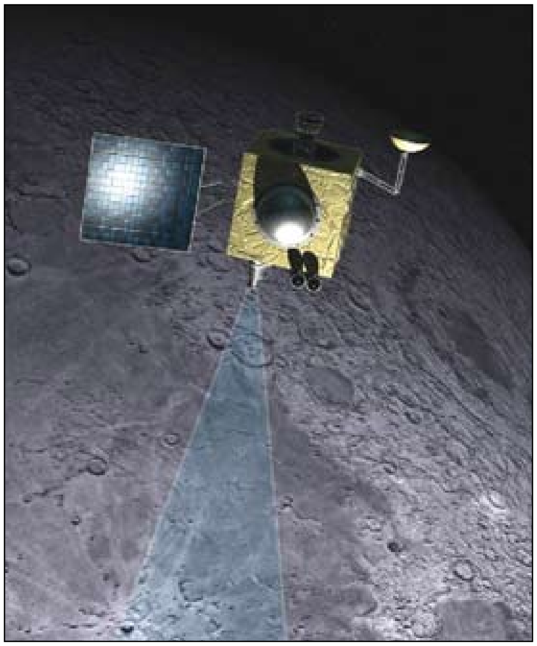
DLR and the Technical University of Braunschweig developed and tested the FGM. The FGM measures the background magnetic field in order to identify and time the abrupt reconfigurations of the magnetosphere during substorm onset.

For more information about THEMIS, please see the following URL: *http://www.nasa.gov/mission_pages/themis/main/index.html.*

An artist concept of the THEMIS probes once in orbit around the Earth

India

Chandrayaan-1

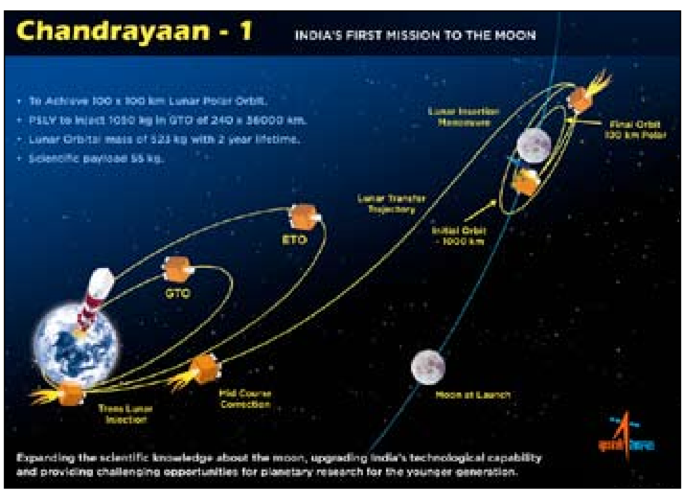


Artist concept of the Chandrayaan-1 spacecraft above the lunar surface

Chandrayaan-1, India's first lunar mission, is intended to perform high resolution, three-dimensional mapping of the Moon's topographic features and to define the distribution of elements and minerals covering the entire lunar surface. It is being developed by the Indian Space Research Organization (ISRO) and will launch in early 2008 on an Indian launch vehicle into a lunar polar orbit for a two year mission.

The Chandrayaan-1 spacecraft, which India is providing, will carry eleven instruments: four instruments and a small lunar impactor provided by ISRO, four instruments from Europe, and two NASA-sponsored instruments. The NASA-sponsored instruments are the Moon Mineralogy Mapper (M3), built by NASA's Jet Propulsion Laboratory, and the Miniature Synthetic Aperture Radar (Mini-SAR), built by the Naval Air Warfare Center. The M3 instrument is a state-of-the-art imaging spectrometer that will provide the first map of the entire lunar surface at high spatial and spectral resolution, revealing the minerals of which the lunar surface is made. Scientists will use this information to answer questions about the Moon's origin and development and the evolution of terrestrial planets in the early solar system. Future astronauts may use it to locate resources, possibly including water, which can support exploration of the Moon and beyond.

The Mini-SAR instrument is a small imaging radar that will map the scattering properties of the permanently dark lunar polar regions, including large areas that are never visible from the Earth. The objective is to determine the location and distribution of potential water ice deposits. Scientists will use these data to learn about the history of the impact of volatile components (mostly comets) in the inner solar system and dynamic processes that perturb material from the outer into the inner solar system. In addition, significant sources of water ice could become useful for supporting future space exploration activities. In addition to two science instruments, NASA will provide space communications support to Chandrayaan-1. The primary location for the NASA ground tracking station will be at the Applied Physics Laboratory in Maryland.



Planned trajectory of India's Chandrayaan-1 spacecraft

ISRO-provided instruments include a Terrain Mapping Camera to produce a high-resolution map of the Moon, a Hyper Spectral Imager to perform mineralogical mapping, a Lunar Laser Ranging Instrument to determine the surface topography, and an x-ray fluorescence spectrometer to map the abundance of various elements in the lunar surface.

For more information about Chandrayaan-1, please see the following URLs: *http://www.isro.org/chandrayaan-1/ and http://moonmineralogymapper.jpl.nasa.gov/.*

Dawn
Asteroid Rendezvous Mission

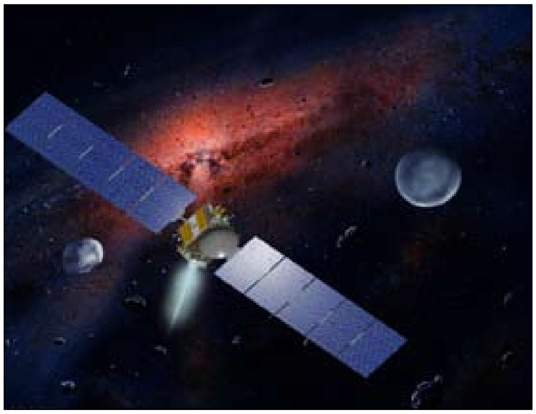
Italy

The Dawn Mission is sending an orbiting space probe to examine the dwarf planet Ceres and the asteroid Vesta, two of the most massive members of the asteroid belt. This is the first science mission to make use of ion propulsion and will also be the first mission to visit and go into orbit around two distinct bodies other than the Earth and the Moon. Dawn launched on September 27, 2007, on a Delta II launch vehicle.

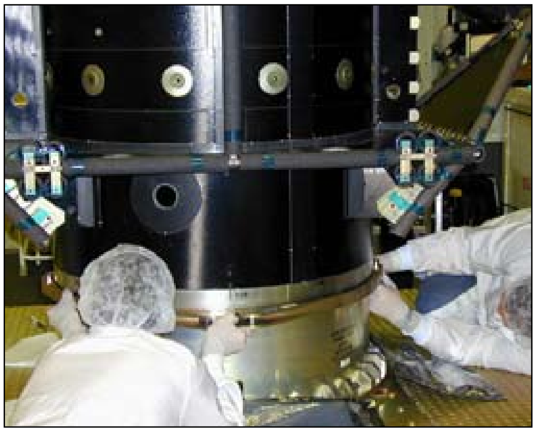
Dawn's goal is to characterize the conditions and processes of the solar system's earliest epoch by investigating in detail two of the largest protoplanets that have remained relatively intact since their formations. Together with many other smaller bodies, Ceres and Vesta reside in the extensive zone between Mars and Jupiter called the asteroid belt. Each has followed a very different evolutionary path, constrained by the diversity of processes that operated during the first few million years of solar system evolution.

The Italian Space Agency (ASI) developed, supported, and integrated the Visual and Infrared Mapping Spectrometer (VIR-MS) instrument for the Dawn Mission. The VIR-MS is a high spatial resolution spectrometer that will be used to study both the surface and atmosphere by acquiring a spectrally resolved image of a two-dimensional scene.

For more information about the Dawn mission, please see the following URL: *http://dawn.jpl.nasa.gov/mission/index.asp.*



Artist concept of the Dawn spacecraft (Credit: UCLA)

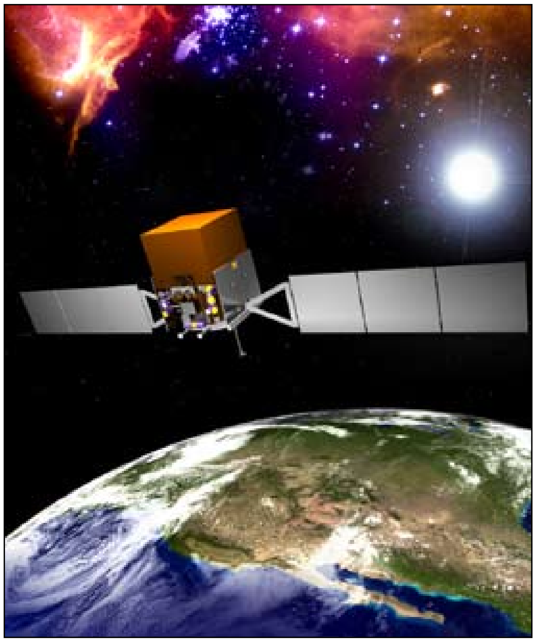


Scientists at the Jet Propulsion Laboratory inspect the Dawn spacecraft.

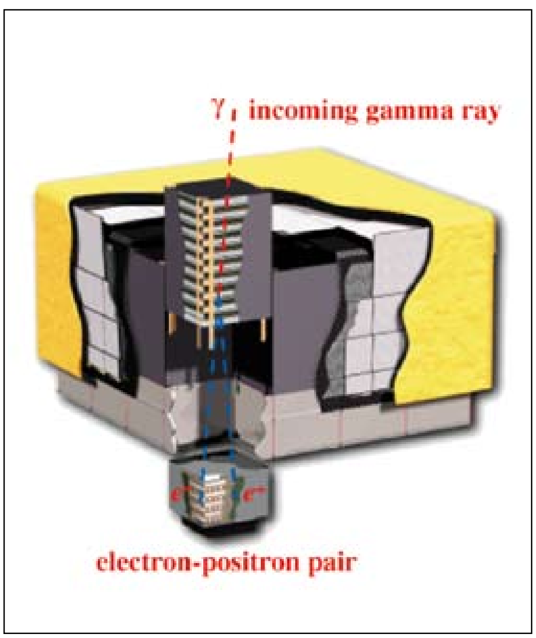
Italy

GLAST

Gamma-ray Large Area Space Telescope



Artist concept image of the GLAST spacecraft above Earth (Credit: General Dynamics C4 Systems



Artist concept image of the LAT instrument (Credit: LAT Collaboration)

The Gamma-ray Large Area Space Telescope (GLAST) is a spacecraft with the ability to detect gamma rays created by the most energetic objects and phenomena in the universe. Among topics of cosmological interest to be studied by the mission will be the periods of star and galaxy formation in the early universe and on dark matter. Planned for launch in 2008 from Cape Canaveral, Florida, GLAST is designed for a mission lifetime of five years, with a goal of 10 years of operations. NASA is working with the French National Centre for Space Studies (CNES) on the GLAST mission.

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For the GLAST mission, the Italian Space Agency (ASI) provided support for the development of the LAT instrument, specifically the trackers that will determine the direction of the gamma waves. Along with ASI and NASA, the following are also cooperating on the GLAST mission: the French National Centre for Space Studies, the German Aerospace Center, the Japan Aerospace Exploration Agency, and the Royal Institute of Technology in Sweden.

For more information about the GLAST mission, please see the following URL: *http://glast.gsfc.nasa.gov/.*

MPLM FOR THE ISS

Multi-Purpose Logistics Module for the International Space Station

Italy

The Italian Space Agency's (ASI) contribution to the International Space Station (ISS) Program consists of three Multi-Purpose Logistics Modules (MPLM) named Leonardo, Raffaello, and Donatello. In exchange for the development and manufacturing of these elements as NASA-provided contributions to the ISS Program, NASA is providing to ASI several astronaut flight opportunities and utilization rights aboard the ISS.

NASA's contributions to the ISS Program include overall management, coordination and integration of the ISS Program, hardware components, and transportation for crew and logistics via the Space Shuttle, and, in the future, the Crew Exploration Vehicle (CEV) and commercial transportation services. Hardware components include the U.S. laboratory module, the Airlock for extravehicular activities (EVA), truss segments to support the U.S. solar arrays and thermal radiators, three connecting nodes, and living quarters.

The ISS functions as an orbital microgravity and life sciences laboratory, a testbed for new technologies in areas such as life support and robotics, and a platform for astronomical and Earth observations. The ISS also serves as a unique engineering testbed for flight systems and operations critical to NASA's exploration mission. U.S. research on the ISS will concentrate on the long-term effects of space travel on humans and engineering development activities in support of exploration. Hailed as the most ambitious engineering feat in human history, the ISS is a stepping stone for human exploration and scientific discovery beyond low-Earth orbit.

MPLMs are pressurized, reusable logistics modules that function both as cargo carriers between the ground and the ISS and as attached ISS modules. As cargo carriers aboard the Space Shuttle, MPLMs carry laboratory racks filled with equipment, experiments, and supplies to the ISS, and carry excess materials from the ISS to the ground. While berthed to the ISS, MPLMs are fully functioning extra work areas (with components that provide life support, fire detection and suppression, electrical distribution, and computer functions) used by the crew for daily living and specific experiments and procedures.

For more information about ASI's contributions to the ISS, please see the following URLs: *http://mplm.msfc.nasa.gov/mission.html, http://scipoc.msfc.nasa.gov/photosmplm.html, and http://ksnn.larc.nasa.gov/rtf/art_greatmovingvan.htm.*

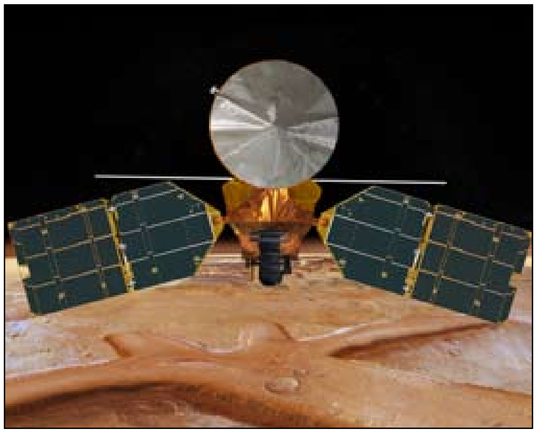
Picture of interior of MPLM

Picture of MPLM berthed at Node 1

Italy

MRO

Mars Reconnaissance Orbiter



The 10-meter long SHARAD radar antenna is visible below the High-Gain Antenna used for telecommunications and above the solar array panels. (Artist concept of the MRO)

The MRO returned this enhanced-color view of the eastern rim and floor of "Victoria Crater" in Mars, which the Mars Exploration Rover, Opportunity, was investigating at the same time. SHARAD will probe the subsurface searching for buried craters and layering.

The Italian Space Agency (ASI) provided the Shallow Subsurface Radar (SHARAD), one of six science instruments, on NASA's Mars Reconnaissance Orbiter (MRO) mission.

NASA's MRO was launched on August 12, 2005, aboard an Atlas V launch vehicle from Cape Canaveral, Florida, and arrived at Mars on March 10, 2006, after which it took six months to enter its final near-circular, near-polar, low-altitude science orbit through a technique called aerobraking.

MRO is primarily intended to investigate the history of water on Mars by performing remote sensing science investigations in Mars orbit. MRO is designed to conduct observations in several parts of the electromagnetic spectrum, including ultraviolet and visible imaging, visible to near-infrared imaging spectrometry, thermal infrared atmospheric sounding, and radar subsurface profiling, at spatial resolutions that are substantially better than any preceding Mars orbiter. MRO will also be used to identify and characterize sites for future landed missions and provide critical telecommunications relay capability for follow-on Mars missions.

SHARAD will be used to probe the three-dimensional cross-sections of the layer structure of the upper 500-1000 meters of the Martian surface with high vertical resolution and landform-scale horizontal sampling for the shallow subsurface. The goal is to characterize subsurface layering and to determine if liquid or frozen water exists within the first few hundreds of feet of Mars' crust. SHARAD works by sending out and recording the return of radar pulses of energy, emitted and captured by the SHARAD antenna. The timing of the radar return is sensitive to changes in the electrical properties of the rock, sand, and any water present in the surface and subsurface. Water, like high-density rock is very conducting, and will have a very strong radar return. Changes in the reflection characteristics of the subsurface, such as layers deposited by geological processes throughout Mars history, will also be visible.

MRO is one of five active robotic missions at Mars, which include NASA's Mars Odyssey, the Mars Exploration Rovers—Spirit and Opportunity—and the European Space Agency's Mars Express orbiter. The orbiters and surface missions complement each other in many ways. Observations by the rovers provide ground-level understanding for interpreting global observations by the orbiters. In addition to their own science missions, the orbiters relay data from the Mars rovers.

For more information about MRO and SHARAD, please see the following URLs: *http://marsprogram.jpl.nasa.gov; and http://www.sharad.org.*

Swift
Swift Gamma Ray Burst Explorer

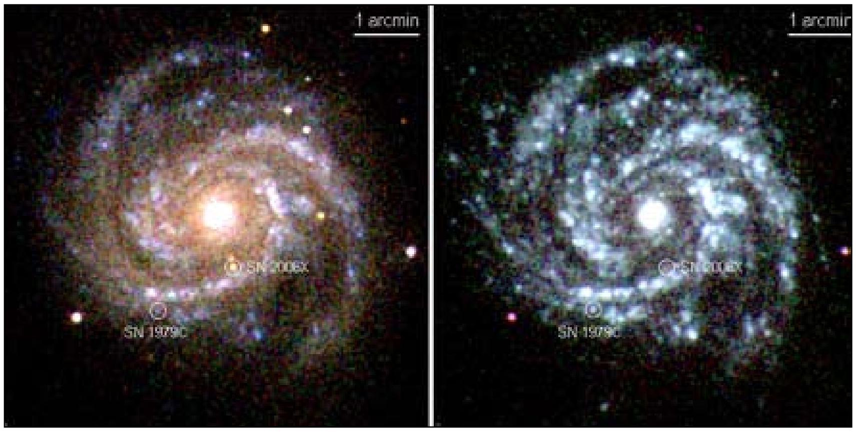
Italy

NASA's Swift Gamma Ray Burst Explorer (Swift) mission is a multi-wavelength astrophysics observatory to make a comprehensive study of hundreds of Gamma Ray Bursts (GRBs) in order to determine the origin and physical processes of GRB events. The Swift mission was launched on November 20, 2004, into low-Earth orbit aboard a Delta II launch vehicle from Cape Canaveral, Florida, and was expected to have a nominal lifetime of two years and an orbital lifetime of approximately eight years. Updated orbital lifetime predictions for Swift project it to remain in orbit up to 2022. The Italian Space Agency (ASI) cooperated with NASA on the development and operation of the Swift mission.

Artist concept image of the Swift spacecraft with a gamma-ray burst in the background

GRBs are incredibly intense releases of gamma radiation, which is a particularly energetic form of light that can only be generated by the most powerful astronomical events. Swift is the next-generation satellite to observe GRBs. In addition, it's a first-of-its-kind multi-wavelength observatory dedicated to the study of GRB science. Its three instruments work together to patrol about 1/6th of the sky at a time in order to pinpoint and observe GRBs and afterglows in the gamma ray, x-ray, ultraviolet, and optical wavebands.

Just 20 to 75 seconds after Swift's large field-of-view telescope, when the Burst Alert Telescope detects and calculates the position of a GRB, the satellite automatically turns, aiming its two narrow field-of-view telescopes, the X-ray Telescope (XRT), and the UltraViolet/Optical Telescope (UVOT) at the GRB. The XRT and UVOT have co-aligned fields-of-view so that any source can be observed in all three wavebands. The Mission data is available to the public via the internet as soon as they are processed.



Two images of the same supernova were taken by the Swift spacecraft. These images were taken at different wavebands using the UVOT instrument.

ASI provided the Swift x-ray mirror and associated components for the XRT, and led the development of XRT data analysis software and data processing software. The XRT takes images and measures light energy (spectra) of afterglows that follow GRBs. Additionally, the Italian ground station at Malinda, Kenya, is the primary ground station for the entire Swift mission. ASI also provided the network infrastructure (ASINet) and maintains the transmission of Swift data between Malinda and the ASINet gateway at NASA's Johnson Space Center. ASI also provides the Italian Swift Archive Center.

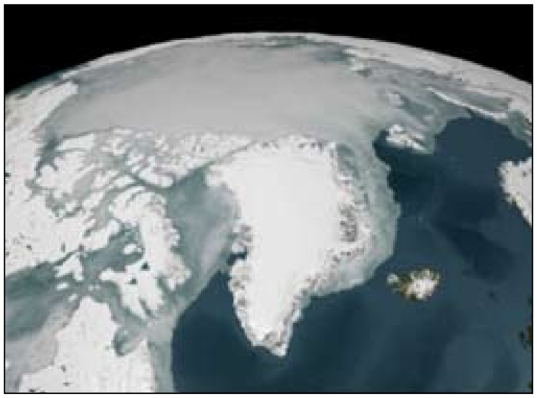
In just ten months of operation, Swift had discovered the farthest GRB ever seen, identified counterparts to short GRBs, and has discovered new GRBs at a rate of 100 per year. Through coordinated observations of ground-based telescopes and NASA satellites, scientists determined that short GRBs arise from violent collisions in space either between a black hole and a neutron star or between two neutron stars, which creates a new black hole. On September 4, 2005, Swift and ground-based telescopes detected the most distant GRB yet, from the edge of the visible universe.

For more information about Swift and the XRT, please see the following URLs: *http://swift.gsfc.nasa.gov and http://www.nasa.gov/mission_pages/swift/spacecraft/index.html.*

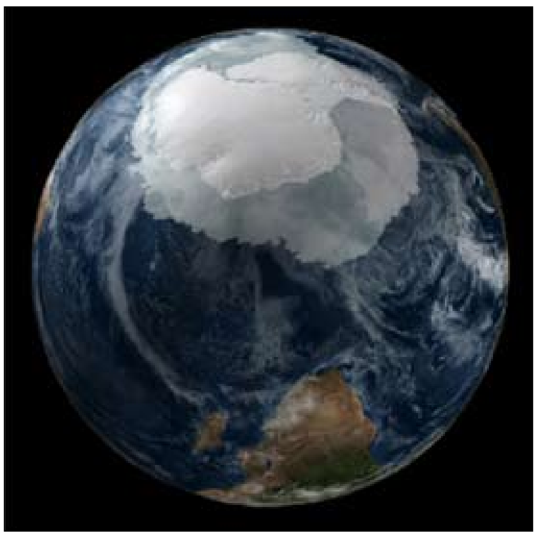
Japan

AMSR-E/Aqua

Advanced Microwave Scanning Radiometer/Aqua



This image of sea ice over the Arctic on March 11, 2005, was created from data collected from the AMSR-E instrument.



This image of Antarctica was taken in September 2005 by the AMSR-E instrument.

The Japan Aerospace Exploration Agency (JAXA) provided the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) instrument for NASA's Aqua satellite, which was launched on May 4, 2002, onboard a Delta II launch vehicle from Vandenberg Air Force Base, California. Aqua is operating in a Sun-synchronous, near-polar low-Earth orbit, and orbits the Earth a little more than 14 times a day. Aqua has a planned mission life of six years.

AMSR-E is one of six state-of-the art instruments onboard Aqua. Each instrument has unique characteristics and capabilities and were designed to serve together to form a powerful package for Earth observations. AMSR-E is a passive, forward-looking scanning radiometer with 12 channels at six discrete microwave frequencies, which measures brightness temperatures in the range of 6.9 to 89.0 gigahertz.

Aqua is part of the NASA-centered international Earth Observing System (EOS). Aqua was named for the large amount of information that the mission will be collecting about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Aqua is also collecting information about radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures. Aqua is the first of a group of six satellite missions that are part of an afternoon constellation, signifying their afternoon equatorial crossing time.

AMSR-E measures geophysical parameters that are critical to understanding the Earth's climate, including precipitation, oceanic water vapor, cloud water, near-surface wind speed, sea surface temperature (SST), soil moisture, snow cover, and sea ice. AMSR-E is providing unprecedented detail and accuracy in the global, all-weather measurement of these variables and thereby will allow a more-complete understanding of climate variability, and ultimately, enabling better climate prediction. Since November 2004, the Japan Meteorological Agency has used AMSR-E data in its Meso-Scale Model that is used to predict small-scale weather phenomena and has contributed to improving the accuracy of predicting heavy rain. The Japan Fisheries Information Center is combining the infrared SST with the AMSR-E SST for a more accurate analysis to assist fisherman in locating different species of fish.

The Joint NASA-JAXA AMSR-E Science Team collaborated on validation activities and AMSR-E data analysis efforts.

Aqua is making critical contributions to monitoring terrestrial and marine ecosystem dynamics.

For more information about AMSR-E, please see the following URLs: *http://www.ghcc.msfc.nasa.gov/AMSR and http://sharaku.eorc.jaxa.jp/AMSR/index_e.htm.*

ASTER/Terra

Advanced Spaceborne Thermal Emission and Reflection Radiometer/Terra

Japan

The Japan Ministry of Economy, Trade and Industry (METI) provided the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument for NASA's Terra satellite, which was launched on December 18, 1999, on a Delta II launch vehicle from Vandenberg Air Force Base, California. ASTER provides high-spatial-resolution, multispectral images of Earth's surface and clouds. It has 14 spectral bands in the visible to the thermal infrared wavelength region and high spatial resolutions of 15 to 90 meters. Terra is NASA's first Earth Observing System platform providing global data on major aspects of the biosphere, atmosphere, and oceans atmosphere. It carries five state-of-the-art sensors that study the interactions among Earth's atmosphere, lands, and oceans. Terra had a planned mission life of six years and is now operating in extended mission phase.

ASTER is the high-spatial-resolution instrument on the Terra satellite. ASTER's ability to serve as a "zoom" lens for the other Terra instruments is particularly important for change detection, calibration/validation, and land surface studies. All three ASTER telescopes (visible and near-infrared, short-wavelength infrared, and thermal infrared) are pointable in the crosstrack direction. In addition, a second visible and near-infrared camera looks aft along a track and provides the capability to produce high-quality digital terrain topography.

Millions of ASTER scenes and derived products have been distributed to users around the world through the Ground Data System at Japan's Earth Remote Sensing Data Analysis Center and the U.S. Land Processes Distributed Active Archive Center in Sioux Falls, South Dakota. ASTER data and derived products—including detailed maps of land surface temperature, emissivity, reflectance, and elevation—are important scientific tools to users from many Earth science disciplines. They are routinely used in studying geologic processes, monitoring land cover conditions and change, investigating hydrologic resources and processes, monitoring crop condition and development, studying natural disasters (e.g., flooding and volcanic activity), and performing many other important research and practical applications.

For more information about ASTER or NASA's Terra mission, please see the following URLs: *http://terra.nasa.gov; http:/asterweb.jpl.nasa.gov and http://www.ersdac.or.jp/eng/index.E.html.*

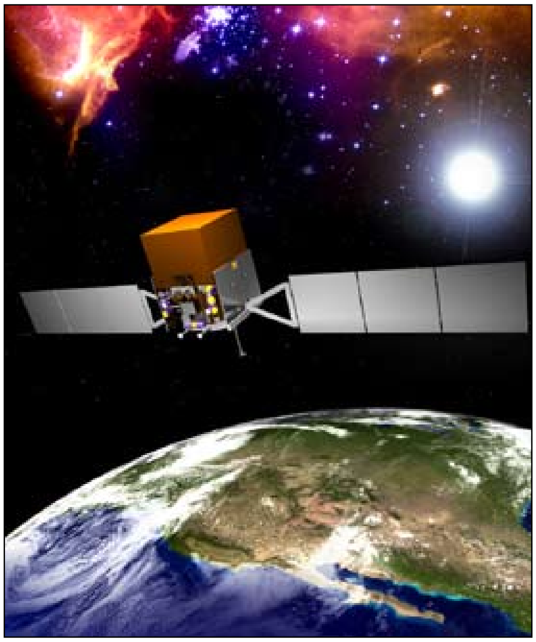
In this ASTER image, short-wavelength infrared bands are combined to highlight the different rock types, thereby illustrating the complex folding of the Anti-Atlas Mountains in Morocco. The yellowish, orange, and green areas are limestones, sandstones, and gypsum; the dark blue and green areas are underlying granitic rocks.

ASTER image of Washington, DC

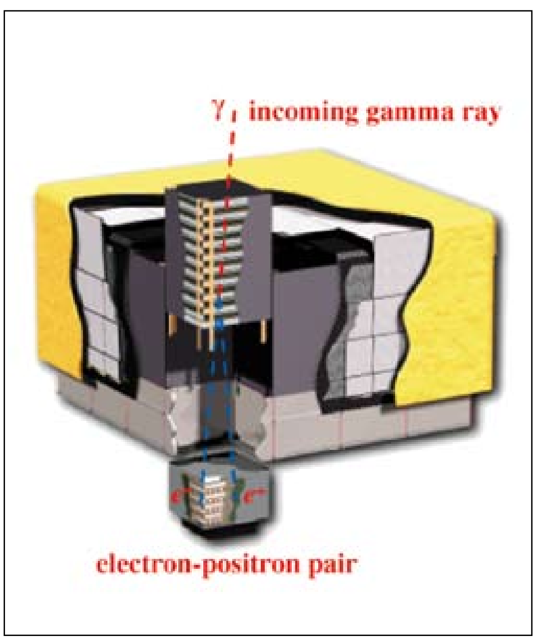
Japan

GLAST

Gamma-ray Large Area Space Telescope



Artist concept image of the GLAST spacecraft above Earth (Credit: General Dynamics C4 Systems)



Artist concept of the LAT instrument (Credit: LAT Collaboration)

The Gamma-ray Large Area Space Telescope (GLAST) is a spacecraft with the ability to detect gamma rays created by the most energetic objects and phenomena in the universe. Among topics of cosmological interest to be studied by the mission will be the periods of star and galaxy formation in the early universe and on dark matter. Planned for launch in 2008 from Cape Canaveral, Florida, GLAST is designed for a mission lifetime of five years, with a goal of 10 years of operations. NASA will be working with the Japan Aerospace Exploration Agency (JAXA) on the GLAST mission.

Because of their tremendous energy, gamma rays travel through the universe largely unobstructed. This means GLAST will be able to observe gamma-ray sources near the edge of the visible universe. Gamma rays detected by GLAST will originate near the otherwise obscured central regions of exotic objects like supermassive black holes, pulsars, and gamma-ray bursts.

In order to study these high energy waves, two main instruments will be used: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The LAT will detect gamma rays by using a technique known as pair-conversion in which a gamma ray slams into a layer of tungsten in the detector, creating a pair of subatomic particles. These particles in turn hit another, deeper layer of tungsten, each creating further particles, and so on. The direction of the incoming gamma ray is determined by tracking the direction of these cascading particles back to their source using high-precision silicon detectors. A separate detector counts up the total energy of all the particles created. The GBM is designed to observe gamma ray bursts, which are sudden, brief flashes of gamma rays that are detectable once or twice a day at random positions across the sky. The sources of these flashes are a mystery, but they are among the most powerful explosions in the universe.

For the GLAST mission, JAXA provided support for the development of the LAT instrument, specifically the silicon detectors that will determine the direction of the gamma waves. Along with JAXA and NASA, the following are also cooperating on the GLAST mission: the French National Centre for Space Studies, the German Aerospace Center, the Italian Space Agency, and the Royal Institute of Technology in Sweden.

For more information about the GLAST mission, please see the following URL: *http://glast.gsfc.nasa.gov/.*

Hayabusa (MUSES-C)

Japan

Hayabusa (MUSES-C) is an unmanned mission led by the Japan Aerospace Exploration Agency (JAXA) to collect a surface sample of material from the asteroid 25143 Itokawa and return the sample to Earth for analysis. After the successful launch of the spacecraft on May 9, 2003, from the Japanese Kagoshima Launch site, the mission name was changed from MUSES-C to Hayabusa.

Hayabusa rendezvoused with Itokawa in mid-September 2005 to map the asteroid in the visible, infrared, and x-ray spectrums, while also performing gravity modeling with its laser altimeter. Since then, the spacecraft has touched down twice, but it is unclear whether or not samples were collected. If collected, the samples are stored in containers inside a sealed sample return capsule that will detach from the spacecraft, enter the Earth's atmosphere, and use a parachute for a soft landing on the ground in Australia in 2010.

While the scientific knowledge of near-Earth asteroids will be significantly advanced by the Hayabusa mission, the primary goals were to test four advanced technology systems: the electric propulsion (ion drive) engines; an autonomous navigation system; the sample collection system; and the sample capsule that re-enters the Earth's atmosphere.

NASA resources provided backup spacecraft tracking, telemetry, command, and navigation support through the Deep Space Network, and NASA scientists are participating in selected spacecraft science experiments.

Although contact was lost with Hayabusa on December 9, 2005, communications were recovered. However, it is not clear from the telemetry that the sample return mechanism operated on the surface. The spacecraft began its return trip to Earth on April 25, 2007, and is scheduled to land in Australia in June 2010.

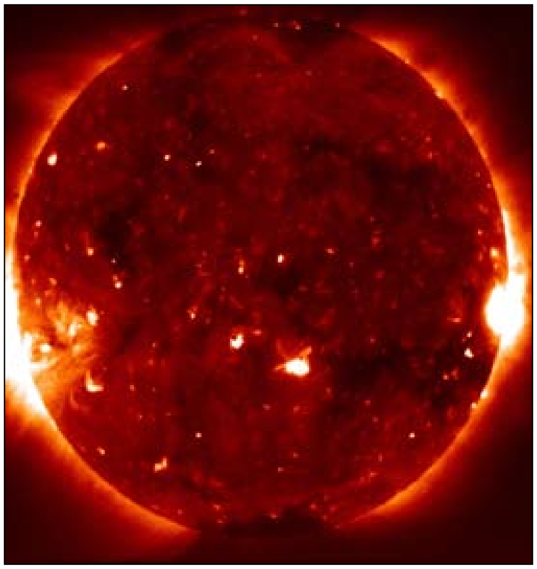
For more information about Hayabusa, please see the following URLs: *http://www.hayabusa.isas.jaxa.jp/ and http://nssdc.gsfc.nasa.gov/database/MasterCatalog?sc=2003-019A.*

Artist concept of the Hayabusa spacecraft near an asteroid

Artist concept of the Hayabusa spacecraft collecting samples from the surface of an asteroid

Japan

Hinode (Solar-B)



Taken on October 28, 2006, this x-ray image of the Sun was taken by the Hinode X-ray Telescope.

Artist concept of the Hinode spacecraft

Launched on September 23, 2006, in a mission led by the Japan Aerospace Exploration Agency (JAXA), Hinode (formerly known as Solar-B) spacecraft that will be used to study the Sun, specifically, to measure the Sun's magnetic field and ultraviolet and x-ray radiation. Hinode is a joint mission between NASA, JAXA, and the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom. Hinode was launched by JAXA on September 23, 2006, from the Uchinoura Space Center, Japan, on an M-V launch vehicle.

The mission consists of a coordinated set of optical, extreme ultraviolet (EUV) and x-ray instruments that will study the interaction between the Sun's magnetic field and its high temperature, ionized atmosphere. Hinode is circling Earth in a polar flight path—a Sun-synchronous orbit—that allows the spacecraft's instruments to remain in continuous sunlight for nine months each year. The three instruments will study the generation, transport, and dissipation of magnetic energy from the photosphere to the corona and will record how energy stored in the Sun's magnetic field is released—either gradually or violently—as the field rises into the Sun's outer atmosphere. By studying the Sun's magnetic field, scientists hope to answer some fundamental questions about our nearest star and to shed new light on explosive solar activity that can interfere with satellite communications and electric power transmission grids on Earth.

JAXA is the overall lead for the Hinode mission, the spacecraft, the launch vehicle, and the management of space operations. The soft x-ray telescope was developed by both JAXA and NASA, while the EUV Imaging Spectrograph was developed by JAXA, NASA and the PPARC. NASA, along with the National Astronomical Observatory of Japan, and JAXA developed the Solar Optical Telescope.

Since the launch, the mission and instruments are proceeding nominally. Scientists report unprecedented initial data. Some of the first images that were returned included an x-ray image of the Sun, a magnified, optical image of the Sun's surface and an exceptional sequence of magnetograms showing development of a major solar flare.

For more information about Hinode, please see the following URL: *http://www.nasa.gov/mission_pages/solar-b/.*

ISS
International Space Station

Japan

The Japan Aerospace Exploration Agency's (JAXA) primary contributions to the ISS Program are the Japanese Experiment Module (JEM) called Kibo, which means "hope" in Japanese, and the H-II Transfer Vehicle (HTV), an unmanned logistics resupply vehicle.

NASA's contributions to the ISS Program include overall management, coordination, and integration of the ISS Program, hardware components, and transportation for crew and logistics via the Space Shuttle, and in the future the Crew Exploration Vehicle (CEV) and commercial transportation services. Hardware components include the U.S. laboratory module, the Airlock for extravehicular activities (EVA), truss segments to support the US solar arrays and thermal radiators, three connecting nodes, and living quarters.

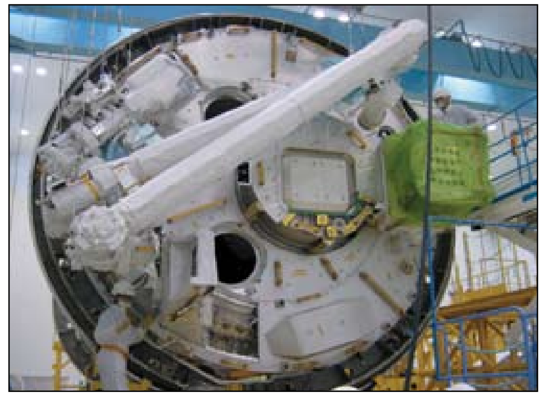
The ISS Program is a partnership among the space agencies of Canada, Europe, Japan, Russia and the United States to build an orbiting outpost and research facility at an altitude of approximately 400 kilometers. Construction began in November 1998, and international crews have continuously inhabited the ISS since November 2000. By the time the ISS is completed in 2010, a crew of six will be able to live and work on board, supported by a cadre of international vehicles, control centers and ground support personnel.

The ISS functions as an orbital microgravity and life sciences laboratory, a testbed for new technologies in areas such as life support and robotics, and a platform for astronomical and Earth observations. The ISS also serves as a unique engineering testbed for flight systems and operations critical to NASA's exploration mission. U.S. research on the ISS will concentrate on the long-term effects of space travel on humans and engineering development activities in support of exploration. Hailed as the most ambitious engineering feat in human history, the ISS is a stepping stone for human exploration and scientific discovery beyond low-Earth orbit.

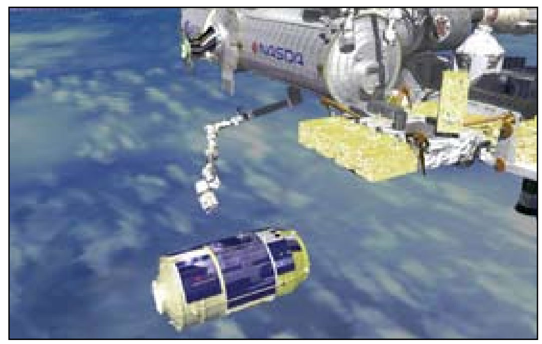
The JEM is Japan's first human space facility and enhances the unique research capabilities of the ISS. The JEM consists of six components: two research facilities (the Pressurized Module and Exposed Facility); a Logistics Module attached to each research facility; a Remote Manipulator System (RMS); and an Inter-Orbit Communication System unit. Experiments in the JEM focus on space medicine, biology, earth observations, material production, biotechnology, and communications research. JEM experiments and systems are operated from the Mission Control Room at Tsukuba Space Center in Japan.

The HTV is an autonomous logistical resupply vehicle designed to berth to the ISS using the Space Station Remote Manipulator System. The HTV offers the capability to carry logistics materials in both its internal pressurized carrier, as well as in an unpressurized carrier for exterior placement. It is launched from southern Japan on the H-II unmanned launch vehicle, and can carry dry cargo, gas and water. After fresh cargo is unloaded at the ISS, the HTV is loaded with trash and waste products; after unberthing and deorbit, it is incinerated during reentry.

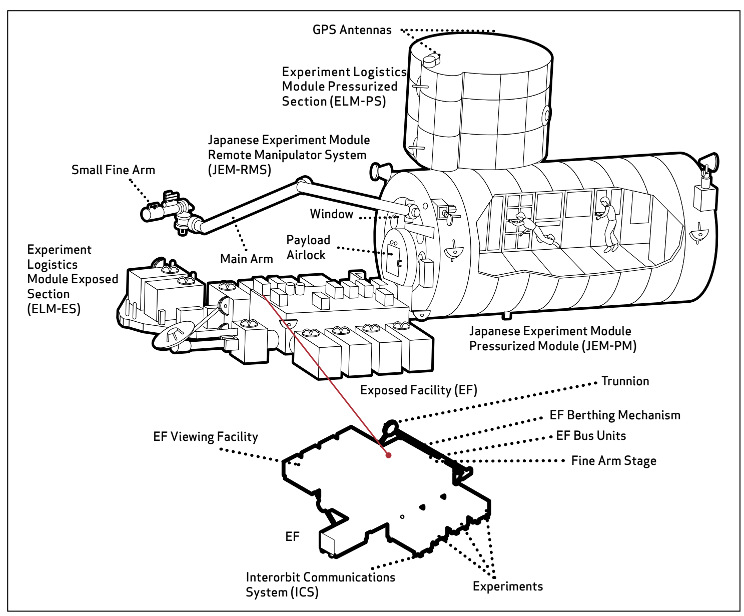
For more information about the ISS and Japan's contributions, please see the following URLs: *http://www.nasa.gov/mission_pages/station/structure/elements/jem.html and http://www.jaxa.jp/projects/iss_human/jem/index_e.html.*



The JEM-PM during testing



Artist concept of the HTV being berthed onto the JEM by the Space Station Remote Manipulator System



The graphic above illustrates the different components of the JEM.

Japan

Kaguya (SELENE)-LRO

SELenological and ENgineering Explorer and Lunar Reconnaissance Orbiter Missions

Artistic rendering of Kaguya/SELENE (Credit: University of Tsukuba, JAXA)

Artistic rendering of LRO spacecraft

In 2007, the Japan Aerospace Exploration Agency (JAXA) and NASA embarked on a unique collaboration to benefit lunar exploration by using data from JAXA's mission to help plan for NASA's future lunar missions; and using NASA's Deep Space Network (DSN) support for various aspects of JAXA's mission.

The Japanese SELenological and ENgineering Explorer (SELENE), recently named "Kaguya" after a Japanese fable, will consist of a main orbiting satellite and two sub-satellites—the Relay Satellite and Very Long Baseline Interferometry (VLBI) radio source (VRAD) satellite. Kaguya/SELENE launched on September 14, 2007, on an H-IIA rocket. NASA's Lunar Reconnaissance Orbiter (LRO) is planned for launch in late 2008 on an Atlas vehicle. A secondary mission, the Lunar CRater Observation and Sending Satellite (LCROSS), will be launched on the same rocket.

Kaguya/SELENE will benefit during the pre-launch phase from testing services provided by DSN, including scheduling and navigation services during critical phases and contingency operation services during the nominal operation phase. As Japan's first lunar explorer, Kaguya/SELENE seeks to help researchers understand the Moon's origin and evolution (largely unexplored by previous lunar missions), and to provide lunar observations that will be utilized in the future. After a year of mapping, the orbiter's propulsion unit will separate and land on the Moon to test Japan's landing technology and send a signal from the lunar surface.

JAXA will provide NASA with early access to data for use in planning future lunar missions, such as LRO—the first of NASA's new robotic missions to explore the Moon in preparation for manned returned and the establishment of a sustained human presence—and the LCROSS mission. The current LRO mission profile calls for at least one year of operation orbiting the Moon to create high-resolution maps, seek landing sites, and continue to search for water ice and other useful resources.

For more information about Kaguya/SELENE and LRO, please see the following URLs: *http://www.jaxa.jp/projects/sat/selene/index_e.html and http://lunar.gsfc.nasa.gov/.*

Suzaku (Astro-E2)

Japan

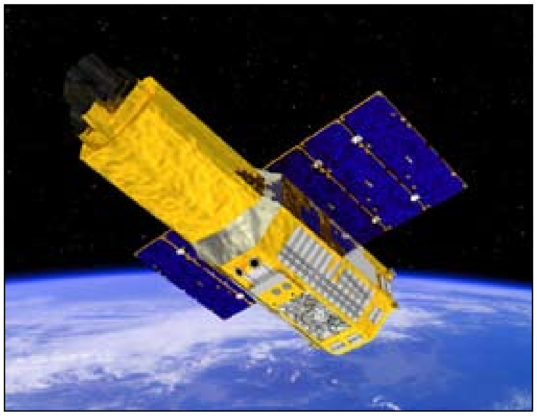
The Suzaku (Astro-E2) satellite is a powerful orbiting observatory for studying extremely energetic processes in the universe, such as neutron stars, active and merging galaxies, black holes, and supernovae. The Suzaku mission was launched on July 10, 2005, from the Uchinoura Space Center in Japan. The Suzaku mission—a cooperative effort between NASA and the Japan Aerospace Exploration Agency (JAXA)—has an expected mission lifetime of five years.

The Suzaku spacecraft features the high-resolution X-ray Spectrometer (XRS), a new type of device based on the x-ray microcalorimeter that detects individual x-ray photons thermally and measures their energies with extraordinary precision and sensitivity. The instrument utilizes a three-stage cooling system that provides enough cooling power for at least two years of operation in space. The X-ray Imaging Spectrometer (XIS) is comprised of four individual CCD x-ray cameras to provide high sensitivity imaging over a larger field of view than the XRS, and will continue to be used after the cryogens in the XRS are exhausted. A hard x-ray detector (HXD) is also on the spacecraft for broadband spectroscopy up to the gamma-ray region. X-rays are focused onto the XRS and XIS instruments using a set of five large-area, grazing incidence x-ray telescope modules, one for the XRS and four for the XIS cameras.

In addition to providing the launch vehicle and satellite, JAXA supported the development of the XRS and XIS instruments in collaboration with NASA. JAXA also developed the HXD instrument.

After the successful launch of Suzaku, the XRS was activated and performed to specifications for almost three weeks. On July 29, 2005, the XRS experienced the first of a series of events associated with helium gas entering the dewar vacuum space. On August 8, 2005, there were two such events, the second of which overwhelmed the dewar vacuum, resulting in the liquid helium boiling off and venting to space. Without the helium cryogen, the XRS instrument can no longer provide the planned science. The XIS and the HXD, however, are still in operation and providing new scientific capabilities and data.

For additional information about the Suzaku mission, please see the following URLs: *http://www.nasa.gov/astro-e2 and http://suzaku.gsfc.nasa.gov/.*



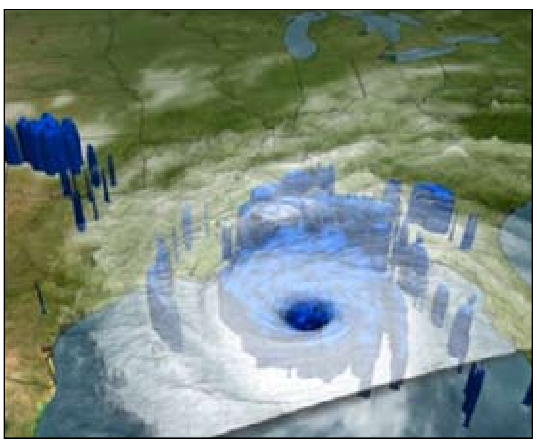
Artist concept image of the Suzaku spacecraft in orbit around the Earth

The four XIS instruments before their installation into the Suzaku spacecraft

Japan

TRMM
Tropical Rainfall Measuring Mission

The TRMM spacecraft observed this view of Hurricane Rita on September 23, 2005. The blue region represents areas where the storm is dumping at least 0.25 inches of rain per hour.



This image was taken on August 29, 2005, by the TRMM spacecraft. It shows the power of Hurricane Katrina just before it made landfall and struck southeastern Louisiana and the northern gulf coast as a category 4 hurricane.

The Japan Aerospace Exploration Agency (JAXA) provided the Precipitation Radar and the launch for the Tropical Rainfall Measuring Mission (TRMM), which was launched on November 27, 1997, aboard a Japanese H-II rocket from the Tanegashima Space Center in Tanegashima, Japan. NASA provided the spacecraft and the other four instruments and is responsible for mission operations. TRMM was designed to monitor tropical rainfall and the associated release of energy that helps to power the global atmospheric circulation, shaping both weather and climate. TRMM had a planned mission life of three years and is now operating in extended mission phase.

TRMM contributes to the understanding of how clouds affect climate and how much energy is transported in the global water cycle. In coordination with other NASA satellites, TRMM scientists are studying the interactions among water vapor, clouds, precipitation, and their role in regulating the climate system.

TRMM is currently in its tenth year of successful operation. This mission has succeeded beyond expectations, producing significant precipitation data and real-time data to operational agencies worldwide. TRMM was boosted to a higher orbit in August 2001 to conserve the onboard fuel necessary for station-keeping maneuvers and to extend its life.

Since launching in 1997, significant accomplishments of TRMM include:

- Providing the highest quality of tropical rainfall information through the first combined radar and radiometer observation of precipitation from space
- Measurements helped scientists reduce the uncertainty in tropical rainfall estimates from 50 percent to better than 15 percent
- Provided 9-year climatology of tropical rainfall, spanning the years 1998 to 2006—information critical to understanding the distribution of tropical rainfall and how its associated energy impacts global atmospheric circulation
- Monitoring El Niño/La Niña events, including the major 1997–1999 El Niño to La Niña transition and the weak 2002 and 2004 El Niños, thereby demonstrating the ability to resolve climate signals using rainfall data
- Assimilating TRMM rainfall data into global models shows significant improvements in representing the hydrologic cycle, clouds, and radiation in such models
- Contributing to improved hurricane and flood analysis and forecasting. Civilian and military operational centers (e.g., the National Hurricane Center, Joint Typhoon Warning Center, and Aviation Weather Center) routinely use TRMM data in day-to-day assessment of hurricane and typhoon intensities, and the assimilation of TRMM data in research models has been shown to reduce uncertainty in tropical cyclone tracks
- Compiling the first global climatology of lightning occurrence in the tropics and subtropics, highlighting a remarkable disparity in lightning activity between land and oceans and among the various continents

For more information about TRMM, please see the following URL: *http://trmm.gsfc.nasa.gov*.

GALEX

Galaxy Evolution Explorer

Korea, Republic of

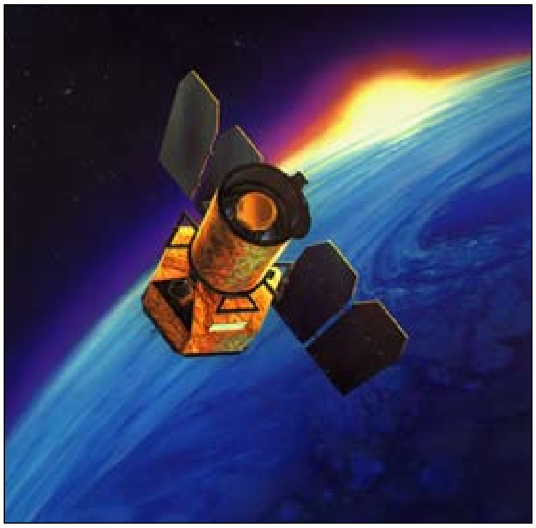
The Galaxy Evolution Explorer (GALEX) is a Small Explorer Mission (SMEX) studying ultraviolet astrophysics. GALEX is an orbiting ultraviolet space telescope mapping the celestial sky in the ultraviolet. The data from GALEX will reach across the last ten billion years—80 percent of the way back to the Big Bang—to determine the history of star formation in the universe. Yonsei University in the Republic of Korea provided members of the science team and tools to test GALEX prior to flight. GALEX was launched on April 28, 2003, aboard a Pegasus XL launch vehicle from Cape Canaveral, Florida.

GALEX is surveying the entire sky at ultraviolet wavelengths for clues as to how the earliest galaxies evolved into mature galaxies like that of the Milky Way. To detect these faint early galaxies, specialized cameras allow the arrival of each photon of ultraviolet light to be timed with the precision of about a microsecond. In addition to studying galaxies, GALEX has also proved useful in observing flares and bursts from stars and streaks from asteroids. The satellite has observed over 84 bonus astrophysical events that were not originally planned.

Yonsei University provided a telescope used as a collimator in ground-testing the flight instrument in which it filtered and directed a stream of rays as part of a test the GALEX telescope. The University also sponsored South Korean members of the GALEX science team who conducted data analysis and calibration.

Originally planned for a 28-month duration, GALEX is currently still active and providing ultraviolet data about galaxy formations and other astrophysical events. On March 7, 2007, GALEX data was used to determine that double star systems can produce full-blown explosions, as well as smaller aftershock-like bursts. Following the first large explosion, GALEX data proved that there was enough matter and pressure to form smaller explosions.

For more information about GALEX, please see the following URLs: *http://galexgi.gsfc.nasa.gov/; and http://www.nasa.gov/galex.*



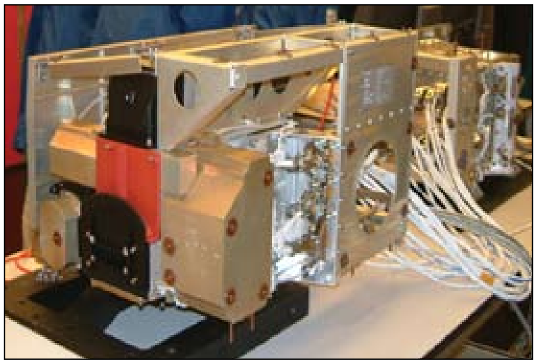
Artist's concept of the GALEX spacecraft

This image of the nearby spiral galaxy M101, better known as the Pinwheel Galaxy, is a three-color combination of images from the GALEX spacecraft.

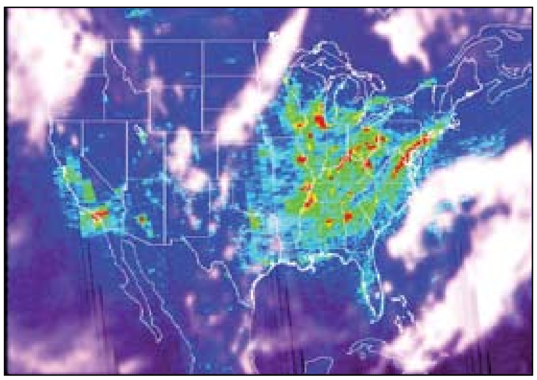
The Netherlands

OMI/Aura

Ozone Monitoring Instrument/Aura



In this photo of the OMI instrument, the red plate covers the instrument's wide field telescope.



The OMI captured this image, which shows nitrogen dioxide (NO_2) that is emitted from automobiles and power plants. NO_2 is an Environmental Protection Agency criteria pollutant and is precursor to surface level ozone. These will be used for air quality forecasting and assessments.

The Netherlands Agency for Aerospace Programmes (NIVR), in cooperation with the Finnish Meteorological Institute (FMI), provided the Ozone Monitoring Instrument (OMI) for NASA's Aura satellite that was launched on July 15, 2004, onboard a Delta II launch vehicle from Vandenberg Air Force Base, California. Aura is operating in a Sun-synchronous, near-polar low-Earth orbit and orbits the Earth 16 times a day. Aura is planned to operate until at least 2010.

Aura (Latin for "breeze")—a NASA Earth Science satellite mission—is part of the international Earth Observing System (EOS). Aura measures changes in the composition, chemistry, and dynamics of the Earth's atmosphere for research and applications relevant to ozone trends, air quality, and climate.

OMI is one of four instruments onboard Aura, each of which contain advanced technologies that have been developed for use on environmental satellites. These instruments offer unique and complementary capabilities that enable daily global observations of Earth's atmospheric ozone layer, air quality, and key climate parameters contributing to Aura's overall mission. OMI is a nadir viewing wide-field imaging spectrometer which measures the solar radiation backscattered by the Earth's atmosphere and surface with a wide-field telescope feeding two imaging grating spectrometers. Each spectrometer employs a charge-couple device (CCD) detector. OMI measures the complete spectrum in the ultraviolet/visible wavelength range with a very high spectral resolution (of about 0.5 nanometers). Daily global coverage is achieved with a spatial resolution of about 15 by 25 kilometers.

OMI measures total ozone and other atmospheric parameters related to ozone chemistry and climate. OMI can distinguish between aerosol types (i.e., smoke, dust, and sulfates) and can measure both the cloud pressure and coverage that provides data to derive tropospheric ozone. OMI maps pollution products on urban scales and tracks its transcontinental transport.

The OMI International Science Team consists of scientists from the Netherlands, Finland, and the U.S. It is responsible for algorithm development, in-flight instrument calibration and trend monitoring, data processing, validation, and analysis.

Since launching in July 2004, the Aura instruments have provided valuable ozone measurements, tropospheric maps of carbon monoxide, water vapor and cloud ice, as well as measurements of the stratosphere. These measurements enable the investigation of questions about ozone trends, air quality changes, and their linkage to climate change. Aura is the third in a series of Earth observation satellites to be flown by NASA with international participation.

For more information about the OMI and Aura, please see the following URLs: *http://aura.gsfc.nasa.gov/index.html, http://aura.gsfc.nasa.gov/instruments/omi/index.html, and http://www.knmi.nl/omi/publ-en/news/index_en.html.*

Isbjørn

NASA Isbjørn Facility at SvalSat

Norway

The Norwegian Space Centre (NSC) provided the facility infrastructure at the Svalbard Satellite Station (SvalSat), in Longyearbyen, Svalbard, to support the establishment and operation of the NASA Isbjørn Facility. NASA established the NASA Isbjørn Facility, a satellite and launch vehicle tracking, data acquisition, and control facility, located at SvalSat. The NASA Isbjørn Facility and SvalSat have both been in operation since 1997.

SvalSat is the northernmost ground station in the world, and is the only commercial ground station able to provide all-orbit-support (14 of 14 daily orbits) for polar orbiting satellites. SvalSat provides telemetry, tracking, and command (TT&C) and data reception for polar-orbiting satellites, launch and early orbit support for orbital launches, and tracking of sounding rockets.

NSC provided the infrastructure at SvalSat for the NASA Isbjørn Facility, including: installation of an access road to SvalSat; installation of basic utilities and communications, such as power, water, and telephone; installation of a fiber optic telecommunications link from Svalsat to Longyearbyen; construction of a station building to house SvalSat tenants, including NASA and the National Oceanic and Atmospheric Administration (NOAA); construction of a foundation for the NASA antenna; coordination of SvalSat activity with Norwegian Government officials, regulatory bodies, and all tenants; maintenance of the basic infrastructure at SvalSat; and spectrum management.

NASA provided, installed, and provides for the operation and maintenance by Kongsberg Satellite Services (KSAT) of the NASA Isbjørn Facility, including all of the instrumentation, one 11-meter, S-X band antenna, and associated ground support equipment. NASA uses the Isbjørn Facility to provide tracking and data acquisition services for polar-orbiting Earth observation satellites, including Landsat-7, EO-1, SAC-C, Acrimsat, Champ, QuickScat, Cobe, Aqua, and Quicktoms.

In 2003, NASA and NOAA provided for the installation by KSAT of approximately 3,000 kilometers of fiber optic cable from SvalSat to the Andøya Rocket Range in Norway, and from Andøya to New York. This fiber optic communication network replaced the need for satellite communications services and enables real-time transmission and processing of tracking, data acquisition, and control data for NASA's Earth science satellites at a substantial savings to NASA.

SvalSat currently has six antenna systems, including two operational 11-meter systems and one 13-meter S- and X-band system. NASA has access to three of these antennae under a pooled-service concept.

For more information about the NASA Isbjørn Facility at SvalSat, please see the following URL: *http://scp.gsfc.nasa.gov/gn/norway.htm.*

This picture is an aerial view of the operations building and the six protective radomes over the telemetry and command antennae at SvalSat. (Credit: KSAT)

This picture shows typical conditions of early or late winter during which there is still daylight. The dome has ropes hanging from it to knock off accumulated snow. The tracking facility is on a plateau several hundred feet above the village of Longyearbyen. A snowcat plows the steeply switchbacked access road daily in winter; even so, the site may become isolated from town for days at a time due to avalanches across the road or severe storm conditions. (Credit: KSAT)

Russia

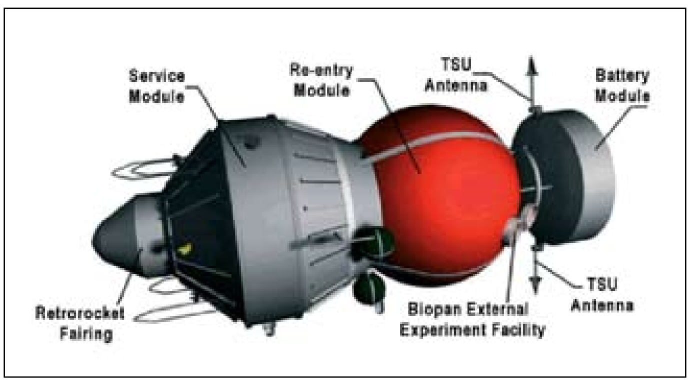
FOTON

Foton-M2 & M3 Free-Flyer Experiments

The Foton-M2 landing and sample retrieval near Kustanay, Kazakhstan

The Russian Federal Space Agency's (Roscosmos) Foton program is designed to provide a platform for space life sciences. The Foton microgravity research capsule permits studies of how living organisms are affected by and adapt to the space environment. NASA cooperated with the Russian Institute of Biomedical Problems (IMBP) on ground studies of samples flown on the 2005 Foton-M2 mission. NASA and IMBP engaged in similar studies of organisms such as bacteria, newts, geckos, and snails on the 2007 Foton-M3 mission. To enhance the scientific return, NASA also provided simple, commercially available components for the IMBP payloads. As part of IMBP's Foton-M3 payload allocation, NASA collaborated on biomedical experiments. Foton M-3 launched on September 14, 2007, on a Soyuz vehicle from the Baikonur Cosmodrome, Kazakhstan. The spacecraft flew in low-Earth orbit for 12 days before releasing its reentry module, which landed in Kazakhstan.

Foton-M2 produced rich data on genetic structures, genetic stability, molecular-biological mechanisms of cell proliferation, tissue regeneration, and the effect of microgravity on the electro-physiology of gravity sensing. Foton-M3 will validate and expand the results of Foton-M2—together they should advance our knowledge of the effects of gravity on terrestrial life.



Foton spacecraft are based on the design of the Russian Vostok spacecraft flown by Yuri Gagarin in 1961, and the Zenit military reconnaissance satellite. However, even though the original Vostok design has developed into the Soyuz spacecraft for manned missions, its principal design aspects have been maintained for the unmanned Foton, which is primarily used for physics and materials science experimentation in weightlessness. (Credit: TsSKB-Progress / ESA)

In addition to NASA's participation in the program, Foton-M3 and Foton-M2 represent a truly multilateral activity in which the European Space Agency (ESA) and the Italian Space Agency (ASI) collaborated in the development of primary life sciences and physical sciences payloads through direct contracts with Roscosmos.

As was the case with Foton-M2, monitoring stations around the world observed the Foton-M3 mission—from Korolev outside Moscow to stations in Sweden. The Russian system provided up- and down-link monitoring and control for the spacecraft and most of the payloads. The ESA Telescience Support Unit (TSU) allowed the use of the ESA ground station in Kiruna, Sweden, to monitor/control ESA payloads. The TSU provided higher bandwidth communication and onboard storage, and could communicate with other ground stations worldwide if necessary.

Reentry was managed by Roscosmos with a parachuted landing, and recovery of the Foton capsule involved locating the descending capsule with radar in conjunction with visually tracking it to the ground.

For more information about the Foton missions, see the following URL: *http://www.spaceflight.esa.int/users/index.htm.*

ISS
International Space Station

Russia

Russia's primary contributions to the International Space Station (ISS) Program are the Soyuz crew transportation, Progress logistics transportation, Zvezda Service Module, Pirs Airlock and Docking Compartment, Multipurpose Laboratory Module (MLM), and the U.S.-purchased/Russian-built Zarya Functional Cargo Block (FGB).

NASA's contributions to the ISS Program include overall management, coordination, and integration of the ISS Program, hardware components, and transportation for crew and logistics via the Space Shuttle, and, in the future, the Crew Exploration Vehicle (CEV) and commercial transportation services. Hardware components include the U.S. laboratory module, the Airlock for extravehicular activities (EVA), truss segments to support the US solar arrays and thermal radiators, three connecting nodes, and living quarters.

The ISS Program is a partnership among the space agencies of Canada, Europe, Japan, Russia and the United States to build an orbiting outpost and research facility at an altitude of approximately 400 kilometers. Construction began in November 1998, and international crews have continuously inhabited the ISS since November 2000. By the time the ISS is completed in 2010, a crew of six will be able to live and work on board, supported by a cadre of international vehicles, control centers and ground support personnel.

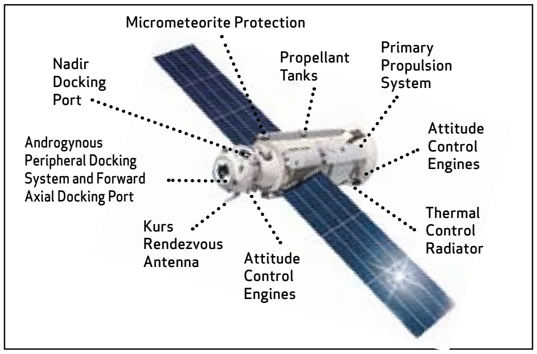
The ISS functions as an orbital microgravity and life sciences laboratory, a testbed for new technologies in areas such as life support and robotics, and a platform for astronomical and Earth observations. The ISS also serves as a unique engineering testbed for flight systems and operations critical to NASA's exploration mission. U.S. research on the ISS will concentrate on the long-term effects of space travel on humans and engineering development activities in support of exploration. Hailed as the most ambitious engineering feat in human history, the ISS is a stepping stone for human exploration and scientific discovery beyond low-Earth orbit.

Zarya was built in Russia under a U.S. contract, and, as such, is a U.S. contribution to the ISS. Zarya, launched to the ISS in November 1998, was the first component of the ISS. During the early stages of ISS assembly, Zarya provided initial power, communications, and attitude control. Zvezda, launched to the ISS in July 2000, provides crew living quarters and early Station core systems. Zvezda replaced many functions of Zarya, which is now used primarily for storage and propulsion. Zvezda remains the structural and functional center of the Russian segment of the ISS.

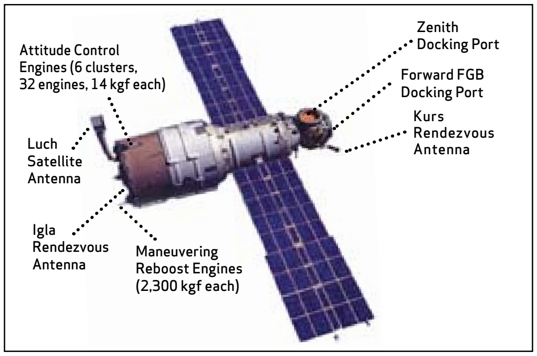
The Pirs Airlock and Docking Compartment was launched to the ISS in September 2001. This Airlock provides the capability for extravehicular activity (EVA) from Zvezda using Russian Orlan suits, and the Docking Compartment provides a port for docking Soyuz and Progress logistics vehicles. The MLM, planned for launch in the 2008-2009 timeframe, will be used for experiments, docking and cargo, and will serve as a crew work and rest area.

The Soyuz vehicle can transport three crewmembers. The Progress is a resupply vehicle used for cargo and propellant deliveries, and Progress engines can boost the ISS to higher altitudes and perform orientation control of the ISS in space. Two Soyuz and, typically, three Progress vehicles are launched to the ISS each year. A Soyuz always remains docked to the ISS for crew return.

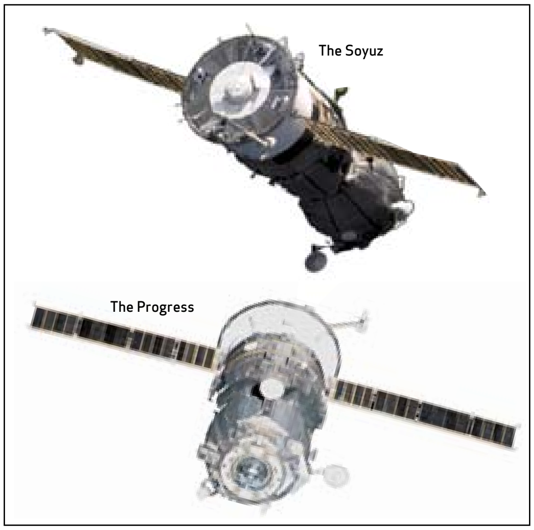
For more information about the ISS and Russia's contributions, please see the following URLs: *http://www.nasa.gov/mission_pages/station/structure/elements/jem.html and http://www.jaxa.jp/projects/iss_human/jem/index_e.html.*



The FGB was the first element of the ISS. During the early stages of ISS assembly, the FGB was self-contained, providing power, communications, and attitude control functions.



The Service Module provided the ISS's early living quarters, life-support system, electrical power distribution, data processing system, flight control system, and propulsion system. The Service Module remains the structural and functional center of the Russian segment of the ISS.

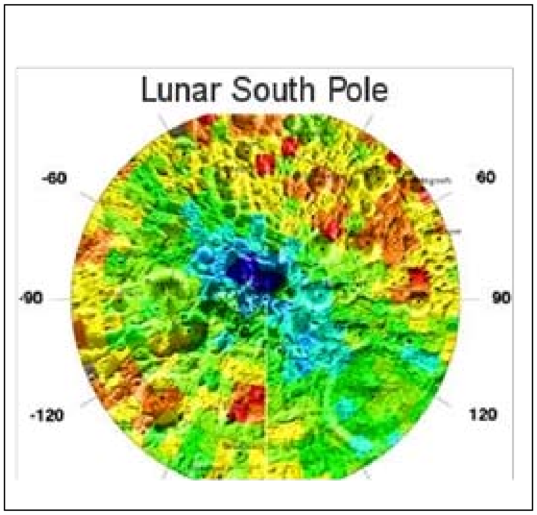


The Soyuz is a crew transportation vehicle and can transport up to three crewmembers. The Progress is a resupply vehicle for cargo and propellant deliveries to the ISS.

Russia

LEND

Lunar Exploration Neutron Detector



The first global mapping of neutron radiation from the Moon was performed by NASA's Lunar Prospector probe in 1998-1999. LEND will improve on the Lunar Prospector data by profiling the energies of these neutrons.

Artist rendering of the LEND instrument

The Russian Federal Space Agency (Roscosmos) will provide the Lunar Exploration Neutron Detector (LEND) instrument for NASA's Lunar Reconnaissance Orbiter (LRO). LRO represents the first step in NASA's return to the moon and the advancement of the Vision for Space Exploration. LRO is scheduled to launch in late 2008 onboard an Atlas V 401 launch vehicle from Cape Canaveral, Florida.

The LRO spacecraft will be a 3-axis stabilized platform with both stored data and real-time downlink capabilities. The LRO baseline mission will be nominally one Earth year at a lunar orbit and may be followed by an extended mission of up to three years, possibly in a low maintenance orbit that allows continued observations.

LRO's mission emphasizes the overall objective of obtaining data that will facilitate returning humans safely to the Moon and enable extended stays. The high priority investigations defined for LRO include high-resolution imaging for characterizing landing site selection and safety, geodetic global topography for the next steps in exploration, measurements to globally assess polar resources and their accessibility for human exploration, and radiation measurements for future human exploration on the Moon.

The LEND team is led by a Principal Investigator at the Russian Institute for Space Research (IKI) of the Russian Academy of Sciences (RAS), and consists of scientists from IKI, the University of Arizona, the University of Maryland, and NASA's Goddard Space Flight Center (GSFC). One of six instruments and a technology demonstration aboard LRO, LEND has passive collimators of neutrons that provide high spatial resolution maps of neutron emission at the lunar surface to search for evidence of water ice and provide measurements of the lunar radiation environment—crucial information for future human exploration. No other neutron instrument with this spatial resolution has ever flown in space.

The availability of water resources could enable the production of oxygen, drinking water, and rocket fuel—all of which have previously been serious barriers to human exploration.

LEND is a modified and enhanced version of the Russian High Energy Neutron Detector (HEND), which launched in 2001 aboard NASA's Mars Odyssey spacecraft and continues to look for water deposits on Mars. The first global mapping of neutron radiation from the Moon was performed by NASA's Lunar Prospector probe in 1998-99. LEND will improve on the Lunar Prospector data by profiling the energies of these neutrons, showing what fraction are of high energy (i.e., the most damaging to people) and what fraction are of lower energies so scientists can design appropriate spacesuits, lunar habitats, Moon vehicles, and other equipment.

For more information about LEND, please see the following URL: *http://lunar.gsfc.nasa.gov/missions/lend.html.*

Mars Odyssey

Russia

The Russian Federal Space Agency (Roscosmos), along with its participating entity, the Russian Institute for Space Research (IKI) of the Russian Academy of Sciences, provided the High Energy Neutron Detector (HEND) instrument for NASA's 2001 Mars Odyssey mission. The Mars Odyssey was launched on April 7, 2001, on a Delta II launch vehicle from Cape Canaveral, Florida.

A very successful mission to date, for the first time the amount and distribution of chemical elements and minerals that make up the Martian surface was mapped. The spacecraft globally mapped many elements, and the maps of hydrogen distribution led scientists to discover vast amounts of water ice in the polar regions buried just beneath the surface. Odyssey recorded the radiation environment in low-Mars orbit to determine the radiation-related risk to future human explorers who may one day go to Mars.

The HEND is a part of the Gamma Ray Spectrometer (GRS) instrument suite, one of three primary instrument packages on the Mars Odyssey. The GRS instrument suite—one of three primary instrument packages on the Mars Odyssey—has studied the elemental distribution at the surface of Mars and searched for water across the planet. Specifically, this instrument suite detects and counts gamma rays and neutrons from the Martian surface. By associating the spectral distribution of the gamma rays with known nuclear transitions lines, it is possible to calculate the ratio of elemental abundances on the surface. By counting the number of neutrons as a function of energy, it is possible to calculate the hydrogen abundance, thus inferring the presence of water.

Odyssey is one of five active robotic missions at Mars, which include NASA's Mars Reconnaissance Orbiter and Mars Exploration Rovers (Spirit and Opportunity) and the European Space Agency's Mars Express orbiter. The orbiters and surface missions complement each other in many ways. For example, observations by the rovers provide ground-level understanding for interpreting global observations by the orbiters. In addition to their own science missions, the orbiters relay data from the Mars Rovers.

For more information about the Mars Odyssey, please see the following URL: *http://marsprogram.jpl.nasa.gov/odyssey/overview/.*

For more information about the HEND instrument, please see the following URL: *http://www.iki.rssi.ru/hend/index-engl.htm.*

Artist concept of the 2001 Mars Odyssey in orbit above Mars

This mosaic image of Valles Marineris canyon—colored to resemble the Martian surface—comes from the Thermal Emission Imaging System (THEMIS), a visible-light and infrared-sensing camera on the Mars Odyssey orbiter.

Russia

MSL
Mars Science Laboratory

Artist concept of the MSL on the Martian surface

This image indicates the growing wheel size between the various Mars explorers: Pathfinder, Mars Exploration Rover, and MSL.

The Russian Institute for Space Research (IKI) of the Russian Academy of Sciences will provide the Dynamic Albedo of Neutrons (DAN) detector on the NASA 2009 Mars Science Laboratory (MSL) mission.

The MSL mission is part of NASA's Mars Exploration Program. Developed by NASA, the MSL mission consists of a long duration rover and mobile scientific laboratory equipped to perform scientific studies of Mars. NASA plans to launch MSL in the fall of 2009 from Cape Canaveral, Florida aboard an Atlas V launch vehicle with an arrival date to Mars of October 2010. The mission is planned to last at least one Martian year (687 Earth days).

The primary scientific objectives, to be carried out during the surface science phase of the MSL mission, will be to assess the biological potential of at least one target area, characterize the local geology and geochemistry, investigate planetary processes relevant to habitability (including the role of water), and to characterize the broad spectrum of surface radiation. The landing site, which has not yet been chosen, will be selected based on an assessment of safety and planetary protection, and an analysis by the scientific community.

One way to look for water on Mars is to look for neutrons escaping from the planet's surface. Cosmic rays from space constantly bombard the surface of Mars, knocking neutrons in surface soils and rocks out of their atomic orbits. If liquid or frozen water happens to be present, hydrogen atoms in water molecules slow the neutrons down. As a result, some of the neutrons escaping into space have less energy and move more slowly. These slower particles can be measured with a neutron detector such as DAN. Scientists expect to find hydrogen on Mars in two forms: water ice and minerals that have molecules of water in their crystal structures. MSL will carry DAN, a pulsing neutron generator sensitive enough to detect water content as low as one-tenth of 1 percent and resolve layers of water and ice beneath the surface. DAN will focus a beam of neutrons onto the Martian surface from a height of 2.6 feet. The neutrons are expected to travel 1 to 2 meters (3 to 6 feet) below the surface before being absorbed by hydrogen atoms in subsurface ice.

For more information about the MSL mission and the DAN instrument, please see the following URLs: *http://mars.jpl.nasa.gov/msl/ and http://marsprogram.jpl.nasa.gov/msl/mission/sc_instru_dan.html.*

Wind/Konus

Russia

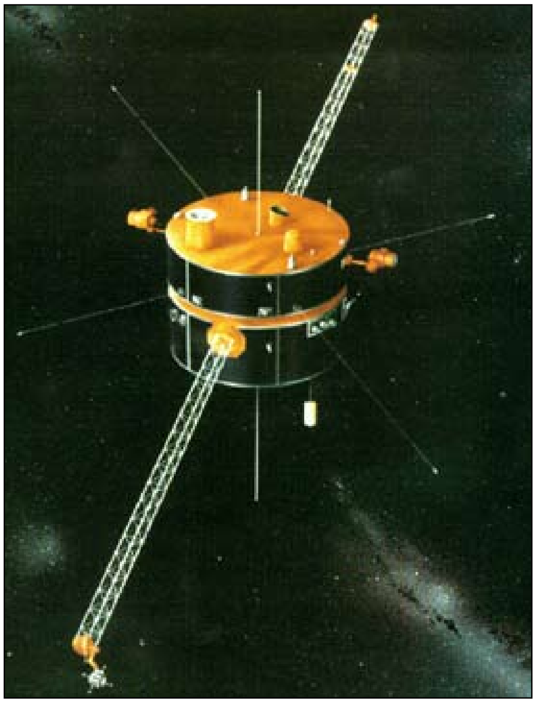
Launched on November 1, 1994, Wind became the first of two NASA spacecraft in the Global Geospace Science Program, in addition to being part of the International Solar-Terrestrial Physics (ISTP) Science Initiative. The Wind mission includes the Russian Konus experiment, which was the first Russian scientific instrument to fly on an American satellite.

NASA's Wind satellite took up a vantage point between the Sun and the Earth, giving scientists a unique opportunity to study the enormous flow of energy and momentum known as the solar wind. The main scientific goal is to measure the mass, momentum, and energy of the solar wind that is transferred into the space environment around the Earth.

The Konus experiment provides omnidirectional and continuous coverage of cosmic gamma-ray transients. The instrument monitors cosmic gamma-ray bursts (GRBs), soft gamma repeaters (SGRs), solar flares, and other transients with the moderate energy resolution available from scintillation spectrometers. In conjunction with other instruments, Konus has helped to rapidly determine gamma-ray burst locations, thereby enabling the prompt and ongoing study of this elusive phenomenon.

NASA's Wind satellite remains in operation at the sunward Sun-Earth equilibrium point (L-1).

For more information about Wind/Konus, please see the following URL: *http://pwg.gsfc.nasa.gov/wind.shtml.*



Artist concept of the Wind spacecraft

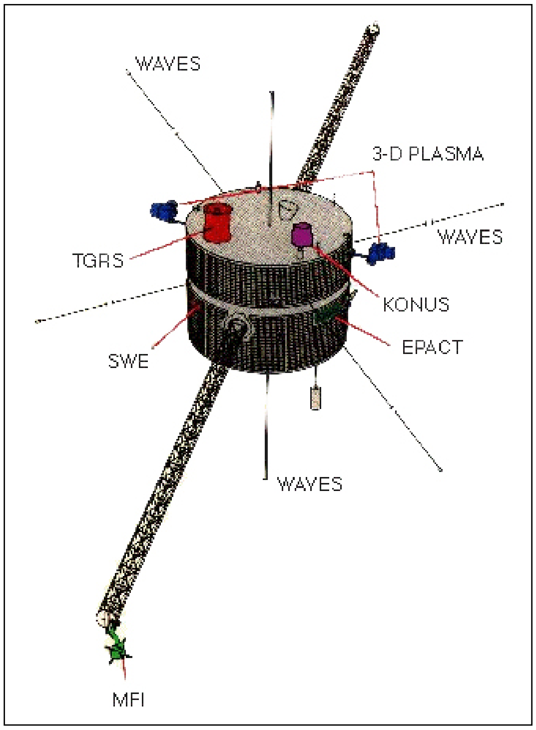


Diagram of the Wind spacecraft and instruments

Spain

DSN
Deep Space Network

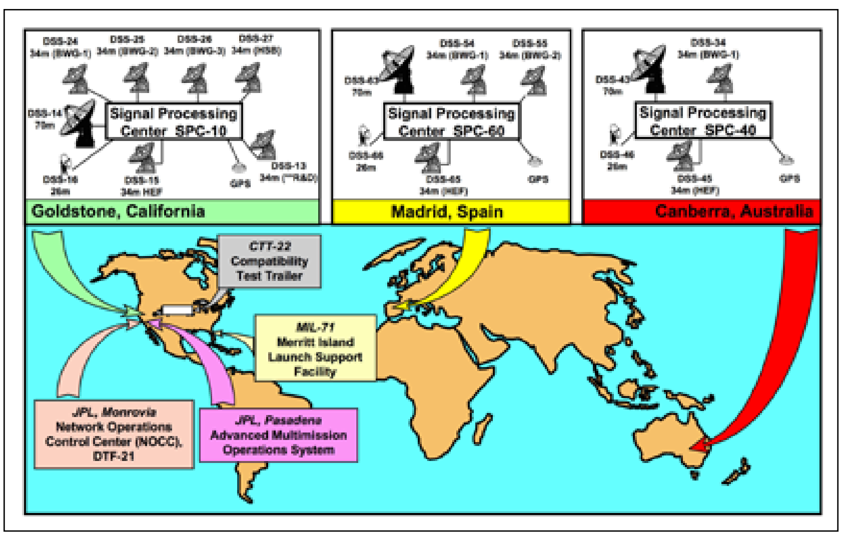
The Madrid Deep Space Communications Complex, located outside Madrid, Spain, is one of the three complexes which comprise NASA's Deep Space Network. The other complexes are located in Goldstone, California, and Canberra, Australia.

The Spanish National Institute for Aerospace Technology, on behalf of NASA, manages the Madrid Deep Space Communications Complex (MDSCC), located 60 kilometers west of Madrid, Spain, at Robledo de Chavela. The MDSCC has been in operation since 1964 as one of three deep space facilities that comprise NASA's Deep Space Network (DSN).

NASA's DSN is an international network of antennae that communicates with interplanetary spacecraft missions, is used by radio and radar astronomers to observe the solar system and the universe, and also supports selected Earth-orbiting missions. In addition, the DSN is critical to NASA's mission to explore the Moon, Mars, and beyond.

NASA's three DSN facilities are in the following locations: 1) Goldstone, in the Mojave Desert, California; 2) Canberra Deep Space Communication Complex (CDSCC), near Canberra, Australia; and 3) MDSCC, near Madrid, Spain.

These DSN facilities are located approximately 120 degrees apart around the world, which permits constant observation of spacecraft as the Earth rotates. Each location has an 8-hour to 14-hour viewing period for contact with spacecraft. The DSN provides the two-way communications link that tracks, guides, and controls the spacecraft, and returns telemetry and scientific data collected by the spacecraft. Incoming data to the three DSN facilities are processed and transmitted to NASA's Jet Propulsion Laboratory, in Pasadena, California, for further processing and distribution to science teams over a modern ground communications network.



DSN overview

Each DSN facility consists of at least four deep space stations equipped with ultra-sensitive receiving systems and large parabolic dish antennae. They are:

- 34-meter (111-foot) diameter High Efficiency antenna
- 34-meter Beam Waveguide antenna (three at Goldstone, two at Madrid, and one at Australia)
- 70-meter (230-foot) antenna
- 26-meter (85-foot) antenna

Five of the existing six 34-meter Beam Waveguide antennae were added to the system in the late 1990s, one of which was located at MDSCC. To support the growing demands on the DSN, a second 34-meter Beam Waveguide antenna was built at MDSCC, completed in 2003, for a total of six Beam Waveguide antennae.

For more information about the DSN and MDSCC, please see the following URLs: *http://deepspace.jpl.nasa.gov/dsn/and http://www.mdscc.org/.*

Icing Research

Spain

NASA is cooperating on in-flight icing research with the Meteorological Service of Canada (MSC), the French National Aerospace Research Center (ONERA), the Spanish National Institute of Aerospace Technology (INTA), Cranfield University in the United Kingdom, and QinetiQ Limited in the United Kingdom. Aircraft in-flight icing causes multitudes of aircraft accidents. One particular type of in-flight icing hazard, known as Supercooled Liquid Droplets (SLD), can contribute to hazardous ice buildup on unprotected aircraft surfaces, which in turn can lead to a loss of aircraft control. Significant international attention has also focused on icing cloud atmospheric characterization, and on in-situ and remote measurement instrumentation.

NASA is working with its partners from Canada, France, Spain, and the United Kingdom to collect and analyze data to develop a better understanding of the icing environment, improve ice accretion modeling techniques, and refine ice detection instrumentation and measurement systems.

Cooperative icing research includes the following collaborations:

- MSC and NASA are conducting collaborative research related to icing cloud and mixed phase (water droplet and ice crystal clouds) atmospheric definition, in-situ and remote instrumentation development, and data processing and analysis techniques. NASA and MSC are conducting flight tests and remote sensing experiments, and will jointly analyze and publish the resulting data. The collaboration began in April 2004 and will continue through December 2010.
- Collaboration with ONERA began in April 2006 and will continue through September 2008. ONERA and NASA are conducting cooperative research in iced aerodynamics and computational fluid dynamics (CFD) modeling of ice accretions. ONERA is developing a wake rake and providing access to their F-1 pressurized low-speed wind tunnel. ONERA and NASA are planning and supporting wind tunnel testing activities whose resulting data will be jointly analyzed and published.
- INTA and NASA are conducting cooperative activities related to ice-accretion physics and water-film thickness. INTA is conducting experiments whose information and results are then provided to NASA. Together, they will publish a joint report describing the research. The collaboration began in October 2004 and will continue through December 2008.
- NASA and Cranfield University began conducting cooperative research related to SLD formation and effects on aircraft surfaces in January 2004 and will continue through December 2008. They are jointly developing the models for testing, defining test plans, and conducting experiments. They will create a technical report documenting the work.
- NASA and QinetiQ are conducting cooperative research related to SLD icing physics and the development of methods for simulating SLDs in icing research facilities. QinetiQ is developing models, conducting experiments, and analyzing data. The collaboration began in September 2004 and will continue through September 2009.

For more information about icing research, please see the following URLs: *http://icebox.grc.nasa.gov/, http://www.onera.fr/dmph-en/icing/index.php and http://www.cranfield.ac.uk/soe/ppae/ti-gti/icing_technology.htm.*

Post-flight image shows ice contamination as a result of encountering SLD conditions near Parkersburg, West Virginia.

Technicians measure ice accretions after an icing test at Glenn Research Center.

Spain

MSL
Mars Science Laboratory

Artist concept of the MSL on the Martian surface

This image indicates the growing wheel size between the various Mars explorers: Pathfinder, Mars Exploration Rover, and MSL.

The Spanish Center for Astrobiology (CAB) will provide the Rover Environmental Monitoring Station (REMS) instrument suite on the NASA 2009 Mars Science Laboratory (MSL) mission. Spain will also provide components of the rover high gain antenna subsystem.

The MSL mission is part of NASA's Mars Exploration Program. Developed by NASA, the MSL mission consists of a long duration rover and mobile scientific laboratory equipped to perform scientific studies of Mars. NASA plans to launch MSL in the fall of 2009 from Cape Canaveral, Florida aboard an Atlas V launch vehicle with an arrival date to Mars of October 2010. The mission is planned to last at least one Martian year (687 Earth days).

The primary scientific objectives, to be carried out during the surface science phase of the MSL mission, will be to assess the biological potential of at least one target area, characterize the local geology and geochemistry, investigate planetary processes relevant to habitability (including the role of water), and to characterize the broad spectrum of surface radiation. The landing site, which has not yet been chosen, will be selected based on an assessment of safety and planetary protection, and an analysis by the scientific community.

The REMS will provide a daily report of atmospheric weather conditions on Mars. REMS will be attached to the vertical mast on the MSL deck; and the station will measure atmospheric pressure, humidity, ultraviolet radiation from the Sun, wind speed, wind direction, ground temperature, and air temperature.

For more information about the MSL mission and the REMS instrument, please see the following URLs: *http://mars.jpl.nasa.gov/msl/ and http://marsprogram.jpl.nasa.gov/msl/mission/sc_instru_rems.html.*

TAL Sites

Transoceanic Abort Landing Sites for the Space Shuttle

Spain

NASA maintains three Transoceanic Abort Landing (TAL) sites for the Space Shuttle. One is in Istres in the South of France, near Marseille, and the other two are in Zaragoza and Moron in Spain.

The three current TAL sites were chosen because of their location near the high-inclination launch path of Space Shuttle missions to the International Space Station (ISS). Other factors, such as runway length, the state of infrastructure and facilities, and local climate, were also considered in choosing these sites.

The TAL site in Zaragoza is a joint Spanish Air Force Base and civilian airport, was designated as a TAL site in 1983, and is the primary TAL site for high-inclination launches of the Space Shuttle to the ISS. If weather is bad in Zaragoza on launch day, the other two TAL sites provide alternate landing options. The TAL site in Zaragoza has two parallel runways; the Shuttle-designated runway is 12,109 feet long by 197 feet wide.

The TAL site in Moron is a Spanish Air Force Base, was designated as a TAL site in 1984, and serves as a weather alternate TAL site for both low- and high- inclination launches of the Space Shuttle. This TAL site has a single runway that is 11,800 feet long by 200 feet wide.

The runways at both of these TAL sites are equipped with Shuttle-unique visual landing aids and a Microwave Landing System (MLS), a Tactical Air Control and Navigation (TACAN) system, a remote weather tower, and a Shuttle Orbiter Arresting System (SOAS). Both of these TAL sites also have typically good weather.

TAL sites provide the capability for an emergency landing during ascent to an augmented site that has been specifically modified and staffed to receive the Space Shuttle. Such a landing would typically be attempted if an emergency were declared roughly between 2 ½ minutes and 8 ½ minutes after liftoff from Kennedy Space Center (KSC), and if the Space Shuttle could not safely enter into orbit or return to the launch site. During a TAL abort, the Space Shuttle would continue on a trajectory across the Atlantic to a predetermined runway at one of the TAL sites.

There is a flight rule indicating that at least one TAL site must be available in order to proceed with launching the Space Shuttle. The combination of three available TAL sites in a geographic configuration that mitigates the risk of adverse weather decreases the likelihood of postponing the launch as a result of a violation of that rule.

For more information about NASA's TAL sites and the TAL sites in Spain, please see the following URLs: *http://www.pao.ksc.nasa.gov/nasafact/tal.htm, http://www.nasa.gov/mission_pages/shuttle/behindscenes/tal_sites.html, and http://www.nasa.gov/returntoflight/main/talsite.html.*

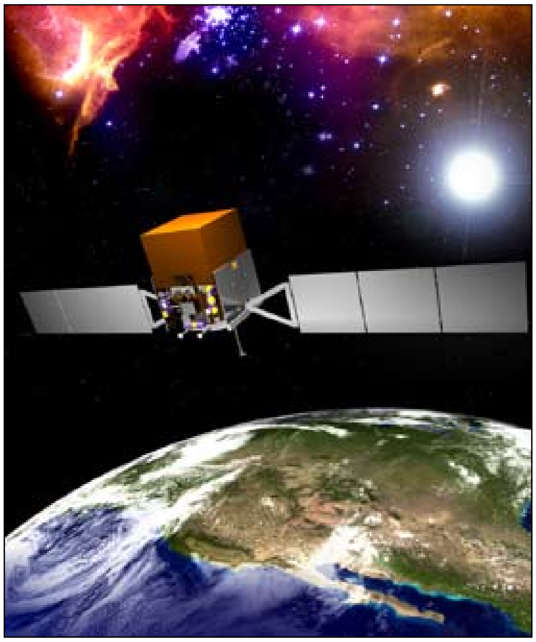
NASA's TAL sites are located almost directly across the Atlantic Ocean from the Space Shuttle launch pads at the Kennedy Space Center in Florida.

Landing convoys such as these at KSC would provide support to the Space Shuttle crew in the event of a landing at a TAL site.

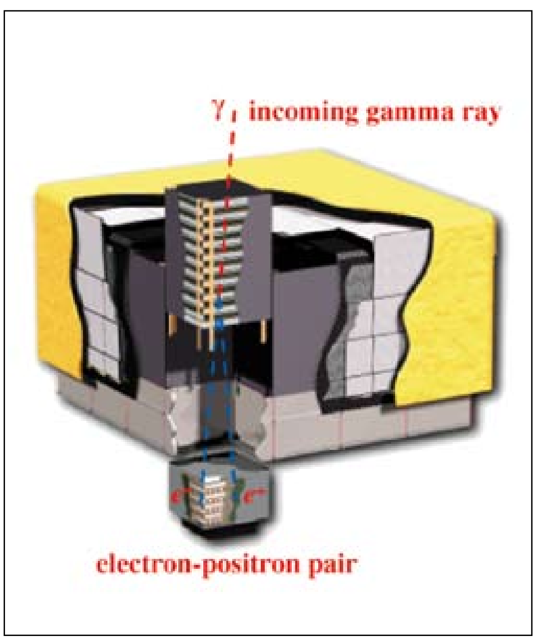
Sweden

GLAST

Gamma-ray Large Area Space Telescope



Artist concept image of the GLAST spacecraft above Earth (Credit: General Dynamics C4 Systems)



Artist concept image of the LAT instrument (Credit: LAT Collaboration)

The Gamma-ray Large Area Space Telescope (GLAST) is a spacecraft with the ability to detect gamma rays created by the most energetic objects and phenomena in the universe. Among topics of cosmological interest to be studied by the mission will be the periods of star and galaxy formation in the early universe and on dark matter. Planned for launch in 2008 from Cape Canaveral, Florida, GLAST is designed for a mission lifetime of five years, with a goal of 10 years of operations. NASA is working with the French National Centre for Space Studies (CNES) on the GLAST mission. NASA is working with the Royal Institute of Technology (KTH) in Sweden on the GLAST mission.

Because of their tremendous energy, gamma rays travel through the universe largely unobstructed. This means GLAST will be able to observe gamma-ray sources near the edge of the visible universe. Gamma rays detected by GLAST will originate near the otherwise obscured central regions of exotic objects like supermassive black holes, pulsars, and gamma-ray bursts.

In order to study these high energy waves, two main instruments will be used: the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The LAT will detect gamma rays by using a technique known as pair-conversion in which a gamma ray slams into a layer of tungsten in the detector, creating a pair of subatomic particles. These particles in turn hit another, deeper layer of tungsten, each creating further particles, and so on. The direction of the incoming gamma ray is determined by tracking the direction of these cascading particles back to their source using high-precision silicon detectors. A separate detector counts up the total energy of all the particles created. The GBM is designed to observe gamma ray bursts, which are sudden, brief flashes of gamma rays that are detectable once or twice a day at random positions across the sky. The sources of these flashes are a mystery, but they are among the most powerful explosions in the universe.

For the GLAST mission, KTH provided support for the LAT instrument, specifically on the detector that will calculate the amount of energy from the gamma waves. Along with KTH and NASA, the following are also cooperating on the GLAST mission: the French National Centre for Space Studies, the German Aerospace Center, the Italian Space Agency, and the Japan Aerospace Exploration Agency.

For more information about the GLAST mission, please see the following URL: *http://glast.gsfc.nasa.gov/.*

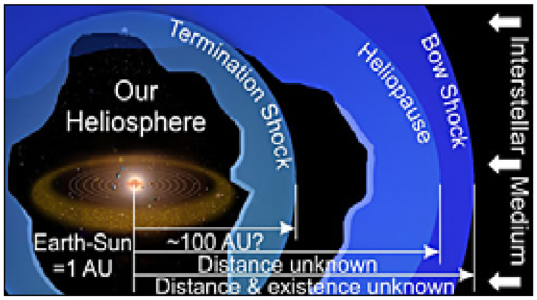
IBEX
Interstellar Boundary Explorer

Switzerland

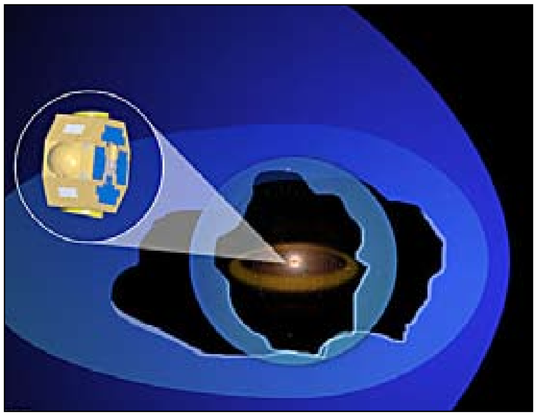
The University of Bern in Switzerland is providing the Interstellar Boundary Explorer (IBEX)-Hi Pre-collimator, the IBEX-Lo Pre-collimator, and the IBEX-Lo Outer Electrostatic Analyzer for the IBEX mission, which is scheduled for launch in 2008 onboard a Pegasus launch vehicle from the Kwajalein Atoll launch site in the central Pacific Ocean. IBEX will carry a pair of energetic neutral atom (ENA) cameras to observe the global interactions between the solar wind and interstellar medium, giving us a much deeper understanding of the Sun's interaction with the Galaxy. IBEX has a planned mission life of two years.

IBEX will orbit the Earth every eight days on a highly elliptical path that takes it to an apogee of 318,900 kilometers, contributing to the first comprehensive map of the boundary between our solar system and interstellar space. Measuring this interstellar interaction is important for understanding how to provide protection from galactic cosmic rays—energetic particles from beyond the solar system that could pose health risks to future astronauts exploring deep space.

For more information about IBEX, please see the following URL: *http://www.ibex.swri.edu/.*



Shown above are the termination shock–where the solar wind abruptly slows prior to deflection by the interstellar flow at the heliopause–and a bow shock in the interstellar flow. The structure and existence of these boundaries remain unknown and will be elucidated by IBEX.

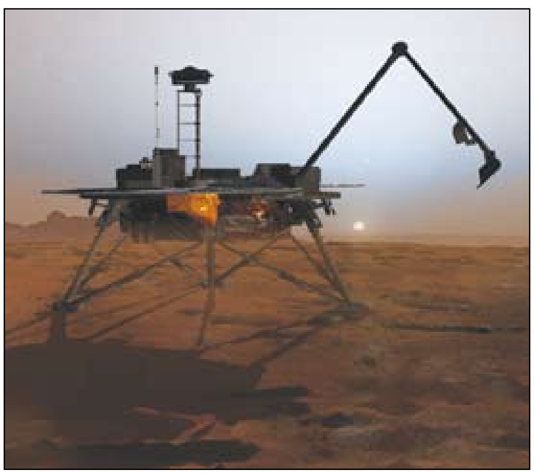


Heliosphere with spacecraft image

Switzerland

Phoenix

Artist concept of the Phoenix lander making its descent to the Martian surface



Artist concept of the Phoenix lander beginning work in twilight on the surface of Mars

The Phoenix mission to Mars involves a telerobotic Mars lander, and is the first in NASA's "Scout Program." The Phoenix mission is managed by the Jet Propulsion Laboratory (JPL), with international contributions by the Canadian Space Agency (CSA) and organizations in Denmark, Germany, and Switzerland. NASA provided the satellite and launch for the Phoenix mission, which launched on August 4, 2007, onboard a Delta II launch vehicle from Cape Canaveral, Florida.

Phoenix is studying the history of water and search for complex organic molecules in the ice-rich soil of the Martian arctic. Scheduled to land in May 2008 at the planet's northern polar region, Phoenix will use its robotic arm to dig through the Martian soil and reach the water ice layer underneath, then deliver soil and ice samples to the mission's experiments. Chemical analysis will be provided on the deck, and imaging systems will provide a view of Mars spanning 12 powers of 10 in scale.

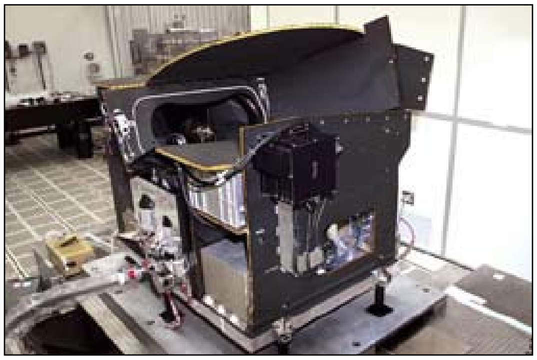
A Swiss consortium led by the University of Neuchatel contributed to the atomic force microscope (AFM) that complements the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA) optical microscopy experiments. The AFM will provide sample images down to 10 nanometers—the smallest scale ever examined on Mars. Using its sensors, the AFM creates a very small-scale topographic map showing the detailed structure of soil grains.

For more information about the Phoenix Mission, please see the following URLs: *http://solarsystem.nasa.gov/missions/profile.cfm?Sort=Target&Target=Mars&MCode=Phoenix and http://phoenix.lpl.arizona.edu/.*

HIRDLS/Aura
High-Resolution Dynamic Limb Sounder/Aura

United Kingdom

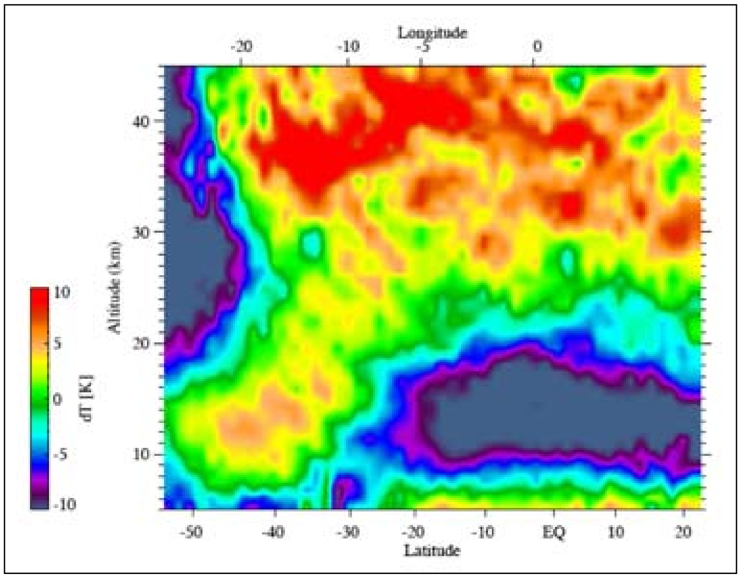
The National Environment Research Council (NERC) of the United Kingdom, in cooperation with the British National Space Centre (BNSC), and NASA jointly developed the High-Resolution Dynamic Limb Sounder (HIRDLS) instrument for NASA's Aura satellite that was launched on July 15, 2004, onboard a Delta II launch vehicle from Vandenberg Air Force Base, California. Aura is operating in a Sun-synchronous, near-polar low-Earth orbit and orbits the Earth 16 times a day. Aura is planned to operate until at least 2010.



The HIRDLS instrument is the most advanced infrared radiometer ever flown on a spacecraft. It is designed to scan vertically and horizontally.

Aura (Latin for "breeze")—a NASA Earth Science satellite mission—is part of the international Earth Observing System (EOS). Aura measures changes in the composition, chemistry, and dynamics of the Earth's atmosphere for research and applications relevant to ozone trends, air quality, and climate.

HIRDLS is one of four instruments onboard Aura, each of which contain advanced technologies that have been developed for use on environmental satellites. These instruments offer unique and complementary capabilities that enable daily global observations of Earth's atmospheric ozone layer, air quality, and key climate parameters contributing to Aura's overall mission. HIRDLS is a 21-channel, infrared limb-scanning radiometer designed to obtain profiles over most of the globe, both day and night, and to provide complete Earth coverage every 12 hours.



HIRDLS high resolution temperature measurements show short vertical wavelength gravity waves, permitting assessment of gravity wave forcing in the stratospheric circulation.

HIRDLS is designed to sound the upper troposphere, stratosphere, and mesosphere in order to determine temperature and the concentrations of gases and aerosols crucial to ozone chemistry and climate. The locations of polar stratospheric clouds and cloud tops are particularly important. To improve understanding of atmospheric processes, HIRDLS will provide vertical concentrations throughout the stratosphere with improved sensitivity, accuracy, and vertical resolution. This critical data on atmospheric chemistry and climate will contribute to the understanding of global change. After launch, it was learned that the space-viewing aperture was blocked, allowing only 20 percent of the Earth's atmosphere to be viewed by the instrument. However, measurements at high vertical resolution can still be made at one horizontal scan angle.

The OMI International Science Team consists of scientists from the Netherlands, Finland, and the U.S. It is responsible for algorithm development, in-flight instrument calibration and trend monitoring, data processing, validation, and analysis.

Since launching in July 2004, the Aura instruments have provided valuable ozone measurements, tropospheric maps of carbon monoxide, water vapor and cloud ice, as well as measurements of the stratosphere. These measurements enable the investigation of questions about ozone trends, air quality changes, and their linkage to climate change. Aura is the third in a series of Earth observation satellites to be flown by NASA with international participation.

For more information about the HIRDLS, please see the following URLs: *http://aura.gsfc.nasa.gov/index.html and http://aura.gsfc.nasa.gov/instruments/hirdls/index.html.*

United Kingdom

Icing Research

Post-flight image shows ice contamination as a result of encountering SLD conditions near Parkersburg, West Virginia.

Technicians taking measurement of ice accretions after an icing test at Glenn Research Center.

NASA is cooperating on in-flight icing research with the Meteorological Service of Canada (MSC), the French National Aerospace Research Center (ONERA), the Spanish National Institute of Aerospace Technology (INTA), Cranfield University in the United Kingdom, and QinetiQ Limited in the United Kingdom. Aircraft in-flight icing causes multitudes of aircraft accidents. One particular type of in-flight icing hazard, known as Supercooled Liquid Droplets (SLD), can contribute to hazardous ice buildup on unprotected aircraft surfaces, which in turn can lead to a loss of aircraft control. Significant international attention has also focused on icing cloud atmospheric characterization, and on in-situ and remote measurement instrumentation.

NASA is working with its partners from Canada, France, Spain, and the United Kingdom to collect and analyze data to develop a better understanding of the icing environment, improve ice accretion modeling techniques, and refine ice detection instrumentation and measurement systems.

Cooperative icing research includes the following collaborations:

- MSC and NASA are conducting collaborative research related to icing cloud and mixed phase (water droplet and ice crystal clouds) atmospheric definition, in-situ and remote instrumentation development, and data processing and analysis techniques. NASA and MSC are conducting flight tests and remote sensing experiments, and will jointly analyze and publish the resulting data. The collaboration began in April 2004 and will continue through December 2010.
- Collaboration with ONERA began in April 2006 and will continue through September 2008. ONERA and NASA are conducting cooperative research in iced aerodynamics and computational fluid dynamics (CFD) modeling of ice accretions. ONERA is developing a wake rake and providing access to their F-1 pressurized low-speed wind tunnel. ONERA and NASA are planning and supporting wind tunnel testing activities whose resulting data will be jointly analyzed and published.
- INTA and NASA are conducting cooperative activities related to ice-accretion physics and water-film thickness. INTA is conducting experiments whose information and results are then provided to NASA. Together, they will publish a joint report describing the research. The collaboration began in October 2004 and will continue through December 2008.
- NASA and Cranfield University began conducting cooperative research related to SLD formation and effects on aircraft surfaces in January 2004 and will continue through December 2008. They are jointly developing the models for testing, defining test plans, and conducting experiments. They will create a technical report documenting the work.
- NASA and QinetiQ are conducting cooperative research related to SLD icing physics and the development of methods for simulating SLDs in icing research facilities. QinetiQ is developing models, conducting experiments, and analyzing data. The collaboration began in September 2004 and will continue through September 2009.

For more information about icing research, please see the following URLs: *http://icebox.grc.nasa.gov/, http://www.onera.fr/dmph-en/icing/index.php, and http://www.cranfield.ac.uk/soe/ppae/ti-gti/icing_technology.htm.*

Swift
Swift Gamma Ray Burst Explorer

United Kingdom

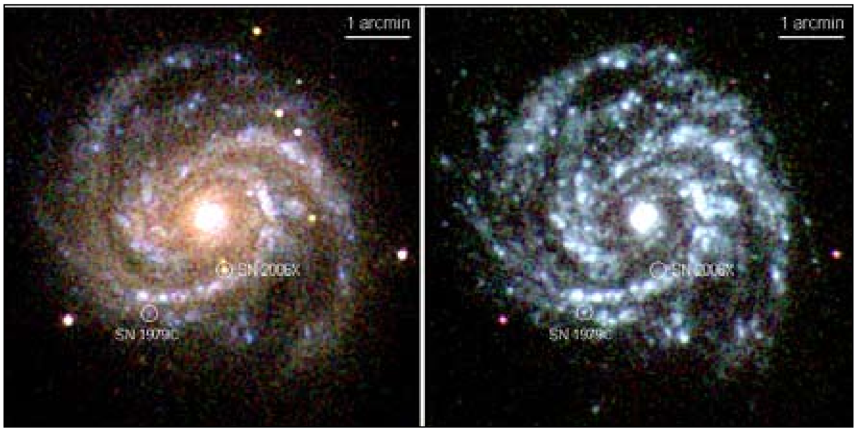
NASA's Swift Gamma Ray Burst Explorer (Swift) mission is a multi-wavelength astrophysics observatory to make a comprehensive study of hundreds of Gamma Ray Bursts (GRBs) in order to determine the origin and physical processes of GRB events. The Swift mission was launched on November 20, 2004, into low-Earth orbit aboard a Delta II launch vehicle from Cape Canaveral, Florida, and was expected to have a nominal lifetime of two years and an orbital lifetime of approximately eight years. Updated orbital lifetime predictions for Swift project it to remain in orbit up to 2022.

Artist concept image of the Swift spacecraft with a gamma-ray burst in the background

For the Swift mission, the Particle Physics and Astronomy Research Council (PPARC) in the United Kingdom, cooperated with NASA on both the development of the X-ray Telescope (XRT) and on the assembly of the Ultraviolet and Optical Telescope (UVOT).

GRBs are incredibly intense releases of gamma radiation, which is a particularly energetic form of light that can only be generated by the most powerful astronomical events. Swift is the next-generation satellite to observe GRBs. In addition, it's a first-of-its-kind multi-wavelength observatory dedicated to the study of GRB science. Its three instruments work together to patrol about 1/6th of the sky at a time in order to pinpoint and observe GRBs and afterglows in the gamma ray, x-ray, ultraviolet, and optical wavebands.

Just 20 to 75 seconds after Swift's large field-of-view telescope, when the Burst Alert Telescope detects and calculates the position of a GRB, the satellite automatically turns, aiming its two narrow field-of-view telescopes, the X-ray Telescope (XRT), and the UltraViolet/Optical Telescope (UVOT) at the GRB. The XRT and UVOT have co-aligned fields-of-view so that any source can be observed in all three wavebands. The mission data is available to the public via the internet as soon as they are processed.



Two images of the same supernova were taken by the Swift spacecraft. These images were both taken using the UVOT instrument but at different wavebands.

PPARC provided lead systems engineering, design and documentation development, and the telescope structure, optical subsystem, and other major components. PPARC also developed data analysis software for the UVOT. PPARC supplied system engineering support and expertise for the XRT design; provided the XRT structural finite element model, thermal finite element model, focal plane camera assembly, and other major components for the XRT; and developed the XRT data analysis software.

In just ten months of operation, Swift had discovered the farthest GRB ever seen, identified counterparts to short GRBs, and has discovered new GRBs at a rate of 100 per year. Through coordinated observations of ground-based telescopes and NASA satellites, scientists determined that short GRBs arise from violent collisions in space either between a black hole and a neutron star or between two neutron stars, which creates a new black hole. On September 4, 2005, Swift and ground-based telescopes detected the most distant GRB yet, from the edge of the visible universe.

For more information about Swift and the XRT, please see the following URLs: *http://swift.gsfc.nasa.gov and http://www.nasa.gov/mission_pages/swift/spacecraft/index.html.*

Worldwide

AERONET

Aerosol Robotic Network

A sun photometer points at the Sun, taking measurements.

A close-up view of a sun photometer site

The Aerosol Robotic Network (AERONET) is an optical, ground-based aerosol-monitoring network and data archive system supported by NASA's Earth Science Division and expanded by a federation of over 40 countries/regions. The network consists of identical automatic Sun- and sky-scanning spectral radiometers. Data from this collaboration provide globally distributed near-real-time observations or aerosol spectral optical depths, aerosol size distributions, and precipitable water in diverse aerosol environments. The data undergo preliminary processing (real-time data), reprocessing (final calibration approximately 6 months after data collection), quality assurance, archiving, and distribution from NASA's Goddard Space Flight Center master archive and several identical databases maintained globally. The data provide algorithm validation of satellite aerosol retrievals, as well as characterization of aerosol properties unavailable from satellite sensors.

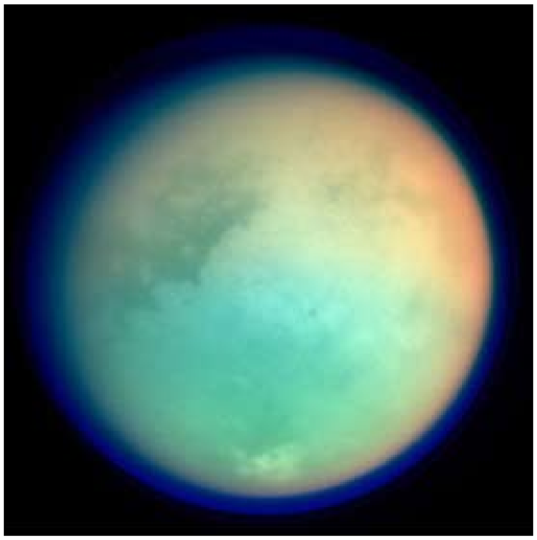
The AERONET Web site provides access to the preliminary data and describes the program objectives, affiliations, instrument description, data products, AERONET browser research activities, and personnel involved in AERONET.

For more information about AERONET, please see the following URL: *http://aeronet.gsfc.nasa.gov/.*

Astrobiology

Worldwide

Astrobiology is a multidisciplinary field of research that encompasses studies of the origin, evolution, distribution, and future of life in the universe. The Astrobiology Program includes Exobiology and Evolutionary Biology research and analysis, the Astrobiology Science and Technology Instrument Development (ASTID), and Astrobiology Science and Technology for Exploring Planets (ASTEP) efforts, and the NASA Astrobiology Institute (NAI)—a virtual research institute that unites 12 multidisciplinary teams to address a wide range of questions in astrobiology. Research in exobiology and evolutionary biology ranges the gamut from the molecular biology of the origin of life to the biochemistry of adaptation to extreme environments to studies of fossil life on Earth to prebiotic chemistry on worlds such as Titan. ASTID and ASTEP projects are developing and demonstrating sensors, robotics, and human exploration techniques and technologies in terrestrial analogue environments for use in space-based astrobiological studies and related investigations.



Titan's heavy atmosphere is loaded with organic molecules that may shed insights on the evolution of Earth's early environment and the emergence of life.

Like many fields of research, astrobiology is inherently transnational, and NASA astrobiologists collaborate with astrobiologists around the world on data analysis, field research, flight experiments, mission planning, and more. Field sites for astrobiology research have ranged from Antarctica to Alaska, Australia, Canada, Chile, China, Hawaii, Mexico, and Norway, as well as elsewhere in the continental United States. In the instrument-development area, NASA Astrobiology has supported the work of U.S. investigators whose investigations are part of the plan for the European Space Agency's ExoMars mission to study the biochemical environment on Mars. Formally, the NAI has six international partners: the European Astrobiology Network Association and national astrobiology research institutes in Australia, Germany, Great Britain, Russia, and Spain. U.S. scientists on NAI research teams are collaborating with researchers at universities in Athens, Leeds, Leiden, Oslo, Paris, Taipei, Tokyo, and Toronto, as well as scientists at the Vatican Observatory and the Brazilian national space agency. NASA also collaborates with astrobiologists from other nations through international organizations such as the Committee on Space Research (COSPAR) of the International Council for Science. COSPAR's Scientific Commission F on Life Sciences as Related to Space has a Subcommission (F3) on Astrobiology, and COSPAR maintains a Panel on Planetary Protection that draws heavily on international astrobiology expertise. In 2006, NASA researchers participated in several sessions on astrobiology research worldwide at the 36th COSPAR Scientific Assembly in Beijing.

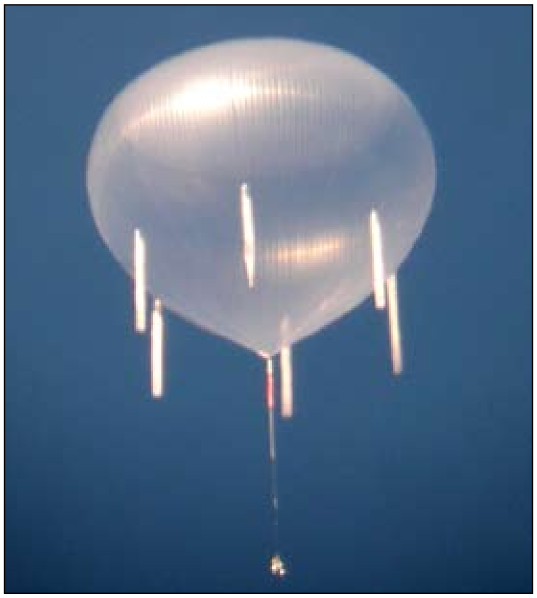
The rugged beauty, ancient fossil beds, and volcanic past of Svalbard make this island an ideal place on Earth to learn how to explore other worlds for signs of life. (Credit: Kjell Ove Storvik–AMASE)

In attempting to learn about the origin and evolution of life, astrobiologists studying microbial communities in extreme environments on Earth have discovered in recent years that the limits within which terrestrial life can exist are far broader and that the diversity of microbial life here is far greater than scientists used to think. These findings are contributing to the important field of genomics (the study of genes and their functions), aiding planning for experiments and missions to search for evidence of possible life on Mars and other planetary bodies, and generally improving our understanding of the nature and diversity of life on Earth and potentially elsewhere.

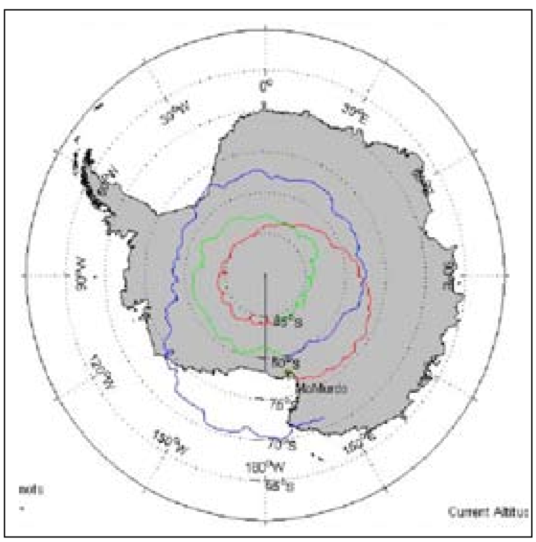
For more information about the Astrobiology program, please see the following URL: *http://astrobiology.nasa.gov.*

Worldwide

Balloons



Photograph of a 40 million cubic foot balloon at float altitude



This graphic depicts the trajectory of the Cosmic Ray Energetics And Mass record-breaking 42-day flight over Antarctica.

Large unmanned helium balloons provide NASA with an inexpensive means to place payloads into a near-space environment at a fraction of the cost of a satellite mission. In addition, balloon missions can be prepared for flight in as little as six months. The unique capabilities of this program are crucial for the development of new technologies and payloads for NASA's space flight missions. Many important scientific observations in fields such as hard x-ray/gamma-ray and infrared astronomy, cosmic rays, atmospheric studies, and others have been made from balloons.

Balloons play a major role in education and training of young scientists and engineers. It is possible for undergraduate and graduate students to design and conduct a balloon science mission within the average time of a graduate degree program. A large fraction of the principal investigators and engineers leading NASA's space missions got their start in the balloon program.

NASA currently flies conventional and long duration balloon missions. Typically, a conventional balloon flight will last from 6 to 36 hours, while a long duration flight can last up to several weeks. NASA is currently developing a super-pressure balloon capable of flying at constant altitude for mission durations up to 100 days at any geographic latitude.

Balloon launches currently occur from permanent launch sites in Palestine, Texas, and Fort Sumner, New Mexico, and remote sites in Sweden, Australia, and Antarctica.

The NASA Balloon Program Office is located at the Goddard Space Fight Center's Wallops Flight Facility.

For more information about NASA's Balloon Program, please see the following URL: *http://www.nasa.gov/centers/wallops/home/organization.html.*

GES
Global Exploration Strategy

Worldwide

In early 2006, NASA initiated a dialogue with representatives of thirteen science and space agencies from around the world with the goal of coordinating a global strategy for exploration. Following a year of focused discussions, NASA–along with organizations representing Australia, Canada, China, the European Space Agency, France, Germany, Great Britain, India, Italy, Japan, Russia, the Republic of Korea, and Ukraine–released "The Global Exploration Strategy: The Framework for Coordination." This framework document—the product of a shared vision of space exploration focused on solar system destinations where humans may someday live and work—represented an important first step in coordinating space exploration efforts toward common goals.

The authors of the framework document recognized the need for a voluntary, non-binding mechanism by which space agencies could exchange information on their respective space exploration plans. Thus, in November 2007, terms of reference for an International Space Exploration Coordination Group (ISECG) were established during the first meeting held in Berlin. The ISECG will play a key role in helping to identify gaps, overlaps, and synergies in the space exploration plans of participating agencies.

The release of the framework document and the subsequent establishment of the exploration coordination group represent important steps in an evolving process toward a comprehensive global approach to space exploration. Although this multilateral effort is non-binding, the process is consistent with ongoing bilateral and multilateral discussions that NASA hopes will lead to cooperative agreements for specific projects.

For more information about the Global Exploration Strategy, please see the following URL: *http://www.nasa.gov/pdf/178109main_ges_framework.pdf.*

Worldwide

GLOBE

Global Learning and Observations to Benefit The Environment

"GLOBE is the quintessentially ideal program for involving kids in science,"
–**Noble laureate Dr. Leon Lederman**.

GLOBE (Global Learning and Observations to Benefit the Environment) is a hands-on, primary and secondary school-based science and education program uniting students, teachers, scientists, and community members around the world in study and research about the dynamics of Earth's environment.

Working in close partnership with NASA and the National Science Foundation (NSF) large-scale Earth System Science Projects (ESSPs), the GLOBE Schools Network consists of over a million GLOBE students in more than 19,000 schools located in 109 countries. GLOBE students take important environmental measurements focusing on atmosphere and climate, hydrology, soils, land cover biology, and phenology. To date, over 16 million environmental measurements have been reported to the GLOBE database on the Web and are freely available for use in student research activities and by scientists around the world. GLOBE improves student understanding by involving students in conducting real science—taking measurements, analyzing data, and participating in research collaborations with other students, as well as with scientists engaged in cutting-edge Earth systems science research.

Scientists and educators have developed environmental science educational materials as a resource for GLOBE teachers. More than 37,000 teachers worldwide have attended GLOBE professional development workshops in their own regions. At these workshops, they learn strategies for guiding their students in taking measurements according to scientific protocols, using the Internet to report and analyze scientific data, and creating international partnerships between GLOBE students and international scientists. Each year, extensive evaluations document GLOBE's impact on students and their teachers around the world.

GLOBE was awarded the 2004 Goldman Sachs Foundation Prize for Excellence in International Education for the unique reach of its work around the world and its ability to bring international education to life through the process of scientific inquiry. GLOBE continues to receive recognition worldwide. Identified as the premiere international science education program, GLOBE is included in the Phi Delta Kappa International Studies Resource Guide.

The GLOBE Program was designed as an international program and has been implemented as such since its initiation on Earth Day in 1994. Bilateral agreements establish partnerships between the United States and its international partner countries. International partners sponsor GLOBE activities in their countries, designing and funding their own implementation strategies to be compatible with their national and regional educational priorities.

For more information about GLOBE, please see the following URL: *http://www.globe.gov.*

Sounding Rockets

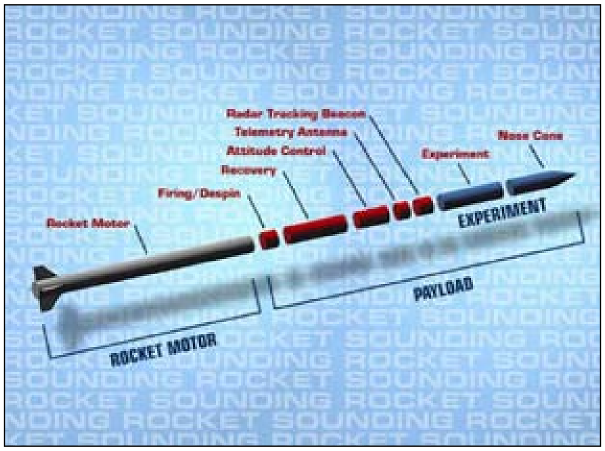
Worldwide

The NASA Sounding Rocket Program is a suborbital space flight program that primarily supports NASA-sponsored science research activities, other U.S. agencies, and international sounding rocket groups and scientists. The Sounding Rocket Program provides unique opportunities for low-cost access to space, specializing in fast-turn-around, focused scientific research across a number of science disciplines. To be flown eventually on various satellite and deep space missions, the Sounding Rocket Program continues to serve as a cost-effective testbed for new scientific techniques, scientific instrumentation, and spacecraft technology. The Sounding Rocket Program also provides new investigators with invaluable experience understanding the spaceflight mission as a whole, as well as providing unique, hands-on experience for students.

Wallops Flight Facility is the only facility in the United States that designs, manufactures, fabricates, integrates, tests, and launches sounding rockets for scientific research. These rockets are launched from a variety of sites throughout the free world. Launch ranges used by NASA include Australia, Brazil, Canada, Greenland, Kenya, Norway, the Marshall Islands, and Peru.

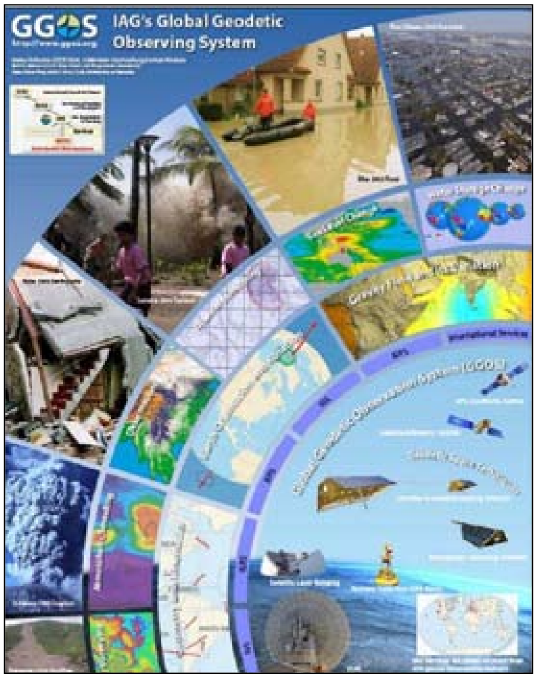
For more information about NASA's Sounding Rocket Program, please see the following URL: *http://sites.wff.nasa.gov/code810/.*

The Black Brank XII was launched into Pulsating Aurora in February 2007 at Poker Flat Research Range, Alaska.

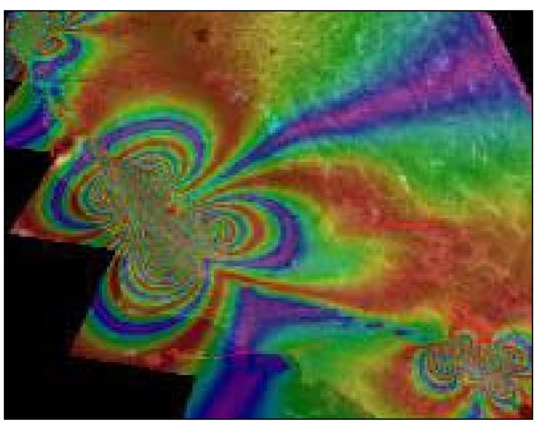


NASA currently uses eight different types of sounding rockets that have configurations similar to this. They come in a variety of sizes ranging from the single-stage improved Orion, which stands at just over 9 feet, to the largest on the four-stage Black Brant XII, which stands 65 feet tall.

Worldwide Space Geodetic Network



NASA's space geodetic network activities directly support the cooperative efforts of the GGOS.



The above animation simulates earthquakes in California using data assimilation techniques of numerical fault systems together with NASA space geodetic and other datasets.

The space geodetic network combines three techniques—Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), and the Global Positioning System (GPS)—to define the terrestrial and celestial reference frames and Earth's orientation in space. Among the many important applications are the study of ocean circulation, sea level change, changes in Earth's ice caps, deformation leading to earthquakes, volcanic eruptions, and landslides. The space geodetic network also enables precision deep space, air, and land navigation used in most scientific and commercial applications.

NASA cooperates with over 30 countries in space geodesy research in the support of the Global Geodetic Observing System (GGOS). These cooperative efforts recognize that geodetic networks are vital for understanding global change phenomena, assessing natural hazards, providing support for local geodetic control, and supplying ground support to space missions. NASA also strongly supports the International GPS Service (IGS), the International VLBI Service (IVS), and the International Laser Ranging Service (ILRS). These three organizations place geodetic network operations, analysis, and standards within an international framework of cooperation and collaboration under the aegis of the International Association of Geodesy.

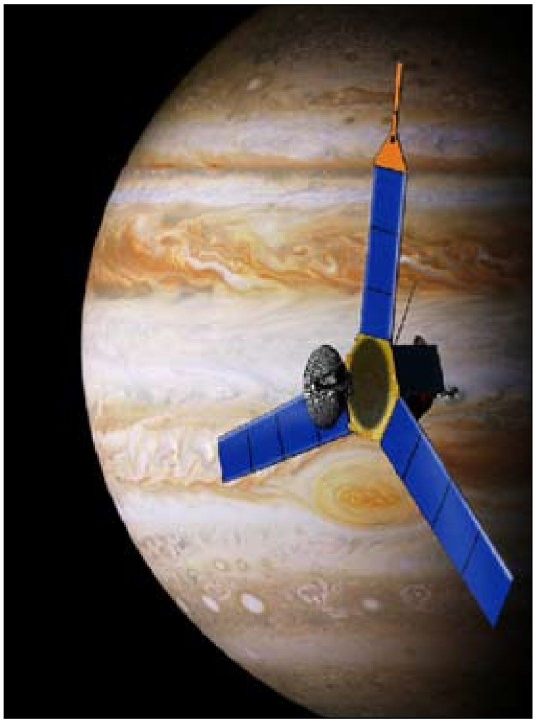
As part of the cooperation, NASA loans equipment to host countries, who in turn provide utilities, security, housing, operation, and maintenance of the equipment. These ground stations provide critical geodetic reference points within the host country. The inclusion of the stations within the global geophysical network significantly improves the accuracy of the global and regional geodetic measurements.

All preprocessed and analyzed NASA space geodetic data are available from the Crustal Dynamics Data Information System (CDDIS) at Goddard Space Flight Center. The CDDIS also is a major data archive for the GGOS.

For more information about the space geodetic network, please see the following URL: *http://cddisa.gsfc.nasa.gov/GPS.*

Italy

Juno



Artist concept image of the Juno spacecraft in orbit around Jupiter

Juno is part of NASA's New Frontier Program with payload participation from the Italian Space Agency (ASI). Juno will further our understanding of planetary and solar system formation by studying the origin and evolution of Jupiter. The spacecraft will probe Jupiter's interior structure, atmospheric composition and dynamics, and polar magnetosphere. Planned for launch in August 2011, Juno will arrive in orbit around Jupiter in fall of 2016. ASI is working with NASA on two instruments for the Juno mission: the Jovian Infrared Auroral Mapper (JIRAM) and the Ka-Band Transponder (KaT).

Using a spinning, solar-powered spacecraft, Juno will make maps of the gravity, magnetic fields, auroral emissions, and atmospheric composition of Jupiter from a unique polar orbit. Juno will carry precise high-sensitivity radiometers, magnetometers, and gravity science systems. Juno's 32 orbits over 11 days will sample Jupiter's full range of latitudes and longitudes. From its polar perspective, Juno will combine in situ and remote sensing observations to explore the polar magnetosphere and determine what drives Jupiter's remarkable auroras. Jupiter's solid core and abundance of heavy metals in the atmosphere make it an ideal model to understand the origin of giant planets. Juno will measure global abundances of oxygen and nitrogen by mapping the gravitational field and using microwave observations of water and ammonia.

ASI will provide testing, calibration, and delivery of the JIRAM and KaT instruments. The JIRAM instrument will be used to collect high resolution images of Jupiter's atmosphere, combining the use of an infrared camera and a spectrometer. KaT will be used to aid in the sensitive gravity tracking experiments.

For more information about the Juno mission, please see the following URLs: *http://newfrontiers.nasa.gov/missions_juno.html; and http://juno.nasa.gov.*

This image from the Voyager 2 mission shows the atmosphere of Jupiter that will be studied by the Juno mission.

GPM
Global Precipitation Measurement

Japan

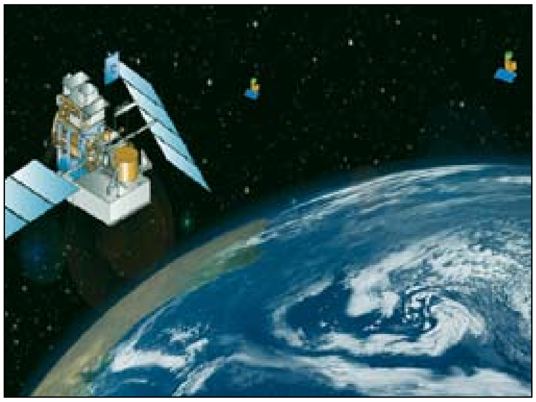
The Japan Aerospace Exploration Agency (JAXA) is providing the Dual-frequency Precipitation Radar (DPR) for the Global Precipitation Measurement (GPM) mission. The spacecraft is scheduled to launch in 2013. GPM will improve the understanding of the global water cycle and fresh water availability, advance the accuracy of precipitation forecasts and precipitation's impact on weather, and provide frequent and complete sampling of Earth's precipitation. GPM has a planned mission life of 3 years with a 5-year goal.

As a follow-on to the successful Tropical Rainfall Measuring Mission (TRMM), GPM will expand observations from the tropics and sub-tropics to the entire globe, improve observing frequency, produce updated global precipitation maps every 3 hours, and enhance measuring methods to identify and characterize rain and snow.

GPM is global in its observations and in its partnerships. It will serve as a benchmark for a coordinated international approach to precipitation observation. The mission will include a core spacecraft carrying the JAXA DPR. NASA will provide the core spacecraft, a multi-channel passive microwave radiometer, a constellation spacecraft and its launch, microwave radiometers, the precipitation processing system, the mission operations system, and an array of ground calibration and validation sites.

A critical part of GPM will be the international constellation of satellites carrying passive microwave radiometers. Through this constellation architecture, GPM will provide frequent precipitation measurements on a global scale. NASA and JAXA are in discussions with other international partners to include their participation in GPM. The GPM mission is seeking participation ranging from spacecraft and instrument contributions to calibration and validation from all areas of the globe. With the potential to vastly improve water resource management, climate research, weather forecasting, and a host of other applications, GPM will have far-reaching and global environmental benefits.

For more information about GPM, please see the following URL: *http://gpm.gsfc.nasa.gov.*



The GPM core spacecraft and international constellation satellites will provide frequent global sampling of Earth's precipitation.

Illustration of the GPM core spacecraft and international constellation satellites

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Aeronautics Research

Exploration Systems

Science

Index By Mission Directorate *cont.*

Space Operations

List of Acronyms

ACE	Atmospheric Chemistry Experiment
ACIS	Advance CCD Imaging Spectrometer
ADRO	Application Development Research Program
AERONET	Aerosol Robotic Network
AFM	atomic force microscope
AMSR-E	Advanced Microwave Scanning Radiometer for the Earth Observing System
ANITA	Analyzing Interferometer for Ambient Air
APMS	Aviation Performance Measuring System
APXS	Alpha Particle X-ray Spectrometer
ARIS	Active Rack Isolation System
AsA	Airservices Australia
ASA	Austrian Space Agency
ASI	Italian Space Agency
ASPERA-3	Analyzer of Space Plasmas and Energetic Atoms Version 3
ASTEP	Astrobiology Science and Technology for Exploring Planets
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTID	Astrobiology Science and Technology Instrument Development
ATM	Air Traffic Management
ATV	Automated Transfer Vehicle
BNSC	British National Space Centre
CAB	Spanish Center for Astrobiology
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CCD	charge-coupled device
CDDIS	Crustal Dynamics Data Information System
CDSCC	Canberra Deep Space Communication Complex
CEV	crew exploration vehicle
CFD	computational fluid dynamics
CMB	Cosmic Microwave Background
CME	coronal mass ejection
CNES	French Centre for Space Studies
CONAE	Argentine Commission on Space Activities
COSPAR	Committee on Space Research
COTS	commercial transportation services
CSA	Canadian Space Agency

List of Acronyms *cont.*

CSIRO	Commonwealth Scientific and Industrial Research Organization
D2	direct-to
DAN	Dynamic Albedo of Neutrons
DLR	German Aerospace Center
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DPR	Dual-frequency Precipitation Radar
DRS	Disturbance Reduction System
DSN	Deep Space Network
EDA	En Route/Descent Advisor
EMCS	European Modular Cultivation System
ENA	energetic neutral atom
EOS	Earth Observing System
EPHIN	Electron, Proton, Helium Instrument
EPM	ESA European Physiology Module
ERA	European Robotic Arm
ESA	European Space Agency
ESSP	Earth System Science Project
ESTEC	European Space Research and Technology Centre
EUMETSAT	European Meteorological Satellite Organization
EUV	extreme ultraviolet
EVA	extravehicular activities
EXPRESS	EXpedite the PRocessing of Experiments to Space Station
FACET	Future ATM Concepts Evaluation Tool
FAF	French Air Force
FC	framing cameras
FGB	Functional Cargo Block
FGM	fluxgate magnetometer
FGS/TF	Fine Guidance Sensor/Tunable Filter
FMI	Finnish Meteorological Institute
FTIR	Fourier transform infrared
FTS	Fourier transform spectrometer
GALEX	Galaxy Evolution Explorer
GBM	GLAST Burst Monitor
GBO	ground-based observatory
GES	Global Exploration Strategy
GGOS	Global Geodetic Observing System

List of Acronyms *cont.*

GLAST	Gamma-ray Large Area Space Telescope
GLOBE	Global Learning and Observations to Benefit the Environment
GPM	Global Precipitation Measurement
GPS	global positioning system
GRACE	Gravity Recovery and Climate Experiment
GRB	gamma-ray burst
GRS	gamma ray spectrometer
GSFC	Goddard Space Flight Center
HEND	High Energy Neutron Detector
HFI	high frequency instrument
HIFI	Heterodyne Instrument for the Far-Infrared
HIRDLS	High-Resolution Dynamic Limb Sounder
HRC	high-resolution camera
HRF	Human Research Facility
HRSC	high resolution stereo camera
HSO	Hungarian Space Office
HST	Hubble Space Telescope
HTV	H-II Transfer Vehicle
HXD	Hard X-ray Detector
IBEX	Interstellar Boundary Explorer
IBIS	Imager on Board the INTEGRAL Satellite
IGS	International GPS Service
IKI	Russian Institute for Space Research
ILRS	International Laser Ranging Service
IMBP	Institute of Biomedical Problems
IMPACT	In-situ Measurements of Particles and CME Transients
INTA	Spanish National Institute of Aerospace Technology
INTEGRAL	International Gamma-Ray Astrophysics Laboratory
IPN	InterPlanetary Network
ISIM	Integrated Science Instrument Module
ISPR	International Standard Payload Rack
ISRO	Indian Space Research Organization
ISS	International Space Station
ISTP	International Solar-Terrestrial Physics
IUS	Inertial Upper Stage
IVS	International VLBI Service
JAXA	Japan Aerospace Exploration Agency

List of Acronyms *cont.*

JEM	Japanese Experiment Module
JEM-X	Joint European X-ray Monitor
JIRAM	Jovian Infrared Auroral Mapper
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KaT	Ka-band transponder
KSAT	Kongsberg Satellite Services
KSC	Kennedy Space Center
KTH	Royal Institute of Technology
LASCO	Large Angle and Spectrometric Coronograph Experiment
LAT	large area telescope
LCROSS	Lunar CRater Observation and Sending Satellite
LEND	Lunar Exploration Neutron Detector
LETGS	Low Energy Transmission Grating for Cosmic X-ray Spectrometer
LFI	low frequency instrument
LIDAR	light detection and ranging
LISA	Laser Interferometer Space Antenna
LRO	Lunar Reconnaissance Orbiter
LTP	LISA Technology Package
M3	Moon Mineralogy Mapper
MAESTRO	Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation
MaRS	Mars Radio Science Experiment
MARSIS	Mars Advanced Radar for Subsurface and Ionospheric Sounding
MB	Mössbauer Spectrometer
MDSCC	Madrid Deep Space Communications Complex
MECA	Microscopy, Electrochemistry, and Conductivity Analyzer
MELFI	Minus 80C Laboratory Freezer for ISS
MER	Mars Exploration Rover
MET	Meteorological Station
METI	Ministry of Economy, Trade and Industry
Mini-SAR	Miniature Synthetic Aperture Radar
MIRI	mid-infrared instrument
MIRO	Microwave Instrument for the Rosetta Orbiter
MLM	Multipurpose Laboratory Module
MLS	microwave landing system
MOPITT	Measurements of Pollution in the Troposphere

MPLM	Multi-Purpose Logistics Modules
MPS	Max Planck Institute for Solar System Research
MRO	Mars Reconnaissance Orbiter
MSC	Meteorological Service of Canada
MSG	Microgravity Science Glovebox
MSL	Mars Science Laboratory
MSRR-1	Materials Science Research Rack-1
MSS	Mobile Servicing System
NAI	NASA Astrobiology Institute
NBI	Niels Bohr Institute for Astronomy, Physics, and Geophysics
NERC	National Environment Research Council
NIRCam	near-infrared camera
NIRSpec	near-infrared spectrograph
NIVR	Netherlands Agency for Aerospace Programmes
NOAA	National Oceanic and Atmospheric Administration
NSC	Norwegian Space Centre
OMC	optical monitoring camera
OMEGA	Visible and Infrared Mineralogical Mapping Spectrometer
OMI	ozone monitoring instrument
ONERA	French National Aerospace Research Center
OSTM	Ocean Surface Topography Mission
OTE	Optical Telescope Element
PACS	Photoconductor Array Camera and Spectrometer
PAM-S	Payload Assist Module-S
PARASOL	Polarization and Anisotropy of Réflectances for Atmospheric Sciences coupled with Observations from a Lidar
PCMCIA	Personal Computer Memory Card International Association
PFS	Planetary Fourier Spectrometer
PLASTIC	PLAsma and SupraThermal Ion Composition
PPARC	Particle Physics and Astronomy Research Council
RA	robotic arm
RAC	robotic arm camera
RAD	Radiation Assessment Detector
RAS	Russian Academy of Sciences
REMS	Rover Environmental Monitoring Station
ROSINA	Rosetta Orbiter Spectrometer for Ion and Neutral Analysis
RPC/IES	Rosetta Plasma Consortium/Ion Electron Spectrometer
RSH	RAD Sensor Head

List of Acronyms *cont.*

RTG	Radioisotope Thermoelectric Generator
SAM	Sample Analysis at Mars
SAR	Synthetic Aperture Radar
SCM	Search Coil Magnetometer
SELENE	SELenological and ENgineering Explorer
SGR	soft gamma repeater
SHARAD	Shallow Subsurface Radar
SLD	Supercooled Liquid Droplets
SLR	Satellite Laser Ranging
SMEX	Small Explorer Mission
SOAS	Shuttle Orbiter Arresting System
SOFIA	Stratospheric Observatory For Infrared Astronomy
SOHO	Solar and Heliospheric Observatory
SPI	Spectrometer on INTEGRAL
SPICAM	Ultraviolet and Infrared Mars Atmospheric Spectrometer
SPIRE	Spectral and Photometric Imaging Receiver
SRON	Space Research Organization Netherlands
SSO	Swiss Space Office
SSRMS	Space Station Remote Manipulator System
SST	sea surface temperature
STEREO	Solar TErrestrial RElations Observatory
TACAN	Tactical Air Control and Navigation
TAL	Transoceanic Abort Landing
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TRMM	Tropical Rainfall Measuring Mission
TSU	Telescience Support Unit
UVOT	ultraviolet/optical telescope
VAFB	Vandenberg Air Force Base
VIR-MS	Visual and Infrared Mapping Spectrometer
VLBI	Very Long Baseline Interferometry
VRAD	VLBI Radio source
WAVES	Wind/Radio and Plasma Wave Experiment
WSOA	Wide-Swath Ocean Altimeter
XIS	X-ray imaging spectometer
XMM	X-ray Multi-Mirror
XRS	X-ray spectrometer
XRT	X-ray telescope