Japanese Space Programs and Missions

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Japan Aerospace Exploration Agency

Japan Aerospace Exploration Agency
宇宙航空研究開発機構

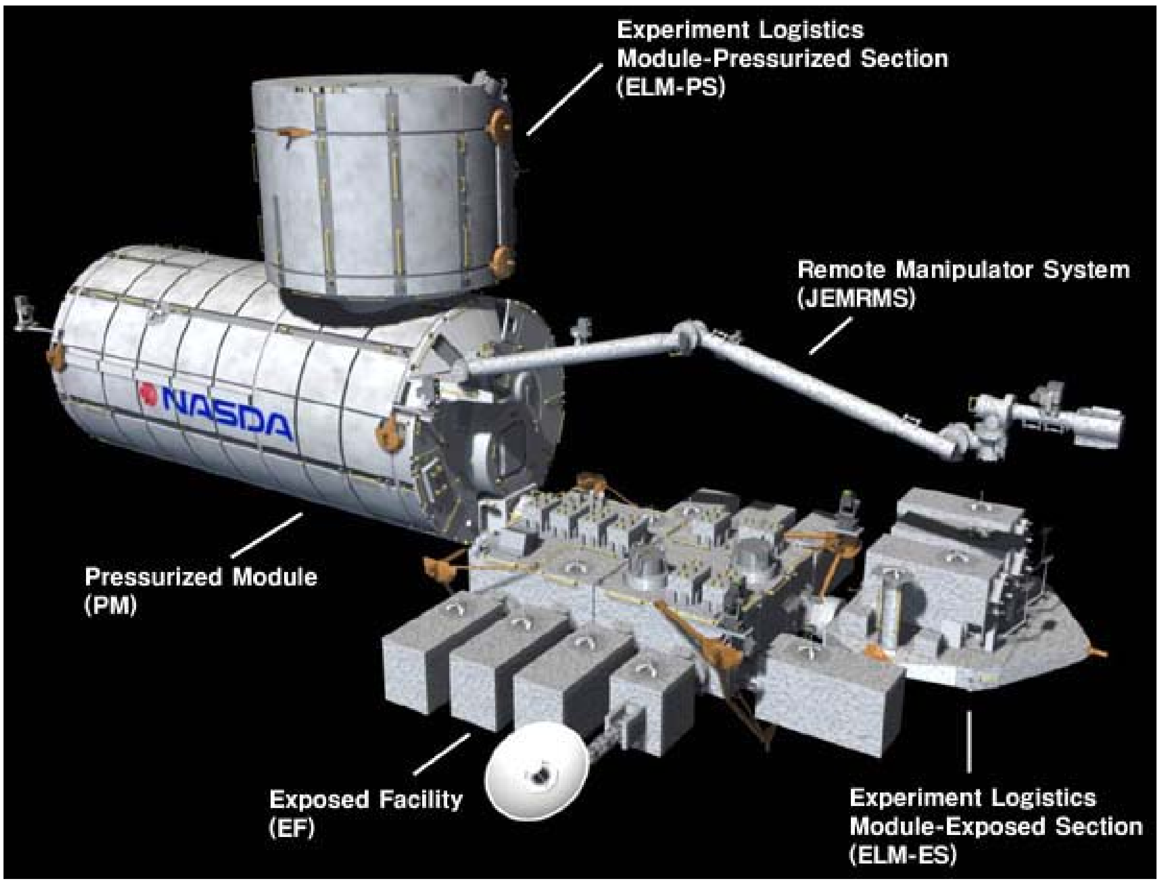
Reaching for the skies, exploring space

Owner	Japan
Established	October 1, 2003 *(Successor agency to NASDA 1969-2003, ISAS 1981–2003 and NAL 1955–2003)*
Headquarters	Chōfu, Tokyo
Primary spaceport	Tanegashima Space Center
Motto	One JAXA
Administrator	Keiji Tachikawa
Budget	¥229 billion/ $2.46 billion (FY2010)
Website	www.jaxa.jp

The **Japan Aerospace Exploration Agency** (独立行政法人宇宙航空研究開発機構 *Dokuritsu-gyōsei-hōjin Uchū Kōkū Kenkyū Kaihatsu Kikō*?, literally "Independent Administrative Institution on Aerospace Research and Development "), or **JAXA**, is

Japan's national aerospace agency. Through the merger of three previously independent organizations, JAXA was formed on October 1, 2003, as an Independent Administrative Institution administered by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Internal Affairs and Communications (MIC). JAXA is responsible for research, development and launch of satellites into orbit, and is fundamentally involved in many missions such as asteroid exploration and a possible human mission to the Moon. Its motto is *One JAXA* and corporate message is *Reaching for the skies, exploring space.*

History



JAXA Kibo, the largest module for the ISS

On October 1, 2003, three organizations were merged to form the new JAXA: Japan's Institute of Space and Astronautical Science (or ISAS), the National Aerospace Laboratory of Japan (NAL), and National Space Development Agency of Japan (NASDA).

Before the merger, ISAS was responsible for space and planetary research, while NAL was focused on aviation research. NASDA, which was founded on October 1, 1969, had developed rockets, satellites, and also built the Japanese Experiment Module. The old NASDA headquarters were located at the current site of the Tanegashima Space Center, on Tanegashima Island, 115 kilometers south of Kyūshū. NASDA also trained Japanese astronauts, who flew with the US Space Shuttles.

Rockets

JAXA uses the H-IIA (H "two" A) rocket from the former NASDA body to launch engineering test satellites, weather satellites, etc. For science missions like X-ray astronomy, JAXA has been using the M-V ("Mu-five") solid-fueled rocket from the former ISAS. Additionally, JAXA is developing together with IHI, United Launch Alliance, and Galaxy Express Corporation (GALEX), the GX rocket. The GX will be the first rocket world wide to use liquefied natural gas (LNG) as the propellant. For experiments in the upper atmosphere JAXA uses the SS-520, S-520, and S-310 sounding rockets.

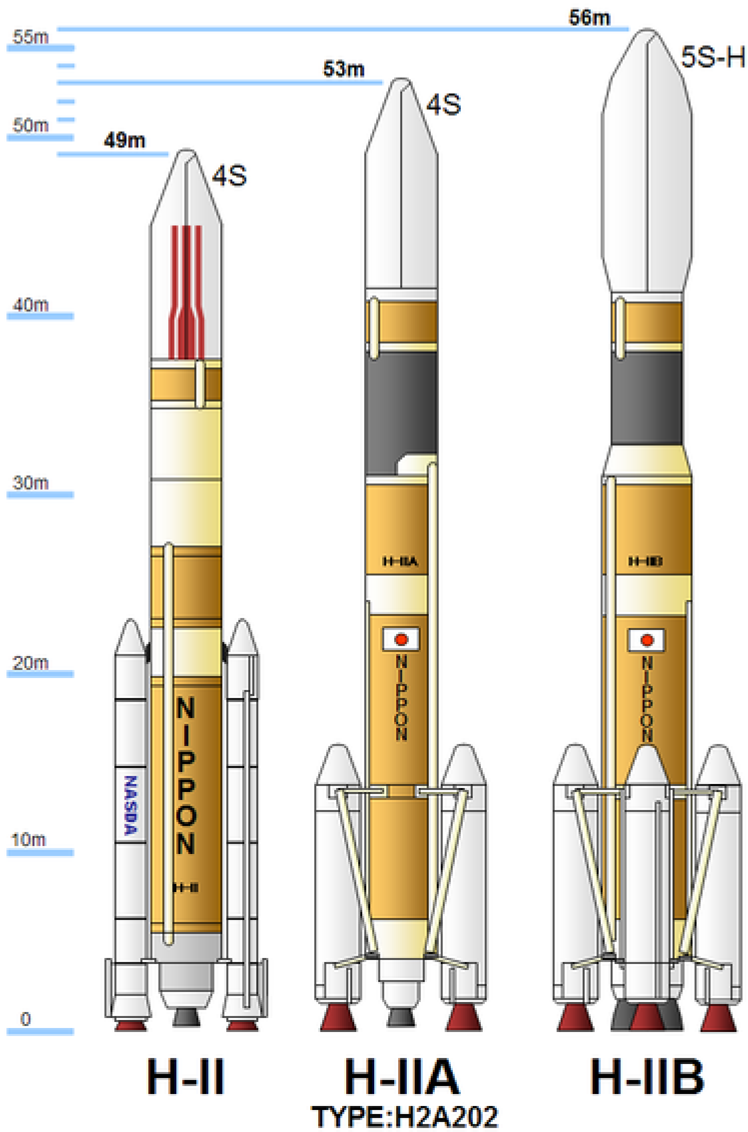
Success

Prior to the establishment of JAXA, ISAS had been most successful in its space program in the field of X-ray astronomy during the 1980s and 1990s. Another successful area for Japan has been Very Long Baseline Interferometry (VLBI) with the HALCA mission. Additional success was achieved with solar observation and research of the magnetosphere, among other areas.

NASDA was mostly active in the field of communication satellite technology. However, since the satellite market of Japan is completely open, the first time a Japanese company won a contract for a civilian communication satellite was only in 2005. Another prime focus of the NASDA body is Earth climate observation.

JAXA was awarded the Space Foundation's John L. "Jack" Swigert, Jr., Award for Space Exploration in 2008.

Launch development and missions



H-IIA & H-IIB

Rocket history

Japan launched its first satellite Ōsumi in 1970 with the L-4S rocket by ISAS. Unlike solid fueled rockets, Japan chose a much slower path with liquid fueled rocket technology. In the beginning NASDA used American models in license. The first model developed in Japan was the H-II introduced in 1994. However at the end of the 90s with two H-II launch failures, Japanese rocket technology came under criticism.

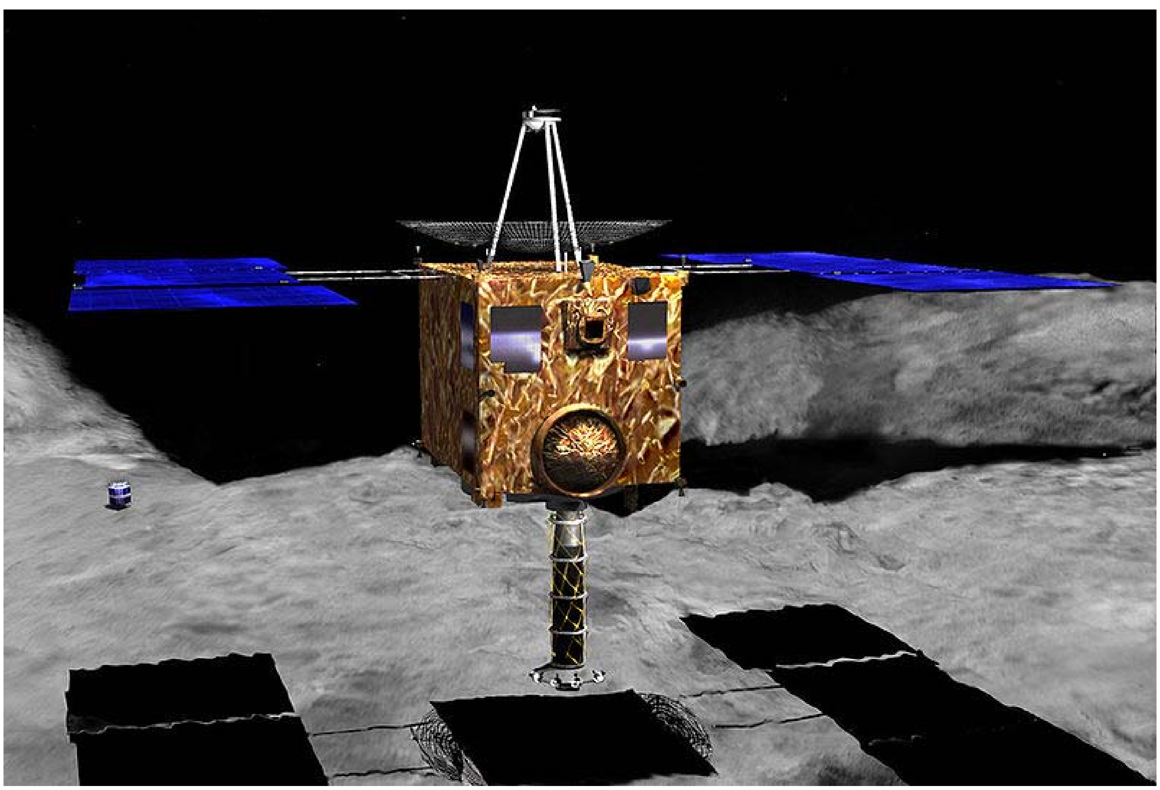
Early H-IIA missions

Japan's first space mission under JAXA, an H-IIA rocket launch on November 29, 2003, ended in failure due to stress problems. After a 15 month hiatus, JAXA performed a successful launch of an H-IIA rocket from Tanegashima Space Center, placing a satellite into orbit on February 26, 2005.

Lunar and interplanetary missions

Japan's first missions beyond Earth orbit were the 1985 Halley comet observation satellites Suisei and Sakigake. To prepare for future missions, ISAS tested Earth swing by orbits with the Hiten mission in 1990. The first Japanese interplanetary mission was the Mars Orbiter Nozomi (Planet-B), which was launched in 1998. It reached its target in 2003, but orbit injection had to be given up. Currently interplanetary missions remain at the ISAS group under the JAXA umbrella. However for FY 2008 JAXA is planning to set up an independent working group within the organization. New head for this group will be Hayabusa project manager Kawaguchi. **Active Mission:** Hayabusa, SELENE, **Under Development:** Planet-C, BepiColombo, Hayabusa 2?

Small body exploration: Hayabusa mission



Hayabusa

On May 9, 2003, Hayabusa (meaning, Peregrine falcon), was launched from an M-V rocket. The goal of this mission is to collect samples from a small near-Earth asteroid named 25143 Itokawa. The craft was scheduled to rendezvous in November 2005, and return to Earth with samples from the asteroid by July 2007. It was confirmed that the spacecraft successfully landed on the asteroid on November 20, 2005, after some initial confusion regarding the incoming data. On November 26, 2005, Hayabusa succeeded in making a soft contact, but whether it gathered the samples or not is unknown. Hayabusa returned to Earth on June 13, 2010.

Solar sail research

On August 9, 2004, ISAS successfully deployed two prototype solar sails from a sounding rocket. A clover type sail was deployed at 122 km altitude and a fan type sail was deployed at 169 km altitude. Both sails used 7.5 micrometer thick film.

ISAS tested a solar sail again as a sub payload to the Astro-F (Akari) mission on February 22, 2006. However the solar sail did not deploy fully. ISAS tested a solar sail again as a sub payload of the Solar-B launch at September 23, 2006, but contact with the probe was lost. The IKAROS solar sail was launched on May 21, 2010. The solar sail deployed successfully. The goal is to have a solar sail mission to Jupiter after 2010.

Lunar explorations

After Hiten in 1990, ISAS planned a lunar exploration mission LUNAR-A but after delays due to technical problems, the project was terminated in January 2007. The seismometer penetrator design for Lunar-A may be reused in future mission.

On September 14, 2007, JAXA succeeded in launching lunar orbit explorer *Kaguya*, also known as SELENE (costing 55 billion yen including launch vehicle), the largest such mission since the Apollo program, on an H-2A rocket. Its mission is to gather data on the moon's origin and evolution. It entered into a lunar orbit on October 4, 2007.

Astronomy program

The first Japanese astronomy mission was x-ray satellite Hakucho (Corsa-B), which was launched in 1979. Later ISAS moved into solar observation, radio astronomy through Space VLBI and infrared astronomy. **Active Mission:** Suzaku, Akari, Hinode **Under Development:** ASTRO-G, ASTRO-H

Infrared astronomy

AKARI (Astro-F)

ASTRO-E

Japan's first infrared astronomy mission was the 15 cm IRTS telescope which was part of the SFU multipurpose satellite in 1995. IRTS scanned during its one month lifetime around 7% of the sky before SFU got brought back to Earth by the Space Shuttle. During the 1990s JAXA also gave ground support for the ESA Infrared Space Observatory (ISO) infrared mission.

The next step for JAXA was the AKARI spacecraft, with the pre-launch designation ASTRO-F. This satellite was launched on 21 February 2006. Its mission is infrared astronomy with a 68 cm telescope. This is the first all sky survey since the first infrared mission IRAS in 1983. (A 3.6 kg nanosatellite named CUTE-1.7 was also released from the same launch vehicle.)

JAXA is also doing further R&D for increasing the performance of its mechanical coolers for its future infrared mission SPICA. This would enable a warm launch without liquid helium. SPICA has the same size as the ESA Herschel Space Observatory mission, but is planned with a temperature of just 4.5 K to be much colder. The launch is planned for the year 2015, however the mission is not yet fully funded. Also ESA and NASA might contribute an instrument each.

X-ray astronomy

Starting from 1979 with Hakucho (CORSA-B), Japan achieved for nearly 20 years continuous observation with its Hinotori, Tenma, Ginga and Asuka (ASTRO-A to D) x-ray observation satellites. However in the year 2000 the launch of Japan's fifth x-ray observation satellite ASTRO-E failed (as it failed at launch it never received a proper name).

Then on July 10, 2005, JAXA was finally able to launch a new X-ray astronomy mission named Suzaku (ASTRO-E II). This launch was important for JAXA, because in the five years since the launch failure of the original ASTRO-E satellite, Japan was without an x-ray telescope. Three instruments were included in this satellite: an X-ray spectrometer (XRS), an X-ray imaging spectrometer (XIS), and a hard X-ray detector (HXD). However, the XRS was rendered inoperable due to a malfunction which caused the satellite to lose its supply of liquid helium.

The next planned x-ray mission is the MAXI all-sky X-ray scanner. It will continuously monitors astronomical X-ray objects over a broad energy band (0.5 to 30 keV). MAXI will be installed on the Japanese external module of the ISS. After this mission JAXA plans to launch ASTRO-H, also known under the name NeXT, in the summer of 2013.

Solar astronomy

Japan's solar astronomy started in the early 80s with the launch of the *Hinotori* (ASTRO-A) x-ray mission. The Hinode (SOLAR-B) spacecraft, the follow-on to the Japan/US/UK

Yohkoh (SOLAR-A) spacecraft, was launched on 23 September 2006. A SOLAR-C can be expected sometime after 2010. However no details are worked out yet other than it will not be launched with the former ISASs Mu rockets. Instead H-2A from Tanegashima could launch it. As H-2A is more powerful SOLAR-C could either be heavier or be stationed at L_1 (Lagrange point 1).

Radio astronomy

In 1998 Japan launched the HALCA (Muses-B) Mission, the world first spacecraft dedicated to create SPACE VLBI observations of Pulsars among others. To do so, ISAS set up a ground network around the world through international cooperation. The observation part of the mission lasted until 2003 and the satellite was retired at the end of 2005. In FY 2006 Japan funded the ASTRO-G as the succeeding mission. Launch is planned for FY 2012.

Technology tests

One of the primary duties of the former NASDA body was the testing of new space technologies, mostly in the field of communication. The first test satellite was ETS-I,launched in 1975. However during the 1990s NASDA was hit by bad luck with the problems surrounding the ETS-VI and COMETS missions.

Testing of communication technologies remains as one of the Jaxas key duties in cooperation with NICT. **Active Mission:** ETS-VIII, WINDS, Index **Under Development:** QZSS-1 **Retired:** OICETS

ETS-VIII and WINDS

To upgrade Japan's communication technology the Japanese state launched the i-Space initiative with the ETS-VIII and WINDS missions.

ETS-VIII was launched on December 18, 2006. The purpose of ETS-VIII is to test communication equipment with two very large antennas and an atomic clock test. On December 26 both antennas were successfully deployed. This didn't come unexpected, since JAXA tested the deployment mechanism before with the LDREX-2 Mission, which was launched on October 14 with the European Ariane 5. The test was successful. The mission of WINDS is to create the worlds fastest satellite internet connection. WINDS was launched in February 2008.

OICETS and INDEX

On August 24, 2005, JAXA launched the experimental satellites OICETS and INDEX with the Dnepr rocket. OICETS mission is to test optical links with the European Space Agency (ESA) satellite ARTEMIS, which is around 40,000 km away from OICETS. The experiment was successful on December 9, when the link could be established. In March

2006 Jaxa could establish with OICETS the worldwide first optical links between a LEO satellite and a ground station first in Japan and in June 2006 with a mobile station in Germany.

INDEX is a small 70 kg satellite for testing various equipment and for a small aurora observation mission. The satellite is currently in the extended mission phase.

Earth observation programme

Japan's first Earth observation satellites were MOS-1a and MOS-1b launched in 1987 and 1990. During the 1990s and the new millennium this programme came under heavy fire, because both Adeos (Midori) and Adeos 2 (Midori 2) satellites failed after just 10 months in orbit.

Active Mission: ALOS, GOSAT **Under Development:** GCOM-W, GCOM-C, ALOS 2 SAR

ALOS

MTSAT-1

In January 2006, JAXA successfully launched the Advanced Land Observation Satellite (ALOS/Daichi). Communication between ALOS and the ground station in Japan will be done through the Kodama Data Relay Satellite, which was launched during 2002. This project is under intense pressure due to the shorter than expected life time of the ADEOS II (Midori) Earth Observation Mission. For the following on mission JAXA plans to split the mission into a radar satellite and an optical satellite. ALOS 2 SAR is currently planned for the winter of FY 2012.

Rainfall observation

Since Japan is an island nation and gets struck by typhoons every year, research about the dynamics of the atmospheric is a very important issue. For this reason Japan launched in 1997 the TRMM mission in cooperation with NASA, to observe the tropical rainfall seasons. JAXA and NASA are planning a successor to the TRMM mission. However because of NASA budget problems the launch date of the GPM project got pushed back to the year 2013. For further research NASDA although launched the ADEOS and ADEOS II missions in 1996 and 2003. However due to various reasons both satellites had a much shorter than expected life term.

Monitoring of carbon dioxide

At the end of the 2008 fiscal year, JAXA launched the satellite GOSAT (Greenhouse Gas Observing SATellite) to help scientists determine and monitor the density distribution of carbon dioxide in the atmosphere. The satellite is being jointly developed by JAXA and Japan's Ministry of the Environment. JAXA is building the satellite while the Ministry is in charge of the data that will be collected. Since the number of ground-based carbon dioxide observatories cannot monitor enough of the world's atmosphere and are distributed unevenly throughout the globe, the GOSAT may be able to gather more accurate data and fill in the gaps on the globe where there are no observatories on the ground. Sensors for methane and other greenhouse gasses are also being considered for the satellite, although the plans are not yet finalized. The satellite weighs approximately 1650 kg and is expected to have a life span of 5 years.

GCOM series

Next funded earth observation mission after GOSAT is the GCOM earth observation programme as a successor to ADEOS II (Midori) and the Aqua mission. To reduce the risk and for a longer observation time the mission will be split into smaller satellites. Altogether GCOM will be a series of six satellites. First launch, GCOM-W is scheduled for February 2012 with the H-IIA. Second launch GCOM-C is currently planned for February 2014.

Satellites for other agencies

For weather observation Japan launched on February 2005 the Multi-Functional Transport Satellite 1R (MTSAT-1R). The success of this launch was critical for Japan, since the original MTSAT-1 couldn't be put into orbit because of a launch failure with the H-2 rocket in 1999. Since then Japan relied for weather forecasting on an old satellite which was already beyond its useful life term and on American systems.

On February 18, 2006, JAXA, as head of the H-IIA at this time, successfully launched the MTSAT-2 aboard a H-2A rocket. MTSAT-2 is the backup to the MTSAT-1R. The MTSAT-2 uses the DS-2000 satellite bus developed by Mitsubishi Electric. The DS-2000 is also used for the DRTS Kodama, ETS-VIII and the Superbird 7 communication satellite, making it the first commercial success for Japan.

As a secondary mission both the MTSAT-1R and MTSAT-2 help to direct air traffic.

Other JAXA satellites currently in use

- Exos-D (Akebono) Aurora Observation, since 1989.
- GEOTAIL magnetosphere observation satellite (since 1992)
- DRTS (Kodama) Data Relay Satellite, since 2002. (Projected Life Span is 7 years)

On going joint missions with NASA are the Tropical Rainfall Measuring Mission (TRMM), the Aqua Earth Observation Satellite.

Finished missions

- OICETS, Technology Demonstration 2005-2009 (retired)
- SELENE, Moon probe 2007-2009 (retired)
- Micro Lab Sat 1, Small engineering mission, launch 2002. (retired 27 September 2006)
- HALCA, Space VLBI 1997-2005 (retired)
- Nozomi, Mars Mission 1998-2003 (failed)
- MDS-1, Technology Demonstration 2002-2003 (retired)
- ADEOS 2, (Midori 2) Earth Observation 2002-2003 (lost)

Future missions

HTV-1

As JAXA shifted away from international efforts beginning in 2005, plans are developing for independent space missions, such as a proposed manned mission to the moon.

2009 and beyond

On February 23, 2008 JAXA launched the Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), also called "KIZUNA." WINDS will facilitate experiments with faster internet connections. The launch, using H-IIA launch vehicle 14, took place from the Tanegashima Space Center.

On September 10, 2009 the first H-IIB rocket was successfully launched, delivering the HTV-1 freighter to resupply the International Space Station.

Another project is the Global Precipitation Measurement/Dual-frequency Precipitation Radar (GPM/DPR) which is a joint development with NASA. This mission is the successor to the highly successful TRMM mission. JAXA will develop the radar and provide the launch vehicle. Other countries/agencies like China, India, ESA etc. will provide the subsatellites. The aim of this mission is to measure global rainfall. However because of NASA budget limitations this project was pushed back to 2010.

In the year 2009 JAXA plans to launch the first satellite of the Quasi Zenith Satellite System (QZSS), a subsystem of the global positioning system (GPS). Two others are expected to follow later. If successful, one satellite will be in a zenith position over Japan full time. The QZSS mission is the last scheduled major independent mission for JAXA, as no major civilian projects were funded after that for now. The only exception is the IGS programme which will be continued beyond 2008. However it seems Japan is pressing forward now with the GCOM earth observation satellites as successors to the ADEOS missions. First launch is planned for 2010. In 2009 Japan also plans to launch a new version of the IGS with an improved resolution of 60 cm.

Launch schedule

First launch of the H-IIB and the HTV is September 1, 2009. After the first flight one HTV launch is planned during each FY until 2015. (If not mentioned otherwise launch vehicle for the following missions is the H-IIA.)

FY 2010

- H-II Transfer Vehicle, Unmanned resupply spacecraft, launch: Winter, 2010
- Quasi Zenith Satellite System, launch: Aug, 2010
- Akatsuki, probe to Venus, launch: May, 2010
- IKAROS, Solar-sail Technology Demonstration satellite, launch: May, 2010

FY 2011

- GCOM-W, Climate Observation satellite, launch: Feb, 2012

FY 2012

- ALOS 2 SAR, Earth Observation satellite, launch: Winter 2012
- ASTRO-G (VSOP-2) successor to the Halca mission, launch: Summer 2012
- TOPS Telescope Observatory for Planets on Small-satellite launch Feb, 2012 (First launch of the new Advanced Solid Rocket, the successor to the M-V.

FY 2013

- GPM, successor to the TRMM joint NASA mission
- BepiColombo, joint ESA mission to Mercury, launch: 2013 (LV: Ariane 5)
- ASTRO-H x-ray observatory, launch: summer 2013.
- GCOM-C, Climate Observation satellite, launch: Feb, 2014

Other missions

For the 2012 ESA EarthCare mission, JAXA will provide the radar system on the satellite. JAXA is also providing the Light Particle Telescope(LPT) for the 2008 Jason 2 satellite by the French CNES. JAXA will provide the Auroral Electron Sensor (AES) for the Taiwanese FORMOSAT-5.

- SmartSat-1, small communication test and sun corona observation, Mission status unclear
- XEUS joint X-Ray telescope with ESA, launch after 2015.
- Sohla-2 Small PETSAT Demonstration Satellite

New orientation of JAXA

Planning interstellar research missions can take up to seven years, such as the ASTRO-E. Due to the lag time between these interstellar events and mission planning time, opportunities to gain new knowledge about the cosmos might be lost. To prevent this, JAXA plans on using smaller, faster missions from 2010 onwards. JAXA is also planning to develop a new solid fueled rocket to replace the twelve year old M-V.

Developing projects

- IKAROS (Interplanetary Kite-craft Accelerated by Radiation Of the Sun), a small size powered-solar sail experimental spacecraft. Future mission will use solar sail for Jupiter and Trojan asteroids exploration.

Plans

- Selene-2, a moon landing mission
- Hayabusa 2, for launch in 2010-2011 for target 1999JU3
- Hayabusa Mk2/Marco Polo

- Human Lunar Systems, conceptual system study on the future human lunar outpost

- ALOS 2, earth observation
- SPICA, a 3,5 meter infrared telescope to be placed at L2
- JASMINE, infrared telescope for measuring the universe
- DIOS, small scale x-ray observation

- Space Solar Power System (SSPS), space-based solar power prototype launch in 2020, aiming for a full power system in 2030

Human space program

The *Spacelab-J* shuttle flight, funded by Japan, included several tons of Japanese science research equipment

Japan has ten astronauts but has not yet developed its own manned spacecraft and is not currently developing one officially. Sometime ago an unmanned mainly and manned prospectively space shuttle-spaceplane HOPE-X project launched by conventional space launcher H-II was developed for several years (including test flights of Hyflex/OREX prototypes) but was postponed. Then the simpler manned capsule Fuji was proposed but not adopted. Projects of single-stage to orbit, reusable launch vehicle horizontal takeoff and landing ASSTS and vertical takeoff and landing Kankoh-maru also exist but have not been adopted.

The first Japanese citizen to fly in space was Toyohiro Akiyama, a journalist sponsored by TBS, who flew on the Soviet Soyuz TM-11 in December 1990. He spent more than seven days in space on the Mir space station, in what the Soviets called their first commercial spaceflight which allowed them to earn $14 million.

Japan participates in US and international manned space programs including flights of Japanese astronauts on a board of US Space Shuttles, Russian Soyuz spacecraft and ISS. Besides this paid for seat flights, one Space Shuttle mission (STS-47, which occurred in September 1992) was partially funded by Japan. On board STS-47 was Japan's first professional astronaut Mamoru Mohri, as the Payload Specialist for the Spacelab-J, one of the European built Spacelab modules. This mission was also designated *Japan*.

A view of the completed Kibo module.

Mainly for Japan, another three US Space Shuttles missions (STS-123, STS-124, STS-127) were in 2008-2009 for delivery of parts of Japan built spacelab-module Kibo to ISS.

Under a new plan, Japan and JAXA has set a goal of constructing a manned lunar base. Japanese robots and then astronauts would be sent to the Moon by beyond 2020 which is approximately the same time as Indian Space Research Organisation (ISRO) manned lunar mission beyond 2020, China National Space Administration (CNSA) manned lunar mission near 2030 and NASA's Project Constellation planned to return to the Moon in 2019 with its Orion-Altair project) so that they will start construction of the base to be completed by 2030.

Before this Moon goals JAXA intends to develop the manned capsule spacecraft launched by space launcher H-IIB.

Supersonic aircraft development

Besides the H-IIA and M-5 rockets, JAXA is also developing technology for a next-generation supersonic transport that could become the commercial replacement for the Concorde. The design goal of the project (working name NEXST) is to develop a jet that can carry 300 passengers at Mach 2. A subscale model of the jet underwent aerodynamic testing in September and October 2005 in Australia. The economic success of such a project is still unclear, and as a consequence the project has been met with limited interest from Japanese aerospace companies like Mitsubishi Heavy Industries so far.

Reusable launch vehicles

Until 2003 JAXA (ISAS) conducted research on a reusable launch vehicle under the Reusable Vehicle Testing (RVT) project.

Research centers and offices

Head Office

Tanegashima Space Center

JAXA has research centers in many locations in Japan, and some offices overseas. Its headquarters are in Chōfu, Tokyo. It also has

- Earth Observation Research Center (EORC), Tokyo
- Earth Observation Center (EOC) in Hatayama
- Noshiro Testing Center (NTC) - Established in 1962. It carries out development and testing of rocket engines.
- Sanriku Balloon Center (SBC) - Balloons have been launched from this site since 1971.
- Kakuda Space Propulsion Center (KSPC) - Leads the development of rocket engines. Works mainly with development of liquid fuel engines.
- Sagamihara Campus (ISAS) - Development of experimental equipment for rockets and satellites. Also administrative buildings.
- Tanegashima Space Center
- Tsukuba Space Center (TKSC) in Tsukuba. This is the center of Japan's space network. It is involved in research and development of satellites and rockets, and tracking and controlling of satellites. It develops experimental equipment for the Japanese Experiment Module ("Kibo"). Training of astronauts also takes place here. For International Space Station operations, the Japanese Flight Control Team is located at the Space Station Integration & Promotion Center (SSIPC) in

Tsukuba. SSIPC communicates regularly with ISS crewmembers via S-band audio.

- Uchinoura Space Center

Other space agencies in Japan

Not included into the JAXA organization is the Institute for unmanned space experiment free flyer (USEF), Japan's other space agency.

Chapter- 2

SELENE

Kaguya (かぐや?) (SELENE)

Operator	JAXA
Major contractors	NEC Toshiba Space Systems
Mission type	Orbiter
Satellite of	The Moon
Launch date	2007-09-14, 01:31:01 UTC
Carrier rocket	H-IIA
COSPAR ID	2007-039A
Homepage	SELENE page
Mass	2,914 kg (Main Orbiter, launch mass)
Power	3,486 W
	Orbital elements
Inclination	90°

Apoapsis	100 km
Periapsis	100 km
Orbital period	2h

SELENE, better known in Japan by its nickname **Kaguya** (かぐや?) after the legendary Japanese moon princess, was the second Japanese lunar orbiter spacecraft. Produced by the Institute of Space and Astronautical Science (ISAS) and the National Space Development Agency (NASDA), both now part of the Japan Aerospace Exploration Agency, JAXA, the spacecraft was launched September 14, 2007. After successfully orbiting the moon for 1 year and 8 months, the main orbiter was intentionally crashed onto the lunar surface near Gill lunar crater at 18:25 UTC on June 10, 2009.

Selene (Ancient Greek: Σελήνη, *moon*) is the Greek goddess of the moon. The orbiter's nickname **Kaguya** was selected by the general public. It comes from the name of a lunar princess in the ancient Japanese folktale *The Tale of the Bamboo Cutter*. After their successful release, its sub-satellites Rstar and Vstar were named **Okina** and **Ouna**, also from the folklore.

Mission objectives

The main scientific objectives of the mission were to:

- Study the origins of the Moon and its geologic evolution
- Obtain information about the lunar surface environment
- Perform radio science, especially precise measurement of the moon's gravity field

Launch

Launch of H-IIA F13 carrying SELENE (Photo by Narita Masahiro)

SELENE launched on 14 September 2007 at 01:31:01 UTC on an H-IIA (Model H2A2022) carrier rocket from Tanegashima Space Center into a 281.55 km (perigee) / 232960 km (apogee) geocentric parking orbit. The total launch mass was 3020 kg.

The SELENE mission was originally scheduled to launch in 2003, but rocket failures on another mission and technical difficulties delayed the launch until 2007. Launch was planned for August 16, 2007, but was postponed when some electronic components were found to be installed incorrectly.

Lunar operations

On October 3, it entered an initial 101 to 11741 km polar lunar orbit. On October 9, the relay satellite was released into a 100 to 2400 km orbit, and on October 12 the VLBI satellite was released into a 100 to 800 km orbit. Finally, by October 19, the orbiter was in an circular 100 km orbit. The nominal mission duration was one year plus possible extensions.

On October 31, 2007 Kaguya deployed its Lunar Magnetometer, Lunar Radar Sounder, Earth-looking Upper Atmosphere and Plasma Imager.

On December 21, 2007, Kaguya began regular operations after all fifteen observation experiments had been satisfactorily verified.

Kaguya completed the planned operation by the end of October 2008 and began extended operations planned to continue through March 2009. The orbit would then be reduced to 50 km circular and finally to 20 km - 100 km elliptical, with a controlled impact occurring by August 2009. Because of a degraded reaction wheel, the plan was changed so that on February 1, 2009, the orbit was lowered to 50 km ± 20 km, and impact occurred at 18:25 UTC on June 10, 2009.

Other Lunar probing operation

SELENE was part of a renewed global interest in lunar exploration; it was "the largest lunar mission since the Apollo program". It followed Japan's first lunar probe, Hagoromo, launched in 1990. China launched its Chang'e 1 lunar explorer on October 24, 2007, followed by India's 22 October 2008 launch of Chandrayaan-1 and the United States Lunar Reconnaissance Orbiter in June 2009. The United States, European countries (ESA), Russia, Japan, India and China are planning future manned lunar exploration missions or Lunar outpost construction on the moon between 2018 and 2025.

Design

The mission featured three separate spacecraft:

Main orbiter

- Shape: rectangular
- Mass: 2,914 kg
- Size: 2.1 x 2.1 x 4.8 m
- Attitude control: Three-axis stabilized
- Power: 3.5 kW (Max.)
- Mission period: 1 year
- Mission orbit: Circular, 100 km
- Inclination: 90 degrees

Okina (small relay satellite)

Okina (formerly Rstar) and Ouna (formerly Vstar) were octagonal prisms to support radio science. Okina relayed radio communications between the orbiter and the earth when the orbiter was behind the moon. This allowed, for the first time, the direct Doppler shift measurements needed to precisely map the gravitational field of the lunar farside; previously, the far side gravity field could only be inferred by near side measurements.

The relay satellite impacted the lunar farside near Mineur D crater at 19:46 JST (10:46 UTC) on February 12, 2009.

- Function: two-way radio science relay, orbiter-earth
- Mass: 53 kg
- Size: 1.0 x 1.0 x 0.65 m
- Attitude control: spin-stabilized
- Power: 70 W
- Initial orbit: 100 x 2,400 km
- Inclination: 90 degrees

Ouna (VLBI satellite)

Ouna used Very Long Baseline Interferometry as a second way to map the moon's gravity field. It was especially useful at the lunar limb where the gravitational acceleration is perpendicular to the line of sight to earth, making Doppler measurements unsuitable.

- Function: VLBI radio science
- Mass: 53 kg
- Size: 1.0 x 1.0 x 0.65 m
- Attitude control: spin-stabilized
- Power: 70 W
- Initial orbit: 100 x 800 km
- Inclination: 90 degrees

Payload

SELENE carried 13 scientific instruments "to obtain scientific data of the lunar origin and evolution and to develop the technology for the future lunar exploration":

- Terrain camera (TC) (resolution 10 meters per pixel)
- X-Ray fluorescence spectrometer (XRS)
- Lunar magnetometer (LMAG)
- Spectral profiler (SP) (resolution per pixel: 562 x 400 m)
- Multi-band imager (MI) (resolution of visible light 20 meters per pixel, near-infrared 62 meters per pixel)
- laser altimeter (LALT)
- Lunar radar sounder (LRS)
- Gamma ray spectrometer (GRS)
- Charged particle spectrometer (CPS)
- Plasma analyzer (PACE)
- Upper atmosphere and plasma imager (UPI)
- Radio wave repeater (RSAT) aboard Okina
- Radio wave source for VLBI (VRAD) aboard Okina and Ouna

Two 2.2 megapixel CCD HDTV cameras, one wide-angle and one telephoto, were also on board primarily for public relations purposes.

JAXA collected names and messages that were carried on SELENE through their "Wish Upon the Moon" campaign. 412,627 names and messages were printed on a sheet measuring 280 mm × 160 mm at 70 µm per character. The sheet was installed under the photovoltaic modules and cooling panels beneath the multi-layered insulation.

Results

Major results include:

- Improved lunar global topography maps. This detailed altitude and geological data is provided to Google for free to make Google moon 3-D.
- Detailed gravity map of the far side of the Moon.
- First optical observation of the permanently shadowed interior of the crater Shackleton at the lunar south pole.

Chapter- 3

Akari (Satellite)

Akari

Artist's conception of Akari

General information

NSSDC ID	2006-005A
Organization	Japan Aerospace Exploration Agency (JAXA)
Launch date	2006-02-21 21:28 UTC
Launched from	Uchinoura Space Center Uchinoura, Kagoshima, Japan
Mission length	elapsed: 4 years, 11 months, and 25 days
Mass	955 kg (2,110 lb)
Orbit height	694.5 km (431.5 mi)
Orbit period	96.6 minutes

Location	Low Earth orbit
Telescope style	Richey-Chrétien reflector
Wavelength	Infrared
Diameter	0.67 m (2 ft 2 in)
Focal length	4.2 m (170 in)
Instruments	
Far-Infrared Surveyor (FIS)	far-infrared camera/spectrometer
Infra-Red Camera (IRC)	near-infrared camera/spectrometer

Akari (**Astro-F**) is an infrared astronomy satellite developed by Japan Aerospace Exploration Agency, in cooperation with institutes of Europe and Korea. It was launched on 21:28, 21 February 2006 UTC (06:28, 22 February JST) by M-V rocket into Earth sun-synchronous orbit. After its launch it was named *Akari* (あかり), which means *light* in Japanese.

Its primary mission is to survey the entire sky in near-, mid- and far-infrared, through its 68.5 cm (27.0 in) aperture telescope.

Its designed lifespan, of far- and mid-infrared sensors, is 550 days, limited by its liquid helium coolant. Near-infrared sensor will continue to operate after that with mechanical coolers at 40K.

The satellite is three-axis stabilized and the telescope is directed anti-Earth direction while the bus module faces toward Earth, to shield the telescope from the heat of Earth surface. The orbit is sun-synchronous and one side of the satellite is always directed toward Sun, and the telescope axis perpendicular to Sun, which simplifies heat shield design.

Its telescope mirror is made of silicon carbide to save weight. The budget for the satellite was ¥13,4 billion (~US$110 million).

Status

By mid-August 2006, Akari finished around 50 percent of the all sky survey.

By early November 2006, first (phase-1) all-sky survey finished. Second (phase-2) all-sky survey started on 10 November 2006.

Due to the malfunction of sun-sensor after the launch, ejection of telescope aperture lid was delayed, resulting the coolant lifespan estimate to be shortened to about 500 days from launch. However after JAXA estimated the remaining helium during early March 2007 observation time will be extended at least until 9 September.

On 11 July 2007, JAXA informed that 90 percent of the sky was scanned twice. Also around 3,500 selected targets have been observed so far.

On 26 August 2007, liquid-Helium coolant depleted, which means the completion of far- and mid-infrared observation. 94 percent of the sky was scanned and more than 5,000 pointed observations were done.

British and Japanese project team members were awarded a Daiwa Adrian Prize in 2004 by The Daiwa Anglo-Japanese Foundation in recognition of their collaboration.

During December 2007 JAXA performed orbit correction manoeuvres to bring Akari back into its ideal orbit. This was necessary because the boiled off helium led to an increase in altitude. If this would have continued energy supply would have been cut off.

Results

- Star formation over three generations in the nebula IC4954/4955 in the constellation Vulpecula.
- The first infrared detection of a supernova remnant in the Small Magellanic Cloud
- Detection of mass-loss from relatively young red-giant stars in the globular cluster NGC 104
- Detection of the molecular gas surrounding the active galactic nucleus in the ultra luminous infrared galaxy
- The constellation Orion and the winter Milky Way at 140 micrometre
- Star forming region in the constellation Cygnus
- Active star formation viewed from the outside: The peculiar spiral galaxy M101
- Dust processing in the supernova remnants in the Large Magellanic Cloud

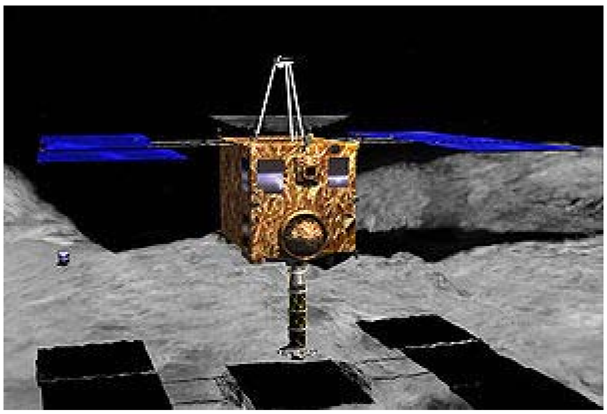
The Akari All-Sky Survey Point Source Catalogues was released on March 30, 2010.

Astronomy and Astrophysics, Vol. 514 (May 2010) was a feature issue of Akari's result.

Chapter- 4

Hayabusa

Hayabusa



A computer rendering of Hayabusa above Itokawa's surface

Operator	JAXA
Mission type	Asteroid sample return
Current destination	Returned to Earth on 13 June 2010
Launch date	9 May 2003
Launch vehicle	M-V
Mission duration	7 years, 1 month and 4 days
COSPAR ID	2003-019A
Mass	510 kg (dry 380 kg)

Instruments

AMICA, LIDAR, NIRS, XRS

Hayabusa (はやぶさ?, literally "peregrine falcon") was an unmanned spacecraft developed by the Japan Aerospace Exploration Agency to return a sample of material from a small near-Earth asteroid named 25143 Itokawa to Earth for further analysis.

Hayabusa, formerly known as **MUSES-C** for Mu Space Engineering Spacecraft C, was launched on 9 May 2003 and rendezvoused with Itokawa in mid-September 2005. After arriving at Itokawa, Hayabusa studied the asteroid's shape, spin, topography, colour, composition, density, and history. In November 2005, it landed on the asteroid and collected samples in the form of tiny grains of asteroidal material, which were returned to Earth aboard the spacecraft on 13 June 2010.

The spacecraft also carried a detachable minilander, MINERVA, but this failed to reach the surface.

Mission firsts

Denis J. P. Moura (left) and Junichiro Kawaguchi (right) at the 2010 International Astronautical Congress (IAC)

Other spacecraft, notably Galileo and NEAR Shoemaker both sent by NASA, have visited asteroids before, but the Hayabusa mission was the first time that an attempt was made to return an asteroid sample to Earth for analysis.

In addition, Hayabusa was the first spacecraft designed to deliberately land on an asteroid and then take off again (*NEAR Shoemaker* made a controlled descent to the surface of 433 Eros in 2000, but it was not designed as a lander and was eventually deactivated after it arrived). Technically, Hayabusa was not designed to "land"; it simply touches the surface with its sample capturing device and then moves away. However, it was the first craft designed from the outset to make contact with the surface of an asteroid. Junichiro Kawaguchi of the Institute of Space and Astronautical Science was appointed to the leader of the mission.

Despite its designer's intention of a momentary contact, Hayabusa did land and sit on the asteroid surface for about 30 minutes.

Mission profile

The half-scale model of Hayabusa at the IAC in 2010

The replica of the re-entry capsule exhibited at JAXAi (closed on December 28, 2010)

The Hayabusa spacecraft was launched on 9 May 2003 at 04:29:25 UTC on an M-V rocket from the Uchinoura Space Center (still called Kagoshima Space Center at that time). Following launch, the spacecraft's name was changed from the original MUSES-C to Hayabusa, the Japanese word for falcon. The spacecraft's xenon ion engines (four separate units), operating near-continuously for two years, slowly moved Hayabusa toward a September 2005 rendezvous with Itokawa. As it arrived, the spacecraft did not go into orbit around the asteroid, but remained in a station-keeping heliocentric orbit close by.

Hayabusa surveyed the asteroid surface from a distance of about 20 km, the "gate position". After this the spacecraft moved closer to the surface (the "home position"), and then approached the asteroid for a series of soft landings and for the collection of samples at a safe site. Autonomous optical navigation was employed extensively during this period because the long communication delay prohibits Earth-based real-time commanding. At the second Hayabusa touchdown with its deployable collection horn, the spacecraft was programmed to fire tiny projectiles at the surface and then collect the resulting spray. Some tiny specks were collected by the spacecraft for analysis back on Earth.

After a few months in proximity to the asteroid, the spacecraft was scheduled to fire its engines to begin its cruise back to Earth. This maneuver was delayed due to problems with attitude control and the thrusters of the craft. Once it was on its return trajectory, the re-entry capsule was released from the main spacecraft three hours before reentry, and the capsule coasted on a ballistic trajectory, re-entering the Earth's atmosphere at 13:51, 13 June 2010 UTC. It is estimated that the capsule experienced peak deceleration of about 25 G and heating rates approximately 30 times those experienced by the Apollo spacecraft. It landed via parachute near Woomera, Australia.

In relation to the mission profile, JAXA defined the following success criteria and corresponding scores for major milestones in the mission prior to the launch of the Hayabusa spacecraft. As it shows, the Hayabusa spacecraft is a platform for testing new technology and the primary objective of the Hayabusa project is the world's first implementation of microwave discharge ion engines. Hence 'operation of ion engines for more than 1000 hours' is an achievement that gives a full score of 100 points, and the rest of the milestones are a series of world's first-time experiments built on it.

Success Criteria for HAYABUSA	**Points**	**Status**
Operation of Ion Engines	50 points	Success
Operation of Ion Engines for more than 1000 hours	100 points	Success
Earth Gravity Assist with Ion Engines	150 points	Success
Rendezvous with Itokawa with Autonomous Navigation	200 points	Success
Scientific Observation of Itokawa	250 points	Success
Touch-down and Sample Collection	275 points	Success
Capsule Recovered	400 points	Success
Sample obtained for Analysis	500 points	Success

MINERVA mini-lander

Hayabusa carried a tiny mini-lander (weighing only 591 g, and approximately 10 cm tall by 12 cm in diameter) named "MINERVA" (short for MIcro/Nano Experimental Robot Vehicle for Asteroid). Unfortunately, an error during deployment resulted in the craft's failure.

This solar-powered vehicle was designed to take advantage of Itokawa's very low gravity by using an internal flywheel assembly to hop across the surface of the asteroid, relaying images from its cameras to Hayabusa whenever the two spacecraft were in sight of one another.

MINERVA was deployed on 12 November 2005. The lander release command was sent from Earth, but before the command could arrive, Hayabusa's altimeter measured its distance from Itokawa to be 44 m and thus started an automatic altitude keeping sequence. As a result, when the MINERVA release command arrived, MINERVA was released while the probe was ascending and at a higher altitude than intended, so that it escaped Itokawa's gravitational pull and tumbled into space.

Had it been successful, MINERVA would have been the first space hopper to see action. Instead it joins ranks with the hopper carried on the failed Phobos 2 mission, which also never saw use.

Scientific and engineering importance of the mission

Scientists' current understanding of asteroids depends greatly on meteorite samples, but it is very difficult to match up meteorite samples with the exact asteroids from which they came. Hayabusa would solve this problem by bringing back pristine samples from a specific, well-characterized asteroid. Accordingly, Hayabusa "will bridge the gap between ground observation data of asteroids and laboratory analysis of meteorite and cosmic dust collections," says mission scientist Hajime Yano. Also in comparing the data from the onboard instruments of the Hayabusa with the data from the NEAR Shoemaker mission will put the knowledge on a wider level.

The Hayabusa mission has a very deep engineering importance for JAXA, too. It allows JAXA to further test its technologies in the fields of ion engines, autonomous and optical navigation, deep space communication, and close movement on objects with low gravity among others. Second, since it was the first-ever preplanned soft contact with the surface of an asteroid (the NEAR Shoemaker landing on 433 Eros was not preplanned) it has enormous influence on further asteroid missions.

Changes in mission plan

The Hayabusa mission profile has been modified several times, both before and after launch.

- The spacecraft was originally intended to launch in July 2002 to the asteroid 4660 Nereus (the asteroid (10302) 1989 ML was considered as an alternative target). However, a July 2000 failure of Japan's M-5 rocket forced a delay in the launch, putting both Nereus and 1989 ML out of reach. As a result, the target asteroid was changed to 1998 SF_{36}, which was soon thereafter named for Japanese rocket pioneer Hideo Itokawa.
- Hayabusa was to deploy a small rover supplied by NASA and developed by JPL, called Muses-CN, onto the surface of the asteroid, but the rover was canceled by NASA in November 2000 due to budget constraints.
- In 2002, launch was postponed from December 2002 to May 2003 to recheck the O-rings of its reaction control system since one of them had been found to be using a different material than specified.
- In 2003, while Hayabusa was en-route to Itokawa, a large solar flare damaged the solar cells aboard the spacecraft. This reduction in electrical power reduced the efficiency of the ion engines, thus delaying the arrival at Itokawa from June to September 2005. Since orbital mechanics dictated that the spacecraft still had to leave the asteroid by November 2005, the amount of the time it was able to spend

at Itokawa was greatly reduced and the number of landings on the asteroid was reduced from three to two.

- In 2005, two reaction wheels that govern the attitude movement of Hayabusa failed; the X-axis wheel failed on July 31, and the Y-axis on October 2. After the latter failure, the spacecraft was still able to turn on its X and Y axes with its thrusters. JAXA claimed that since global mapping of Itokawa had been completed, this was not a major problem, but the mission plan was altered. The failed reaction wheels were manufactured by Ithaco Space Systems, Inc, New York, which was later acquired by Goodrich Company.
- The 4 November 2005, 'rehearsal' landing on Itokawa failed, and was rescheduled.
- The original decision to sample two different sites on the asteroid was changed when one of the sites, Woomera Desert, was found to be too rocky for a safe landing.
- The 12 November 2005, release of the MINERVA miniprobe ended in failure.

Mission timeline

Up to the launch

The asteroid exploration mission by ISAS originates in 1986–1987 when the scientists investigated the feasibility of a sample return mission to Anteros and concluded that the technology was not yet developed. Between 1987 and 1994, joint ISAS / NASA group studied several missions: an asteroid rendezvous mission later became NEAR, and a comet sample return mission later became Stardust.

In 1995, ISAS selected the asteroid sampling as an engineering demonstration mission, MUSES-C, Nereus as the first choice of target, 1989 ML as the secondary choice, and MUSES-C project started in fiscal year 1996. In early development phase, Nereus was considered out of reach and 1989 ML became the primary target. July 2000 failure of M-V forced a delay in the launch from July 2002 to November/December, putting both Nereus and 1989 ML out of reach. As a result, the target asteroid was changed to 1998 SF_{36}. In 2002, launch was postponed from December 2002 to May 2003 to recheck O-rings of reaction control system since one of it was found using different material than specification. On May 9, 2003 04:29:25 UTC, MUSES-C was launched by M-V rocket, and the probe was named "Hayabusa".

Cruising

Ion thruster checkout started on 27 May 2003. Full power operation started on 25 June.

Asteroids are named by their discoverer. ISAS asked LINEAR, the discoverer of 1998 SF_{36}, to offer the name after Hideo Itokawa, and on 6 August, Minor Planet Circular reported that the target asteroid 1998 SF_{36} was named *Itokawa*.

On October 2003, ISAS and two other national aerospace agencies were merged to form JAXA.

On March 31, 2004, ion thruster operation was stopped to prepare for the Earth swing-by. Last manoeuvre operation before swing-by on May 12. On May 19, Hayabusa performed Earth swing-by. On 27 May, ion thruster operation was started again.

On February 18, 2005, Hayabusa passed aphelion at 1.7 AU. On 31 July, the X-axis reaction wheel failed. On 14 August, Hayabusa's first image of Itokawa was released. The picture was taken by the star tracker and shows a point of light, believed to be the asteroid, moving across the starfield. Other images were taken from 22 to 24 August. On August 28, Hayabusa was switched over from the ion engines to the bi-propellant thrusters for orbital maneuvering. From 4 September, Hayabusa's cameras were able to confirm Itokawa's elongated shape. From September 11, individual hills were discerned on the asteroid. On 12 September, Hayabusa was 20 km from Itokawa and JAXA scientists announced that Hayabusa had officially "arrived".

In proximity of Itokawa

On 15 September, a 'colour' image of the asteroid was released (which is, however, grey in colouring). On 4 October, JAXA announced that the spacecraft had successfully moved to its 'Home Position' 7 km from Itokawa. Closeup pictures were released. It was also announced that the spacecraft's second reaction wheel, governing the Y-axis, had failed, and that the craft was now being pointed by its rotation thrusters. On November 3, Hayabusa took station 3.0 km from Itokawa. It then began its descent, planned to include delivery of a target marker, and release of the Minerva minilander. The descent went well initially, and navigation images with wide-angle cameras were obtained. However, at 1:50 am UTC (10:50 am JST) on 4 November, it was announced that due to a detection of an anomalous signal at the Go/NoGo decision, the descent, including release of Minerva and the target marker had been canceled. The project manager, Jun-ichiro Kawaguchi, explained that the optical navigation system was not tracking the asteroid very well, probably caused by the complex shape of Itokawa. A few days delay was required to evaluate the situation and reschedule.

On 7 November, Hayabusa was 7.5 km from Itokawa. On November 9, Hayabusa performed a descent to 70 m to test the landing navigation and the laser altimeter. After that, Hayabusa backed off to a higher position, then descended again to 500 m and released one of the target markers into space to test the craft's ability to track it (this was confirmed). From analysis of the closeup images, the Woomera Desert site (Point B) was found to be too rocky to be suitable for landing. The Muses Sea site (Point A) was selected as the landing site, for both first and, if possible, second landings.

On 12 November, Hayabusa closed in to 55 m from the asteroid's surface. MINERVA was released but due to an error failed to reach the surface. On 19 November, Hayabusa landed on the asteroid. There was considerable confusion during and after the maneuver about precisely what had happened, because the high-gain antenna of the probe could not be used during final phase of touch-down, as well as the blackout during handover of ground station antenna from DSN to Usuda station. It was initially reported that Hayabusa had stopped at approximately 10 meters from the surface, hovering for 30 minutes for unknown reasons. Ground control sent a command to abort and ascend, and by the time the communication was regained, the probe had moved 100 km away from the asteroid. The probe had entered into a safe mode, slowly spinning to stabilize attitude. However, after regaining control and communication with the probe, the data from the landing attempt were downloaded and analyzed, and on 23 November, JAXA announced that the probe had indeed landed on the asteroid's surface. Unfortunately, the sampling sequence was not triggered since a sensor detected an obstacle during descent; the probe tried to abort the landing, but since its attitude was not appropriate for ascent, it chose instead a safe descent mode. This mode did not permit a sample to be taken, but there is a high probability that some dust may have whirled up into the sampling horn when it touched the asteroid, so the sample canister currently attached to the sampling horn was sealed. On November 25, a second touchdown attempt was performed. It was initially thought that this time, the sampling device was activated; however, later analysis decided that this was probably another failure and that no pellets were fired. Due to a leak in the thruster system, the probe was put in a "safe hold mode".

On 30 November, JAXA announced that control and communication with Hayabusa had been restored, but a problem remained with the craft's reaction control system, perhaps involving a frozen pipe. Mission control was working to resolve the problem before the craft's upcoming launch window for return to Earth. On December 6, Hayabusa was 550 km from Itokawa. JAXA held a press conference about the situation so far. On 27 November, the probe experienced a power outage when trying attitude correction, probably due to a fuel leakage. On 2 December, an attitude correction was tried, but the thruster did not generate enough force. On 3 December, the probe's Z-axis was found to be 20 to 30 degrees from the sun direction and increasing. On 4 December, as an emergency measure, xenon propellant from the ion engines was blown to correct the spin, and it was confirmed successful. Attitude control was commanded using the xenon gas. On 5 December, attitude was corrected enough to regain communication through the medium gain antenna. Telemetry was obtained and analyzed. As the result of telemetry analysis, it was found that there was a strong possibility that the sampler projectile had not penetrated when it landed on 25 November. Due to the power outage, the telemetry log data was faulty. On 8 December, a sudden attitude change was observed, and communication with Hayabusa was lost. It was thought likely that the turbulence was caused by evaporation of 8 or 10cc of leaked fuel. This forced a wait of a month or two for Hayabusa to stabilize by conversion of precession to pure rotation, after which the rotation axis needed to be directed toward the Sun and Earth within a specific angular range. The probability of achieving this was estimated at 60% by December 2006, 70% by spring 2007.

Recovery and return to Earth

On 7 March 2006, JAXA announced that communication with Hayabusa had been recovered in the following stages: On 23 January, the beacon signal from the probe was detected. On 26 January, the probe responded to commands from ground control by changing beacon signal. On 6 February, an ejection of xenon propellant was commanded for attitude control to improve communication. The spin axis change rate was about two degrees per day. On 25 February, telemetry data was obtained through low-gain antenna. On 4 March, telemetry data was obtained through medium-gain antenna. On 6 March, Hayabusa's position was established at about 13,000 km ahead of Itokawa in its orbit with a relative speed of 3 m per second.

On 1 June, Hayabusa project manager Jun-ichiro Kawaguchi reported that they confirmed two out of four ion engines work normally, which would be sufficient for return journey. On 30 January 2007, Jaxa reported that 7 out of 11 batteries are working and the return capsule was sealed. On 25 April, JAXA reported that Hayabusa started the return journey. On 29 August, it was announced that Ion Engine C onboard Hayabusa, in addition to B and D, has been successfully re-ignited. On 29 October, JAXA reported that the first phase of trajectory maneuver operation has finished and the spacecraft is now put in spin-stabilized state. On 4 February 2009, JAXA reported success in reignition of ion engines and starting second phase of trajectory correction maneuver to return to the Earth. On 4 November 2009, the ion engine D automatically stopped working due to the anomaly from degradation.

On 19 November 2009, JAXA announced that they managed to combine the ion generator of ion engine B and the neutralizer of ion engine A. It is suboptimal but expected to be sufficient to generate the necessary delta-v. Out of 2,200 m/s delta-v necessary to return to the earth, about 2,000 m/s had been performed already, and about 200 m/s still necessary. On 5 March 2010, Hayabusa was on a trajectory that would have passed within the lunar orbit. Ion engine operation was suspended to measure the precise trajectory in preparation to perform Trajectory Correction Maneuver 1 to the Earth-rim trajectory. On 27 March, 06:17 UTC, Hayabusa was on a trajectory which would pass 20,000 km from Earth center, completing the orbit transfer operation from Itokawa to Earth. By 6 April, completed first stage of Trajectory Correction Maneuver (TCM-0) which controlled coarsely to Earth rim trajectory. It was planned to be 60 days before reentry. By 4 May, completed TCM-1 maneuver to control precisely to Earth rim trajectory. On 22 May, TCM-2 started, continued for about 92.5 hours, and finished on 26 May. TCM-3 from 3 through 5 June to change the trajectory from the Earth rim to Woomera, South Australia, TCM-4 was performed on June 9 for about 2.5 hours for a precision control to Woomera Prohibited Area. The reentry capsule was released at 10:51 UTC of 13 June.

Reentry and capsule retrieval

Hayabusa re-entry filmed by a camera onboard NASA's DC-8 Airborne Laboratory. The glowing return capsule is seen forward of and below the main Hayabusa probe bus as the latter breaks up. The heat-shielded capsule continues leaving a wake after the main bus fragments have faded.

The glowing return capsule is seen forward of and below the parent Hayabusa probe bus as the latter breaks up.

The re-entry seen from the Woomera Test Range.

The reentry capsule and the spacecraft reentered to the Earth atmosphere on 13 June 2010 at 13:51 UTC. The heat-shielded capsule made a parachute landing in the South Australian outback while the spacecraft broke up and incinerated in a large fireball.

An international team of scientists observed the 12.2 km/s entry of the capsule from 11.9 km (39,000 ft) on board NASA's DC-8 airborne laboratory, using a wide array of imaging and spectrographic cameras to measure the physical conditions during atmospheric reentry in a mission led by NASA's Ames Research Center, with Peter Jenniskens of the SETI Institute as the project scientist.

Since the reaction control system no longer functioned, the 510 kilograms (1,124 lb) space probe re-entered the Earth's atmosphere similar to the approach of an asteroid along with the sample re-entry capsule, and, as mission scientists expected, the majority of the spacecraft disintegrated upon entry.

The return capsule was predicted to land in a 20 km by 200 km area in the Woomera Prohibited Area, South Australia. Four ground teams surrounded this area and located the re-entry capsule by optical observation and a radio beacon. Then a team on board a helicopter was dispatched. They located the capsule and recorded its position with GPS. The capsule was successfully retrieved at 7:08 UTC of 14 June 2010. The two parts of the heat shield, which were jettisoned during the descent, were also found.

After confirming that the explosive devices used for parachute deployment were safe the capsule was packed inside a double layer of plastic bags filled with pure nitrogen gas to reduce the risk of contamination. The soil at the landing site was also sampled for reference in case of contamination. Then the capsule was put inside a cargo container which had air suspension to keep the capsule below 1.5 G shock during transportation. The capsule and its heat shield parts were transported to Japan by a chartered plane and arrived at the curation facility at the JAXA/ISAS Sagamihara campus on June 18.

Before the capsule was extracted from the protecting plastic bag, it was inspected using X-ray CT to determine its condition. Then the sample canister was extracted from the reentry capsule. The surface of the canister was cleaned using pure nitrogen gas and carbon dioxide; it was then placed in the canister opening device. The internal pressure of the canister was determined by a slight deformation of the canister as the pressure of the environment nitrogen gas in the clean chamber was varied. The nitrogen gas pressure was then adjusted to match the internal canister pressure to prevent the escape of any gas from the sample upon the opening of the canister.

On October 7, 2010, it was announced that approximately 100 particles were collected by the sample canister, and stated that some may be cosmic materials. The particles are smaller than 0.001 millimeters. Starting in November, JAXA plans the detailed analyses of the samples by splitting each particle and examining their crystal structure at SPring-8.

Confirmation of asteroid particles

On 16 November 2010, JAXA confirmed that most of the particles found in one of two compartments inside the Hayabusa sample return capsule came from Itokawa. Analysis with a scanning electron microscope identified about 1,500 grains as rocky particles, according to the JAXA press release. After further studying the analysis results and comparison of mineral compositions, most of them were judged to be of extraterrestrial origin, and definitely from the asteroid Itokawa.

According to Japanese scientists, the composition of Hayabusa's samples was more similar to primitive meteorites than known rocks from Earth. Their size is mostly less than 10 micrometers. The material matches chemical maps of Itokawa from Hayabusa's remote sensing instruments. The researchers found concentrations of olivine and pyroxene in the Hayabusa samples.

Further study of the samples will wait until 2011 because researchers are still developing special handling procedures to avoid contaminating the particles during the next phase of research.

Chapter- 5

Akatsuki (Spacecraft)

Akatsuki	
Operator	Japan Aerospace Exploration Agency (JAXA)
Mission type	Orbiter
Satellite of	Venus
Orbital insertion date	2010-12-06 23:49:00 UTC (anticipated)
Launch date	2010-05-20 21:58:22 UTC
Carrier rocket	H-IIA 202
Launch site	Tanegashima Space Center Tanegashima, Japan
Mission duration	~2 years elapsed: 9 months, and 4 days
COSPAR ID	2010-020D
Mass	320 kg (710 lb)
Power	1,200 W
Orbital elements	
Eccentricity	0.992
Inclination	172 degrees
Apoapsis	79,000 km (49,000 mi)

Periapsis	300 km (190 mi)
Orbital period	30 hours

Akatsuki (あかつき, 暁?, literally "dawn"), formerly known as the **Venus Climate Orbiter (VCO)** and **Planet-C**, is a Japanese unmanned spacecraft which was intended to explore Venus. It was launched aboard an H-IIA 202 rocket on 20 May 2010, after being delayed because of weather from its initial 18 May scheduled target. The total launch mass of the spacecraft including propellant was 480 kg, 34 kg out of this was scientific instruments. The mission reached Venus on 7 December 2010 (JST) but failed to enter orbit around the planet. It had been intended to conduct scientific research for two or more years from an elliptical orbit ranging from 300 km to 80,000 km from Venus.

Akatsuki is Japan's first planetary exploration mission since the Nozomi probe, which was launched in 1998 but failed to go into a Mars orbit in 2003 as planned.

Design

The mass of the spacecraft is 640 kg (1,400 lb), including 320 kg (710 lb) of propellants and 34 kg (75 lb) of scientific instruments.

The main bus is a 1.6 m x 1.6 m x 1.25 m box with two solar arrays, each with an area of 1.4 m^2 (15 sq ft). The solar array panels provide over 1,200 watts of power in Venus orbit.

Propulsion is provided by a 500 newton (N) bi-propellant, hydrazine / nitrogen tetroxide orbital maneuvering engine and 12 mono-propellant hydrazine reaction control thrusters, eight with 23 N thrust and four with 3 N.

Communications is via a 8 GHZ X-band 20 W transponder using the 1.6 m slot array high gain dish antenna used for most telemetry data. Akatsuki also has a pair of medium gain horn antennas mounted on turntables and two low gain antennas for command uplink. The medium gain horn antennas will be used for housekeeping data downlink when the high gain antenna is not facing Earth.

Instruments

The scientific payload consists of six instruments including a Lightning and airglow camera (LAC), an ultraviolet imager (UVI), a longwave infrared camera (LIR), a 1-µm camera (IR1), a 2-µm camera (IR2), and the radio science (RS) experiment. The five cameras will explore Venus in wavelengths from ultraviolet to the mid-infrared.

The LAC will look for lightning in the visible wavelengths of 552 to 777 nanometers. The LIR will study the structure of high-altitude clouds at a wavelength where they emit heat (10 microns). The UVI will study the distribution of specific atmospheric gases such as sulfur dioxide in ultraviolet wavelengths (293 to 365 nanometers). The IR1 will peer through semi-transparent windows in Venus' atmosphere to see heat radiation emitted from Venus' surface rocks (0.9 to 1.01 microns) and will help researchers to spot active volcanoes, if they exist. The IR2 will peer through semi-transparent windows in Venus' atmosphere to see heat radiation emitted from the lower reaches of the atmosphere (1.65 to 2.32 microns). The last science instrument - Akatsuki's radio dish, will be used to actively probe the atmosphere.

Mission

Planned investigations include surface imaging with an infrared camera and experiments designed to confirm the presence of lightning and to determine whether volcanism occurs on the surface.

The budget for this mission is ¥13 billion (US$110 million) for the satellite and ¥12 billion (US$100 million) for the launch.

Public relations

There was a public relations campaign held between October 2009 and January 2010 by The Planetary Society and JAXA, to allow individuals to send their name and a message aboard *Akatsuki*. Names and messages were printed in fine letters on an aluminum plate and placed aboard *Akatsuki*. 260,214 people submitted names and messages for the mission. Around 90 aluminum plates were created for the spacecraft, including three aluminum plates in which the images of the Vocaloid Hatsune Miku and her super deformed figure Hachune Miku were printed.

Operation

Launch

The launch of Akatsuki

Akatsuki left the Sagamihara Campus on 17 March 2010, and arrived at the Tanegashima Space Center's Spacecraft Test and Assembly Building 2 on 19 March. On 4 May, *Akatsuki* was encapsulated inside the large payload fairing of the H-IIA rocket that launched the spacecraft, along with the IKAROS solar sail, on a 6-month journey to Venus. On 9 May, the payload fairing was transported to the Tanegashima Space Center's Vehicle Assembly Building, where the fairing was mated to the H-IIA launch vehicle itself. The spacecraft was launched on May 20, 2010 at 21:58:22 (UTC) from the Tanegashima Space Center.

Orbit insertion failure

Akatsuki was planned to initiate orbit insertion operations by igniting the orbital maneuvering engine at 23:49:00 on 6 December UTC. The burn was supposed to continue for 12 minutes, to an initial orbit of 180,000 – 200,000 km apoapsis / 550 km periapsis / 4 days orbital period around Venus.

The orbit insertion maneuver was confirmed to have started on time. But after the expected blackout due to occultation by Venus, the communication with the probe did not recover as planned. The probe was found to be in safe-hold mode, spin-stabilized state with 10 minutes per rotation. Due to the low communication speed through low-gain antenna, it took a while to determine the state of probe. JAXA stated on December 8, that the probe's orbital insertion maneuver has failed. At a press conference on 10 December, officials reported that Akatsuki's engines fired for less than 3 minutes far short of what was required to enter into Venus orbit.

JAXA is developing plans to attempt another orbital insertion burn when the probe returns to Venus in 6 years. This requires placing the probe into a hibernation state to prolong its life beyond the original 4.5 year design. JAXA expressed some confidence in keeping the probe operational, pointing to reduced battery wear, since the probe is orbiting the Sun instead of its intended Venusian orbit.

Chapter- 6

BepiColombo

BepiColombo	
Operator	European Space Agency, Japan Aerospace Exploration Agency
Major contractors	EADS Astrium is Prime-Contractor for ESA modules.
Mission type	Orbiter
Flyby of	Moon, Earth, Venus, and Mercury
Satellite of	**Mercury**
Orbital insertion date	2020
Launch date	2014
Launch vehicle	Ariane 5
COSPAR ID	BEPICLMBO
Homepage	ESA JAXA ISAS
Power	5.5 kW available at 1 AU
Orbital elements	
Apoapsis	1508 km (MPO) and 12000 km (MMO)
Periapsis	400 km (MPO) and 400 km (MMO)
Orbital period	2.3 h (MPO) and 9.2 h (MMO)

BepiColombo is a joint mission of the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) to the planet Mercury , due to launch in 2014. The mission is still in the planning stages so changes to the current description are likely over the next few years. Due to budgetary constraints and technological difficulties, the lander portion of the mission, the Mercury Surface Element (MSE) was cancelled.

Mission

The mission as currently envisioned involves three components: the Mercury Transfer Module (MTM) built by ESA, the Mercury Planetary Orbiter (MPO) built by ESA and the Mercury Magnetospheric Orbiter (MMO) built by JAXA (whose sunshield (MOSIF) will be built by ESA). The prime contractor for ESA is EADS Astrium. The three components are planned to be launched together on a Ariane 5 launch vehicle in 2014. The spacecraft will have a six year interplanetary cruise to Mercury using solar-electric propulsion and gravity assists from the Moon, Earth, Venus and eventual gravity capture at Mercury.

Arriving in Mercury orbit in August 2020, the spacecraft will have a 1-year nominal scientific life. The MPO will be equipped with eleven scientific instruments provided by various European countries including visible imagers, a laser altimeter and an imaging X-ray spectrometer. Russia will provide a gamma ray and neutron spectrometer. It will attempt to map the entire surface in several different wavelengths, and to find water ice in polar craters which are permanently in shadow from the Sun's rays.

One of the goals of the mission is testing general relativity measuring the parameters gamma and beta of the Parameterized post-Newtonian formalism with a high accuracy.

Mercury Transfer Module

The Mercury Transfer Module is at the base of the 'stack' and provides propulsion to escape Earth and to approach Mercury. It carries no significant scientific instruments.

Mercury Planetary Orbiter (MPO)

The Mercury Planetary Orbiter will be a 357 kg spacecraft in the shape of a flat prism with three short sides slanted at 20 degrees covered with solar cells providing 420 W at perihelion. A radiator with an area of 1.5 square meters is mounted on one side to provide thermal control. The radiator is always pointed away from the Sun and is protected from planetary IR with a 3.4 square meter shield. High efficiency insulation is also used. A 1.5 m diameter high gain antenna is mounted on a short boom on the zenith side of the spacecraft. The MPO will be 3-axis stabilized and nadir pointing with a planned lifetime of over 1 year in Mercury orbit. Communications will be on the X/Ka band with an average bit rate of 50 kbit/s and a total data volume of 1550 Gb/year. A UHF dipole antenna mounted on the nadir side will be used for possible communications with the MSE. Navigation knowledge is provided by 3 star sensors.

The MPO will carry an imaging system consisting of a wide-angle and narrow angle camera, an infrared spectrometer, an ultraviolet spectrometer, gamm, X-ray, and neutron spectrometers, a laser altimeter, an ion and neutral spectrometer, a Near Earth Object telescope and detection system, and radio science experiments.

ESA has selected Astrium as the prime contractor for the construction of the MPO.

Mercury Magnetospheric Orbiter (MMO)

The Mercury Magnetospheric Orbiter has the shape of a flat cylinder with a mass of 250 kg including Nitrogen gas for attitude control (551.16 lb). The MMO is spin stabilized at 15 rpm with the spin axis perpendicular to the equator of Mercury. The top and bottom of the cylinder act as radiators with louvers for active temperature control. The side is covered with solar cells which provide 185 W and second surface mirrors and protected by thermal blankets. Communications with Earth are maintained through a despun 1-meter diameter high-gain offset antenna and two medium-gain antennas operating in the X-band. Telemetry will return 160 Gb of data per year at about 5 kbit/s over the lifetime of the craft, which is expected to be greater than one year. A microstrip UHF patch antenna will be used for communication with the MSE. The reaction and control system is based on cold gas thrusters. Deployable booms and wire antennas are stowed until orbit is achieved. The MMO will carry a set of fluxgate magnetometers, charged particle detectors, a wave receiver, a positive ion emitter, and an imaging system.

Mercury Surface Element (MSE)

The Mercury Surface Element has been cancelled due to budgetary constraints.

At the time of cancellation, MSE was meant to be a small (44 kg) lander designed to operate for about one week on the surface of Mercury. Shaped as a 0.9 m diameter disc, it was designed to land at a latitude of 85 degrees near the terminator region. Following the release of the MMO, a burn of the 4 kN thruster would put the MSE into a 10 km orbit. Another braking maneuver controlled by gyros/accelerometers and an optical range/range-rate sensor would bring the MSE to zero velocity at an altitude of 120 meters at which point the propulsion unit would be ejected, the airbags inflated, and the module would fall to the surface with a maximum impact velocity of 30 m/s. If the landing occurs in sunlight a thermal protection cover would deploy. Since 40% of the terrain at the landing point would be in shadow, primary power would be supplied by a 1.7 kWh battery. Scientific data would be stored onboard and relayed via a cross-dipole UHF antenna to either the MPO or MMO at a data rate of 8.7 kbit/s, providing for a total of 75 Mb over 7 days, assuming 18 contact periods of 480 seconds each. The MSE would carry a 7 kg payload consisting of an imaging system (a descent camera and a surface camera), a heat flow and physical properties package, an alpha particle X-ray spectrometer, a magnetometer, a seismometer, a soil penetrating device (mole), and a micro-rover.

Propulsion

The MTM (Mercury Transfer Module) will utilise two propulsion systems. A standard CPS (Chemical Propulsion System) which is bipropellant using MMH/MON3. The CPS will be utilised for Earth escape and the Lunar fly-by. Post-Lunar escape the CPS will be pyrotechnically isolated and function in blowdown mode for the cruise. The spacecraft will be propelled in cruise by a form of ion drive dubbed solar electric propulsion, which has a very high specific impulse and very low thrust. Unlike a chemical rocket which fires for a few seconds, it will keep propelling the craft for years, building up far more speed per mass of fuel in the long run. This will be the ESA's first mission outside the Earth-Moon system using such a form of propulsion. BepiColombo is also the largest solar electric mission so far planned.

This drive will be tested by the unusual need to actually push against the direction of travel, instead of with it; the ship will be falling toward the sun, accelerated by its gravity, and will have to constantly fight to keep its velocity slow enough to eventually enter Mercury's orbit.

Namesake

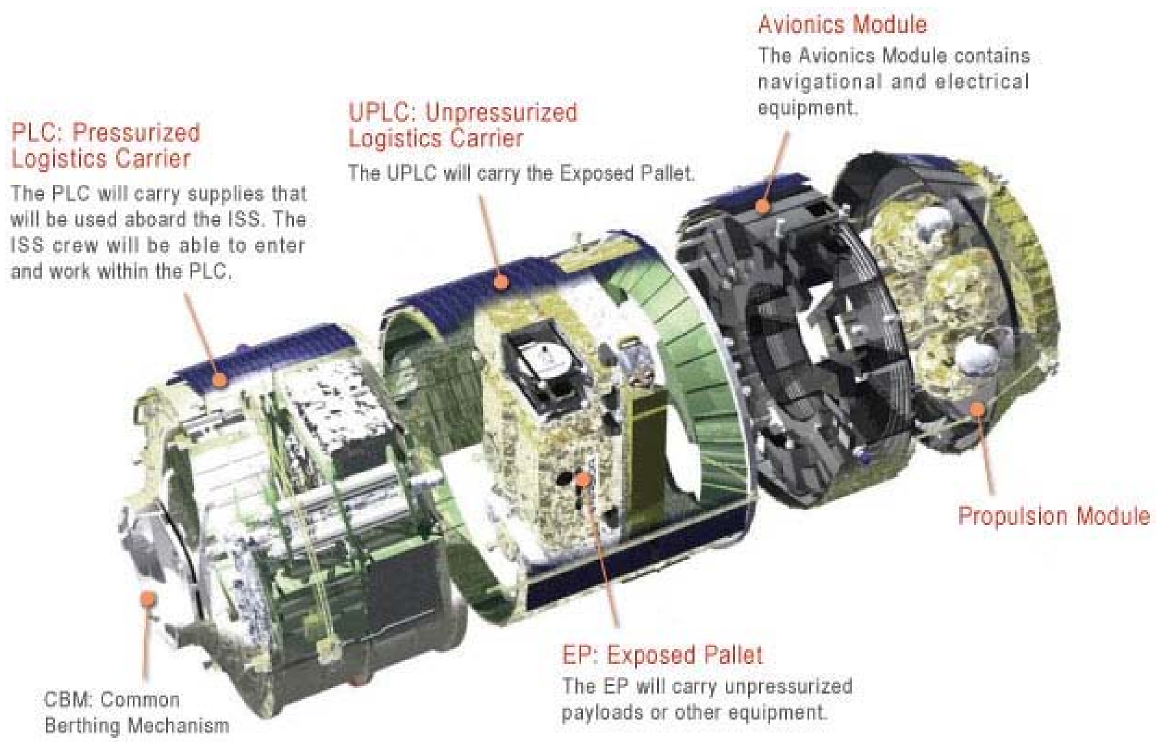
BepiColombo is named for Giuseppe (Bepi) Colombo (1920–1984), scientist, mathematician and engineer at the University of Padua, Italy, who developed the gravity-assist maneuver commonly used by planetary probes today. He helped NASA to devise the trajectory of Mariner 10, the only spacecraft to encounter Mercury during the twentieth century, exploiting this maneuver for the first time around Venus.

Chapter- 7

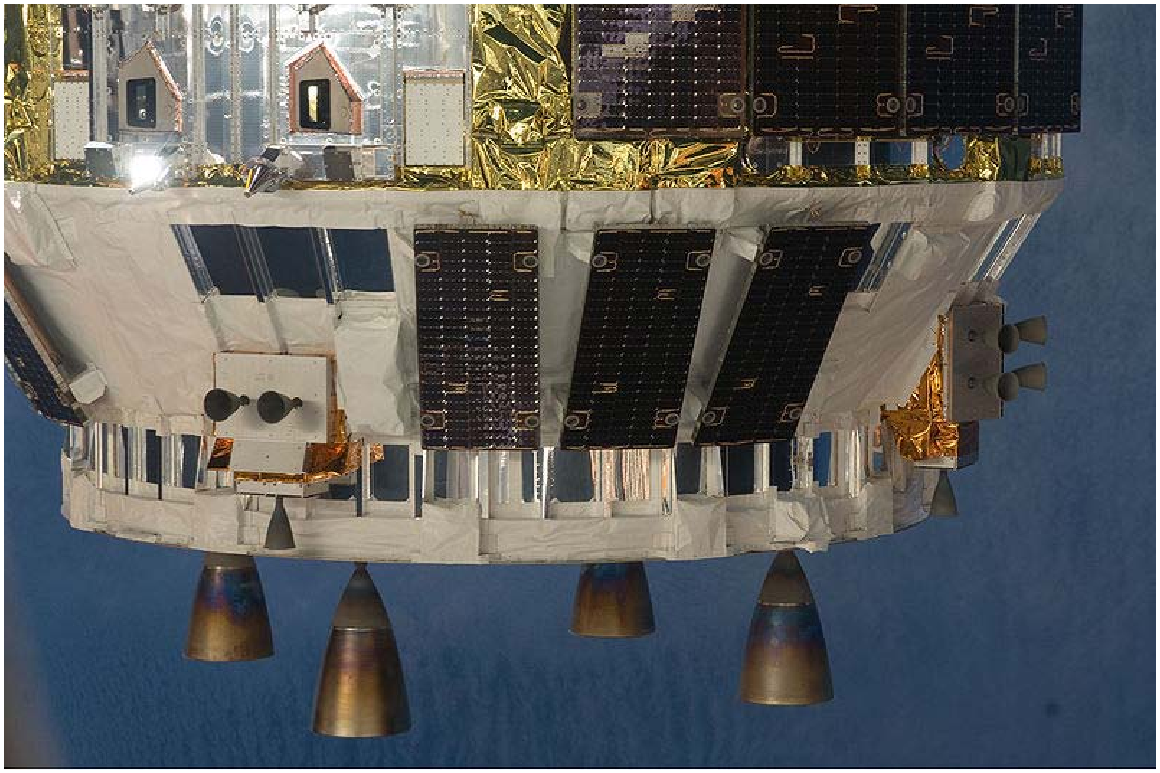
H-II Transfer Vehicle

H-II Transfer Vehicle	
 H-II Transfer Vehicle (HTV-1) approaching the ISS	
Description	
Role:	Unmanned spacecraft intended to resupply the *Kibō* Japanese Experiment Module on the International Space Station, and the rest of the station, if necessary.
Crew:	Unmanned
Dimensions	
Height:	10 m (including thrusters)
Diameter:	4.4 m
Spacecraft weight:	10,500 kg
Total Launch Payload:	6,000 kg
Pressurized	5,200 kg

Payload:	
Unpressurized Payload:	1,500 kg
Return Payload:	None
Mass at launch:	16.5 ton
Pressurized Volume:	
Performance	
Endurance:	Solo flight about 100 hours, stand-by more than a week, docked with the ISS about 30 days
Apogee:	460 km
Perigee:	350 km
Inclination:	51.6 degrees



Structure

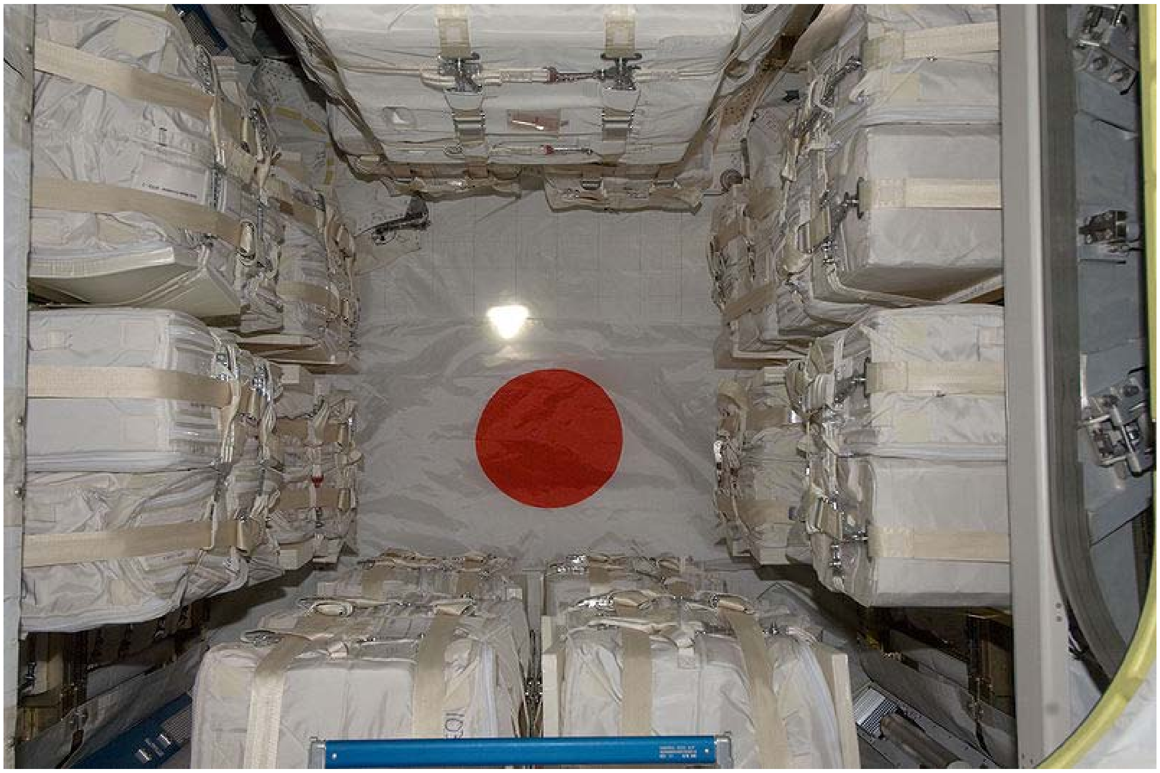


At the bottom the four main thrusters. Smaller attitude control thrusters can be seen at the right side of this view of HTV-1.

The **H-II Transfer Vehicle** (**HTV**), nicknamed ***Kounotori*** (こうのとり?, Oriental Stork or White Stork), is an unmanned resupply spacecraft used to resupply the *Kibō* Japanese Experiment Module (JEM) and the rest of the International Space Station (ISS). The Japan Aerospace Exploration Agency (JAXA) has been working on the design since the early 1990s. The first mission, HTV-1, was originally intended to be launched in 2001. It lifted-off at 17:01 UTC on September 10, 2009 on an H-IIB launch vehicle.

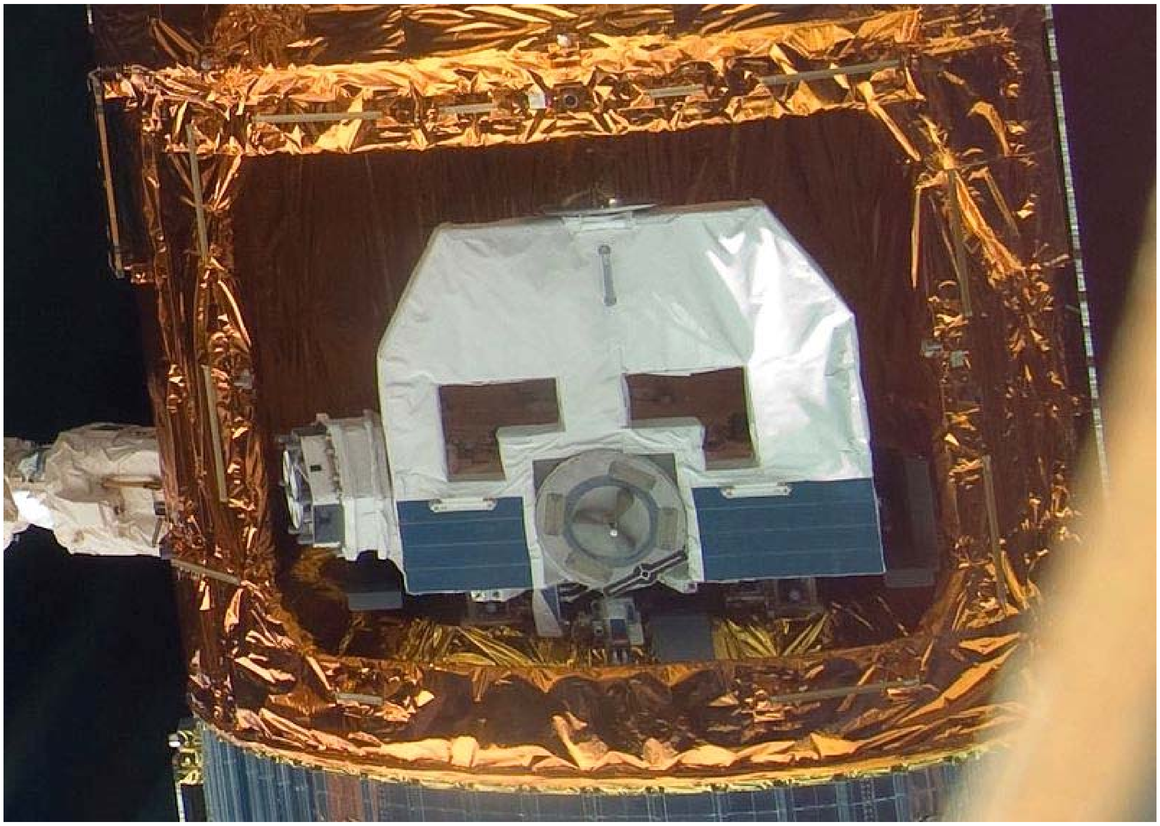
Design

HTV is about 10 m long (including maneuvering thrusters at one end) and 4.4 m in diameter. Total mass is 10.5 tonnes, with a 6,000 kilograms (13,000 lb) payload. HTV is a larger and simpler vehicle than the Progress spacecraft currently used by Russia to bring supplies to the station, since it does not have a complex docking and approach system. Instead, it will be flown just close enough to the station to allow capture by Canadarm2, which will pull it to a berthing port on the ISS *Harmony* module.



Inside view of the Pressurised Logistics Carrier section of HTV-1.

HTV can carry supplies in a combination of two different "segments" that can be attached together. One is a pressurized hold with a capacity of 6,000 kg, which includes an optional docking adapter at one end to allow it to be unloaded in a shirt-sleeves environment. It is designed specifically to carry eight International Standard Payload Racks (ISPRs) in total. After the planned retirement of NASA's Space Shuttle in 2010, HTV will be the only vehicle which can carry ISPRs to the ISS. It will also have a tank to deliver up to 300 kg of water to the station. The other is a lighter and slightly longer unpressurized segment, which includes a hatch on the side to allow it to be unloaded remotely.



The Unpressurised Logistics Carrier section of HTV-1.

The baseline configuration, known as the "Mixed Logistics Carrier", uses one pressurized and one unpressurized segment and can carry 7,600 kg of cargo in total and is 9.2 m long. When two pressurized units are used together the cargo decreases slightly to about 7,000 kg, and the overall length is reduced to 7.4 m. These numbers are somewhat vague in the various sources, some suggesting that the pressurized/unpressurized combination carries only 6,000 kg in total, less than the pressurized/pressurized combination, which should be heavier. No sources suggest an unpressurized/unpressurized combination is planned, perhaps due to the overall length.

HTV propulsion is used to generate the torque to control the HTV attitude and the thrust to perform the orbital maneuvers such as rendezvous and re-entry. The HTV has four 500 N class main thrusters and twenty-eight 110 N class attitude control thrusters. Both are using bipropellant, namely monomethylhydrazine (MMH) as fuel and the mixed oxides of nitrogen (MON3) as oxidizer.

Both types of thrusters are manufactured by Aerojet, the 500 N is of the R-4D type of Apollo heritage and the 110 N is of the R-1E type (Shuttle vernier engine). The HTV carries about 2400 kg of propellant in four tanks.

After the on-orbit unloading process is completed, the HTV will be loaded with waste and undocked. The vehicle will then be de-orbited and destroyed during re-entry, the debris falling into the Pacific Ocean.

Possible usage by NASA

In July 2008, it was reported that the United States space agency NASA had begun unofficial negotiations with JAXA on the purchase of HTV spacecraft as the successor to the space shuttle fleet due to NASA's concerns about refueling and servicing the ISS after it retires the shuttle fleet in 2010. A day later, NASA released a press statement declaring that "NASA has not officially or unofficially been discussing the purchase of H-II Transfer Vehicles." The space agency remains committed to "domestic commercial cargo resupply to the space station." NASA has been working with private launch firms such as SpaceX and Orbital Sciences Corporation.

Flights

The first vehicle was launched on an H-IIB rocket, a more powerful version of the earlier H-IIA, at 17:01 GMT on September 10, 2009, from Launch Pad 2 of the Yoshinobu Launch Complex at the Tanegashima Space Center. Six subsequent missions are planned.

HTV	Launch date/time	Carrier rocket	Re-entry date/time
HTV-1	September 10, 2009, 17:01 (UTC)	H-IIB F1	November 1, 2009, 21:26 (UTC)
HTV-2	January 22, 2011, 05:37:57 (UTC)	H-IIB F2	
HTV-3	January 12, 2012 planned	H-IIB	
HTV-4		H-IIB	
HTV-5		H-IIB	
HTV-6		H-IIB	
HTV-7		H-IIB	

Chapter- 8

HTV-1

HTV-1

HTV-1 Mission Patch

Type	HTV
Organisation	JAXA
Space station	ISS
Station crew	Expedition 20/21
Contractors	JAXA Mitsubishi (LSP)
Carrier Rocket	H-IIB
Launch site	Tanegashima Yoshinobu-2
Launch date	10 September 2009 17:01:46 UTC
Decay Date	2 November 2009 6:26 a.m. approx. (JST)

	Docking
Docking port	*Harmony* Nadir
Docking date	17 September 2009 22:26 GMT
Undocking date	30 October 2009 15:02 GMT
	Orbit
Regime	LEO
Inclination	51.6°
	Mass
Cargo	4,500 kg (9,900 lb)

HTV-1, also known as the **HTV Demonstration Flight** or **HTV Technical Demonstration Vehicle**, was the first Japanese H-II Transfer Vehicle, launched in September 2009 to resupply the International Space Station. It was an unmanned cargo spacecraft carrying a mixture of pressurised and unpressurised cargo to the space station. After a 52-day successful mission, HTV departed the ISS on 31 October 2009 after being released by the station's robotic arm. The spacecraft re-entered the Earth's atmosphere on 2 November and disintegrated on re-entry as planned.

Payloads

HTV-1 carried four and a half tonnes of payload, lower than the six tonne maximum payload of the HTV in order to allow the spacecraft to carry additional propellant and batteries for the in-orbit verification phase of the flight.

In the Unpressurised Logistics Carrier, the HTV-1 carried SMILES (Superconducting Submillimetre-Wave Limb Emission Sounder) and HREP (HICO-RAIDS Experiment Payload), which both were installed in the JEM Exposed Facility on the ISS. The Pressurised Logistics Carrier carried 3.6 tonnes of supplies for the International Space Station. It consisted of foods (33% of weight), laboratory experiment materials (20%), robot arm and other hardware for JEM (18%), crew supplies including garments, toiletries, mails and photographs, fluorescent lights, and waste buckets (10%), packing materials (19%).


H-IIB lifts off from the Tanegashima Space Center carrying HTV-1.

Interior view of the HTV-1 docked to the ISS.

NASA astronaut Nicole Stott working inside HTV-1.

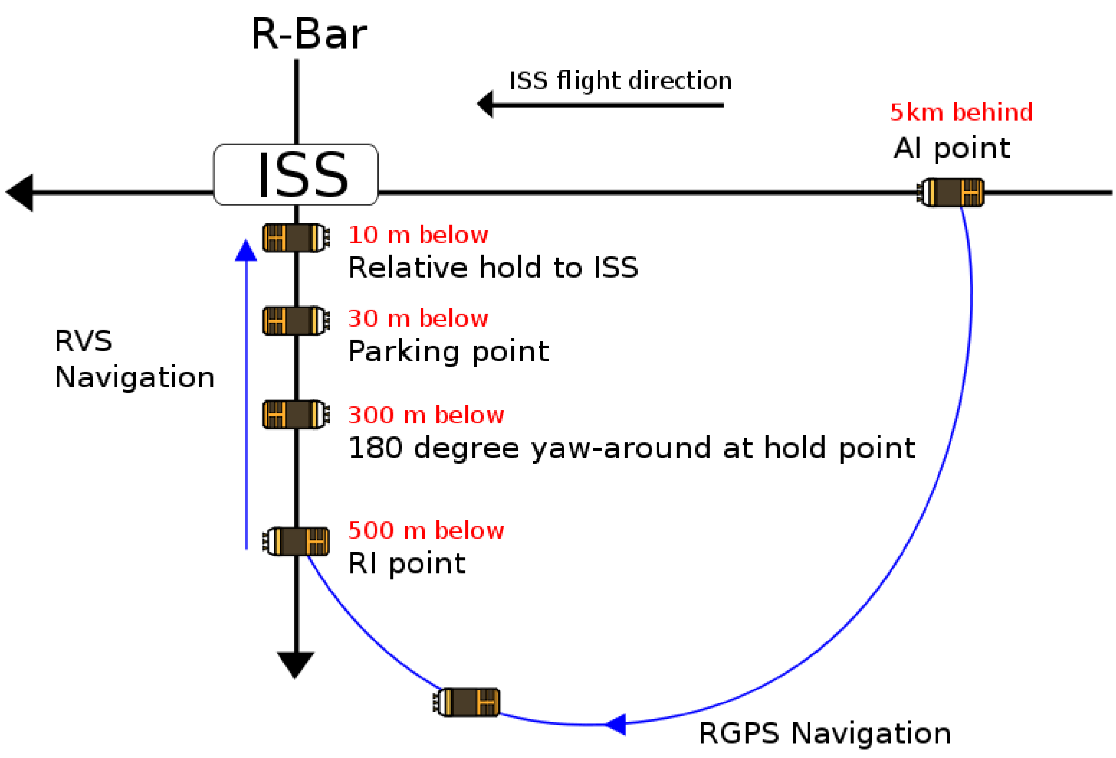
NASA astronaut Nicole Stott moving a stowage container inside HTV-1.

Carrier rocket

HTV-1 was launched on the maiden flight of the H-IIB carrier rocket. The H-IIB 304 configuration was used, with a type 5S-H payload fairing. Before launch, two Captive Firing Tests were conducted on the rocket which was to launch HTV-1. The first test, which consisted of firing the first stage for ten seconds, was originally scheduled to occur at 02:30 GMT on 27 March 2009, however it was cancelled after the launch pad's coolant system failed to activate. This was later discovered to have been due to a manual supply valve not being open. The test was rescheduled for 1 April, but then postponed again due to a leak in a pipe associated with the launch facility's fire suppression system. The test was rescheduled for 2 April, when it was successfully conducted at 05:00 GMT. Following this, the second test, which involved a 150 second burn of the first stage, was scheduled for 20 April. This was successfully conducted at 04:00 GMT on 22 April, following a two day delay due to unfavourable weather conditions. A ground test, using a battleship mockup of the rocket was subsequently conducted on 11 July.

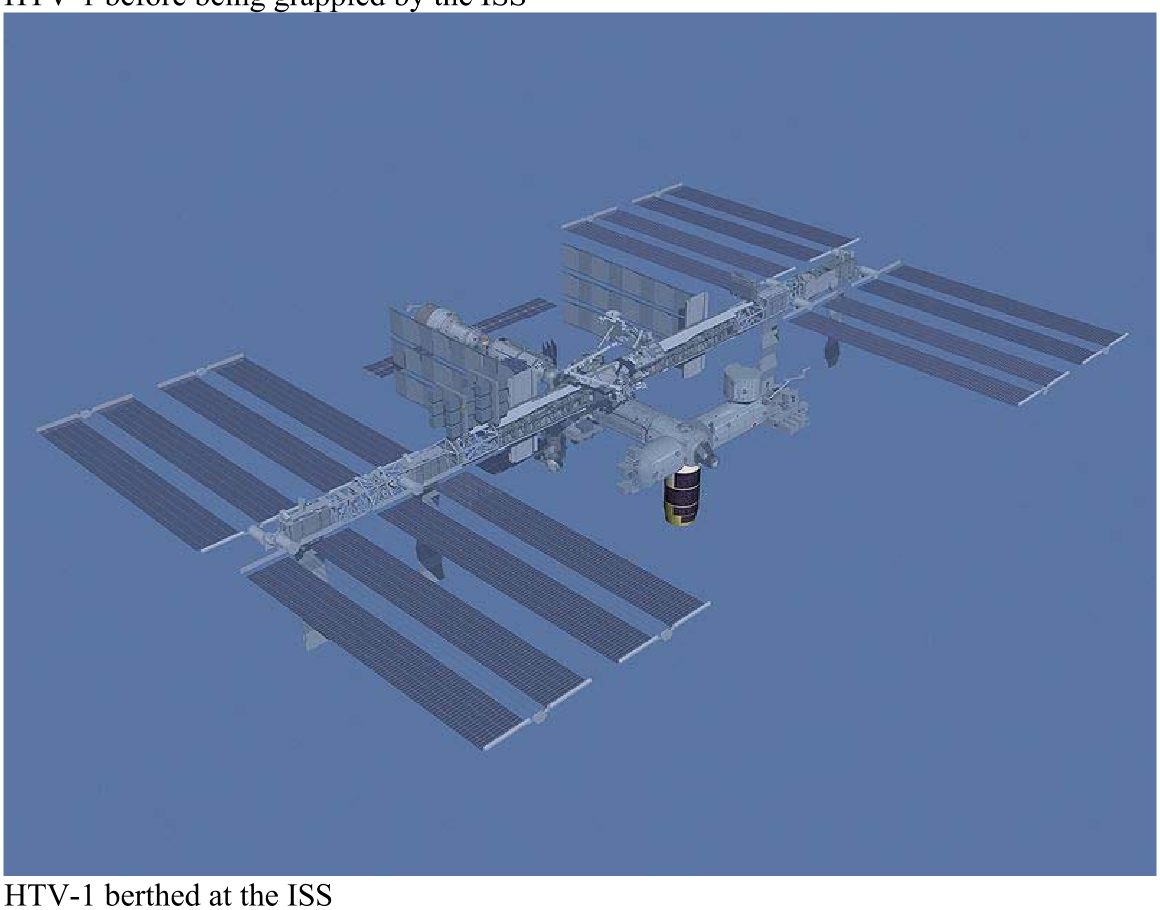
Operation

Launch and rendezvous with ISS



Approach to the ISS


HTV-1 before being grappled by the ISS


HTV-1 berthed at the ISS

HTV-1 was successfully launched at 17:01:46 GMT on 10 September 2009, to the initial orbit of 299.9 km apogee / 199.8 km perigee / 51.69° inclination (planned 300.0 ±2 km / 200.0 ±10 km / 51.67 ±0.15°). The launch took place from the Yoshinobu Launch Complex at the Tanegashima Space Centre, and was the first to use the second pad of the complex.

Flight operations are chronicled using Flight Day (FD), the ISS crew timeline. The launch day is FD1.

On FD3 (September 12), HTV-1 performed the demonstration tests of ISS proximity operation such as collision avoidance manoeuvre. It went successfully and on FD6, ISS Mission Management Team approved the final approach.

Canadarm2 captures HTV-1

HTV-1 before berthing


ISS Expedition 20 crew members entering HTV-1

On 17 September, HTV-1 rendezvoused with the International Space Station. It arrived at the Approach Initiation Point, 5 kilometres behind the space station at 13:59 UTC, and began its final approach sequence at 15:31. It approached to within 10 metres (33 ft) of the station, from where it was grappled using the Canadarm2 robotic arm of the space station, operated by Nicole Stott. Initial capture occurred at 19:47 GMT, with the procedure being completed at 19:51. Robert Thirsk then used Canadarm2 to move it to a "ready-to-latch" position over the nadir CBM port of the *Harmony* module. It arrived at this position at 22:08 GMT, and by 22:12 four latches had engaged to hold it in place. Sixteen bolts were subsequently driven in to achieve a hard mate. It remained berthed at the station until October 30.

Departure from the ISS and Re-entry

Expedition 21 crew members, Nicole Stott, Robert Thirsk and Frank De Winne completed the final steps of preparing for HTV's release from the ISS. These steps included disconnecting the final remaining power jumper line, closing the Node-2 nadir hatch, depressurizing the vestibule & performing leak checks, removing Common Berthing Mechanism bolts and deploying latches and unberthing the HTV-1 with the Space Station Remote Manipulator System

The departure was delayed for one ISS orbit to avoid an approaching debris (COSMOS 2421).

While passing above the Pacific ocean, the robotic arm of the space station released the HTV-1 positioned at 12m below the station on 30 October 2009. HTV-1 was loaded with 199 items of discarded equipment & waste of 727.7 kg, as well as 896 kg empty racks, totaling 1,624 kg. At 17:32 (UTC), HTV-1 was released from SSRMS and began its planned maneuvers to leave the station proximity. HTV-1 gradually departed from the ISS orbit by performing several thruster burns and entered to its solo-flight mode.

The HTV flight control team sent commands for three engine burns at 14:55, at 16:25, and at 20:53, November 1 (UTC) to prepare the vehicle's destruction in Earth's atmosphere. The first de-orbit engine burn lasted for approximately 8 minutes and was completed at 15:03, November 1. The second de-orbit engine burn lasted for approximately 9 minutes and was completed at 16:34. Following the second de-orbit maneuver, the HTV-1 was inserted into an elliptic orbit with an altitude of 143 km perigee and 335 km apogee.

HTV-1 began the third and final de-orbit maneuver at 20:53 on November 1 as planned, while the spacecraft was passing over the Central Asia. The maneuver that lasted for about 8 minutes was successfully wrapped up at 21:01 as the spacecraft flew near the southern half of Japan. According to the Japan Aerospace Exploration Agency, HTV-1's atmospheric re-entry occurred at 21:25. at 120 km above and over the Pacific Ocean just off the coast of New Zealand. The fiery re-entry and disintegration in the Earth's atmosphere marked the successful completion of the HTV-1's 52 day mission.

It is believed that some of the surviving debris from the HTV would have likely fallen in a rectangular box stretching across the Pacific Ocean between New Zealand and South America, according to the Japan Aerospace Exploration Agency.

Crew aboard the ISS

The ISS crew at arrival of HTV-1 were the members of Expedition 20.

- Gennady Padalka, Commander
- Michael Barratt
- Nicole Stott
- Frank De Winne
- Roman Romanenko
- Robert Thirsk

The ISS crew at departure of HTV-1 were the members of Expedition 21.

- Frank De Winne, Commander
- Roman Romanenko
- Robert Thirsk
- Maksim Surayev
- Jeffrey Williams
- Nicole Stott

The station has also been visited by Spaceflight Participant Guy Laliberté. No Japanese astronaut was present during the attached phase of the HTV-1 to the ISS.

Chapter- 9

Other Japanese Space Programs

Shin'en (spacecraft)

	Shin'en
Operator	UNISEC
Mission type	Technology
Flyby of	Venus
Launch date	20 May 2010 21:58:22 UTC
Carrier rocket	H-IIA 202
Launch site	Tanegashima Yoshinobu 1
Mission duration	At least 6-7 months
Homepage	UNITEC-1
Mass	20 kilograms (44 lb)
Power	25 W from Solar cells
Orbital elements	
Regime	Heliocentric
Instruments	
Radiation counter, Mission camera	

Shin'en, known before launch as **UNITEC-1** or **UNISEC Technology Experiment Carrier 1**, is a Japanese student spacecraft which was intended to make a flyby of Venus in order to study the effects of interplanetary spaceflight on spacecraft computers. In doing so, it was intended to become the first student-built spacecraft to operate beyond Geocentric orbit. It was operated by UNISEC, a collaboration between several Japanese universities.

Contact was lost shortly after launch.

Spacecraft

Shin'en measures 30 by 35 centimetres (12 by 14 in), and has a mass of 20 kilograms (44 lb). It has no attitude control or stabilisation system. Power is provided by solar cells attached to the outside of the spacecraft, which will produce around 25 Watts of electricity.

The primary payload of Shin'en consists of six university-built computers, which will be tested in interplanetary space for robustness against the radiation and extremes of temperature. The spacecraft also carries a camera, and a radiation counter. In order to simplify the system and reduce cost, a low power communications system will be used. It will broadcast a continuous wave with a data transfer rate of one bit per second. UNISEC has invited amateur radio operators to assist in collecting data from the spacecraft.

Launch

The launch of Shin'en was successfully conducted from Pad 1 of the Yoshinobu Launch Complex at the Tanegashima Space Centre, at 21:58:22 UTC on 20 May 2010. It was being launched as a secondary payload aboard an H-IIA 202 rocket, with the primary payload being the Akatsuki spacecraft bound for Venus. The IKAROS solar sail experiment was also deployed from the same rocket on a trajectory towards Venus. Three other student spacecraft; Waseda-SAT2, K-Sat and Negai ☆ were also launched, however they separated from the rocket whilst it was still orbiting the Earth. Shin'en was the last spacecraft to separate from the rocket. The launch was conducted by Mitsubishi Heavy Industries on behalf of the Japan Aerospace Exploration Agency.

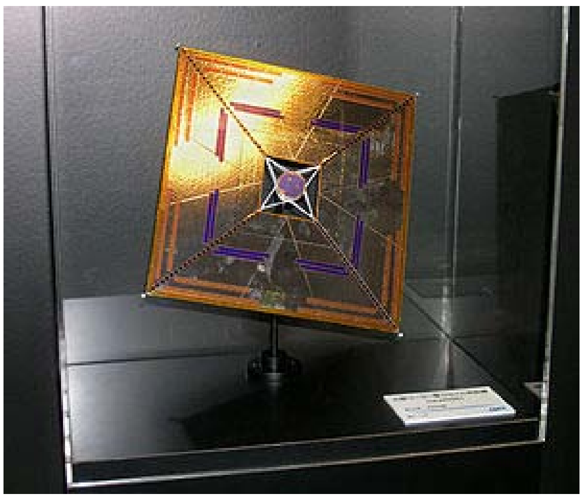
The H-IIA rocket was rolled out to the launch pad on 16 May 2010, departing the assembly building at 21:01 UTC and arriving at the launch pad 24 minutes later at 21:25 UTC, in preparation for a launch scheduled at 21:44:14 UTC on 17 May. The terminal countdown began at 11:30 UTC on 17 May and by 15:28, the loading of cryogenic propellant into the rocket's first and second stages had been completed. This launch attempt was scrubbed a few minutes before the scheduled launch time due to bad weather.

Following launch, Shin'en separated from the carrier rocket into a heliocentric orbit. It was planned to fly past Venus six or seven months into its mission.

Signals from the craft were briefly detected after launch, but contact was then lost. The last signals were received at 15:43 UTC on 21 May 2010, when the spacecraft was 320,000 kilometres (200,000 mi) from Earth. UNISEC explains that Shin'en is the first student spacecraft passed over Van Allen radiation belt. Shin'en is expected to be near Venus as of December 2010.

IKAROS

IKAROS



Model of the IKAROS spacecraft, not to scale.

Operator	JAXA
Flyby of	Venus
Satellite of	The Sun
Orbital insertion date	2010-05-21
Launch date	2010-05-20 21:58:22 UTC
Carrier rocket	H-IIA 202
Launch site	Tanegashima Space Center Tanegashima, Japan
Mission duration	~0.5 years elapsed: 9 months, and 4 days
COSPAR ID	2010-020E
Mass	315 kg

IKAROS (**Interplanetary Kite-craft Accelerated by Radiation Of the Sun**) is a Japan Aerospace Exploration Agency experimental spacecraft. The spacecraft was launched on 21 May 2010 aboard an H-IIA rocket, together with *Akatsuki* (Venus Climate Orbiter) and four other small spacecraft. IKAROS is the first spacecraft to successfully demonstrate solar-sail technology in interplanetary space.

On December 8, 2010, IKAROS passed by Venus at about 80,800 km distance, completing the planned mission successfully, and entered extended operation phase.

Purpose

The IKAROS probe is the world's first spacecraft to use solar sailing as the main propulsion. It plans to demonstrate four key technologies (comments in parentheses refer to figure):

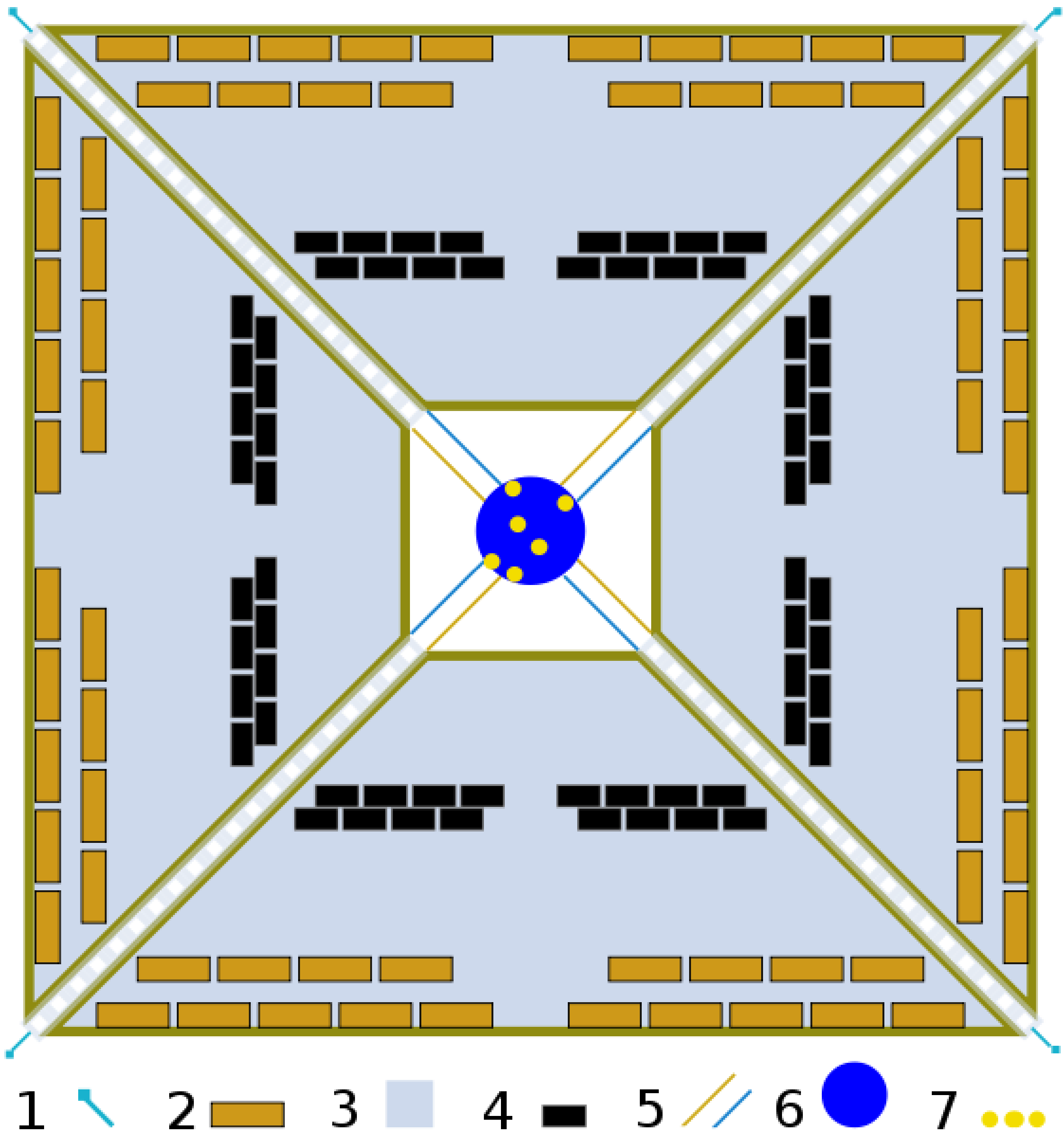
1. Deployment and control of a large, thin solar sail membrane (gray areas numbered 3)
2. Thin-film solar cells integrated into the sail to power the payload (black rectangles numbered 4)
3. Measurement of acceleration due to radiation pressure on the solar sail
4. Attitude control via variable reflectance liquid crystal panels (orange rectangles numbered 2)

The mission also includes investigations of aspects of interplanetary space, such as the gamma-ray burst, solar wind and cosmic dust.

The probe's ALADDIN instrument (ALDN-S and ALDN-E) measured the variation in dust density while its Gamma-Ray Burst Polarimeter (GAP) measured the polarization of gamma-ray bursts during its six month cruise.

If successful, IKAROS is to be followed by a 50 m (160 ft) sail, intended to journey to Jupiter and the Trojan asteroids, later in the decade.

Design



IKAROS sail schematic diagram:
1 (blue square on a line) Tip mass 0.5 kg, 1 of 4
2 (orange rectangle) Liquid crystal device, 1 of 80
3 (blue square) Membrane 7.5 µm thick, 20 metres diameter
4 (black rectangle) Solar cells 25 µm thick
5 (yellow and blue lines) Tethers
6 (blue disc) Main body
7 (yellow dots) Instruments

The square sail, deployed via a spinning motion using 0.5 kg tip masses (1 in key at right), is 20 m (66 ft) on the diagonal and is made of a 7.5-micrometre (0.0075 mm) thick sheet of polyimide (3 in key at right). A thin-film solar array is embedded in the sail (4 in key at right). PowerFilm, Inc. provided the thin-film solar array. Eighty blocks of LCD panels are embedded in the sail, whose reflectance can be adjusted for attitude control (2 in key at right). The sail also contains eight dust counters on the opposite face as part of the science payload.

Mission progress

IKAROS was successfully launched together with *Akatsuki* (the Venus Climate Orbiter) aboard an H-IIA rocket from the Tanegashima Space Center on 21 May 2010.

IKAROS spun at 20–25 revolutions per minute and finished unfurling its sail on 11 June 2010. The craft contains two tiny ejectable cameras, DCAM1 and DCAM2. DCAM2 was used to visualise the sail after deployment on 14 July 2010.

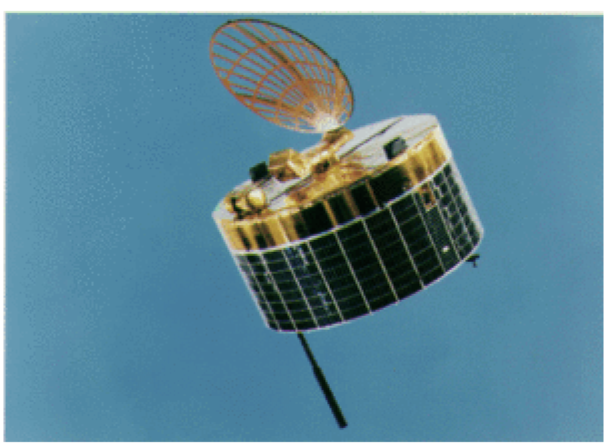
The sail finished deploying on 10 June 2010.

Acceleration and attitude control were successfully tested during the remaining six month voyage to Venus. On 9 July 2010, JAXA confirmed that IKAROS is being accelerated by its solar sail, and on 23 July announced successful attitude control.

IKAROS continues to spin at approx 2 rpm, so attitude control requires the LCD panels to be cycled at that rate.

Suisei (spacecraft)

Suisei



Spacecraft Suisei

Operator ISAS (now part of Japanese Aerospace

	Exploration Agency)
Mission type	Flyby
Satellite of	**Comet Halley**
Launch date	1985-08-18, Uchinoura Space Center
Launch vehicle	M-3SII-2
Mission duration	August 20, 1992
COSPAR ID	1985-073A
Homepage	Suisei
Mass	139.5 kg
	Orbital elements
Eccentricity	-
Periapsis	151000 km (Comet Halley)

Suisei (すいせい; Japanese for *Comet*), originally known as **Planet-A**, was an unmanned space probe developed by the Institute of Space and Astronautical Science (now part of the Japanese Aerospace Exploration Agency, or JAXA).

It constituted a part of the Halley Armada together with Sakigake, the Soviet/French Vega probes, the ESA Giotto and the NASA International Cometary Explorer, to explore Halley's Comet during its 1986 sojourn through the inner solar system.

Spacecraft

Suisei was identical in construction and shape to Sakigake, but carried a different payload: a CCD UV imaging system and a solar wind instrument.

The main objective of the mission was to take UV images of the hydrogen corona for about 30 days before and after Comet Halley's descending crossing of the ecliptic plane. Solar wind parameters were measured for a much longer time period. The spacecraft is spin-stabilized at two different rates (5 and 0.2 rpm). Hydrazine thrusters are used for attitude and velocity control; star and sun sensors are for attitude control; and a mechanically despun off-set parabolic dish is used for long range communication.

Launch

Suisei was launched on August 18, 1985 by M-3SII-2 launch vehicle from Kagoshima Space Center. It was sent on an intercept course with Comet Halley, after which it would remain in a heliocentric orbit for later use as long as it was viable.

Halley encounter

Suisei began UV observations in November 1985, generating up to 6 images/day.

The spacecraft encountered Comet Halley at 151,000 km on sunward side during March 8, 1986, suffering only 2 dust impacts.

Earth flyby

Fifteen burns of Suisei's 3 N motors during the period of April 5–10, 1987, yielded a 65 m/s velocity increase for a 60,000 km Earth gravity assist swingby on August 20, 1992, although the craft was then lost behind the Sun for the summer.

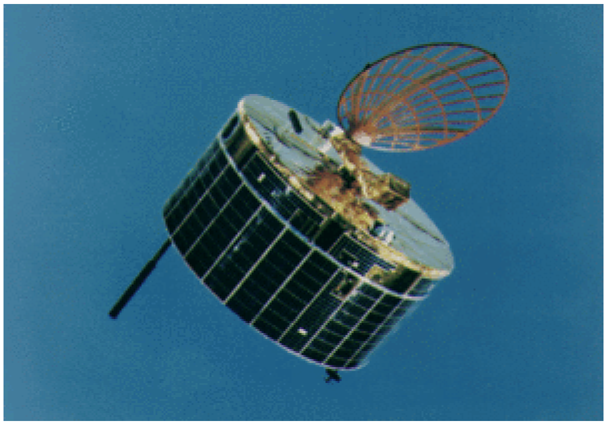
The hydrazine fuel was depleted on February 22, 1991. Preliminary tracking indicated a 900,000 km flyby had been achieved.

Other planned encounters

ISAS had decided during 1987 to guide Suisei to a November 24, 1998, encounter with 21P/Giacobini-Zinner, but due to depletion of the hydrazine, this, as well as plans to fly within several million kilometers of Comet 55P/Tempel-Tuttle on February 28, 1998, were cancelled.

Sakigake

Sakigake



Spacecraft Sakigake

Operator	ISAS (now part of JAXA).
Mission type	Flyby
Flyby of	Comet Halley
Launch date	January 7, 1985 from Kagoshima Space Center
Launch vehicle	M-3SII-1
Mission duration	November 15, 1995
COSPAR ID	1985-001A
Homepage	SAKIGAKE
Mass	138.1 kg
Orbital elements	
Eccentricity	-
Inclination	.07°
Apoapsis	1.15 AU
Periapsis	.92 AU
Orbital period	382.8 d

Sakigake (translating to "pioneer", or "Pathfinder"), pre-launch codename **MS-T5**, was Japan's first interplanetary spacecraft, and the first deep space probe to be launched by any country other than the USA or the Soviet Union. It aimed to demonstrate the performance of the new launch vehicle, test the schemes of the first escape from the Earth gravitation for Japan on engineering basis, observing space plasma and magnetic field in interplanetary space. Sakigake was also supposed to get references for scientists. Early measurements would be used to improve the mission of the Suisei probe several months later.

Sakigake developed by the Institute of Space and Astronautical Science for the National Space Development Agency (both of which are now part of the Japanese Aerospace Exploration Agency, or JAXA). It became a part of the Halley Armada together with Suisei, the Soviet/French Vega probes, the ESA Giotto and the NASA International Cometary Explorer, to explore Halley's Comet during its 1986 sojourn through the inner solar system.

Design

Unlike its twin Suisei, it carried no imaging instruments in its instrument payload.

Launch

Sakigake was launched January 7, 1985 from Kagoshima Space Center by M-3SII-1 launch vehicle.

Halley encounter

It carried out a flyby of Halley's Comet on March 11, 1986 at a distance of 6.99 million km.

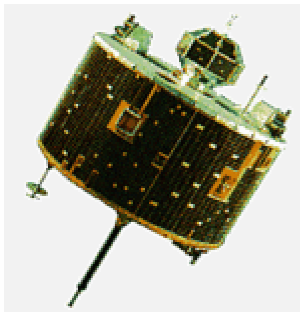
Giacobini-Zinner encounter

There were plans for the spacecraft to go on to an encounter with 21P/Giacobini-Zinner in 1998 but they had to be abandoned due to lack of propellant.

End of mission

Telemetry contact was lost on 15 November 1995, though a beacon signal continued to be received until 7 January 1999.

Hiten

Hiten-Hagoromo (Muses-A)	
	
Hiten spacecraft	
Operator	ISAS
Mission type	Orbiter
Satellite of	**Moon**
Orbital insertion date	19 March 1990
Orbits	10
Launch date	11:46, 24 January 1990 UTC
Launch vehicle	Mu-3S-II (no. 5)
Mission duration	3 years, 2 months
COSPAR ID	1990-007A
Homepage	Hiten
Mass	197.4 kg

The **Hiten** Spacecraft, given the English name **Celestial Maiden** and known before launch as **MUSES-A** (Mu Space Engineering Spacecraft A), part of the MUSES Program, was built by the Institute of Space and Astronautical Science of Japan and launched on January 24, 1990. It was Japan's first lunar probe, the first robotic lunar probe since the Soviet Union's Luna 24 in 1976, and the first lunar probe launched by a country other than Soviet Union or the United States. Hiten was designed to be an Earth to Moon orbiting spacecraft and testing into deep space maneuver using swing-by to the Moon and aerobraking of the Earth. The spacecraft entered a Double Moon swing-by orbit and released a small orbiter, **Hagoromo** (named after the feather mantle of *Hiten*), into lunar orbit at the first swing-by to the Moon. The transmitter on Hagoromo failed (the only mission payload of Hagoromo is a beacon transmitter, so it is small error to ISAS). ISAS considered Hagoromo to have succeeded by optical observation from earth.

After tenth Swing-by to the Moon and second aero-braking mission, (the final mission that was planned before launching) Hiten had some fuel to change her orbit. An additional mission was designed by Edward Belbruno and ISAS. This low energy lunar transfer used Weak Stability Boundary Theory. This, however, would take several months instead of several days. Lastly, Hiten went into circumlunar Moon orbit.

Hiten successfully demonstrated aerobraking technique on March 19 and 30, 1991. This was the first aerobraking maneuver by a deep space probe.

The primary mission was concluded on March 30, 1991 and the follow-on mission was started. On April 24, 1991 Hiten left Earth orbit and went to the Moon using Belbruno's route. On October 2, 1991 Hiten reached the Moon at the prescribed distance. After which, it was put into a looping orbit which passed through the L_4 and L_5 Lagrange points to look for trapped dust particles. No obvious increase was found by the Munich Dust Counter (MDC). After two months in lunar orbit, the spacecraft's orbit was decaying, so the last of Hiten's fuel was used to crash it into the lunar surface on April 10, 1993.

This mission marked the first use of a low-energy (weak stability boundary) transfer to modify an orbit and the first use of a transfer to the Moon requiring no delta V for capture.

The only scientific instrument on Hiten was the Munich Dust Counter (MDC). The MDC provided data on the dust environment between the earth and the moon until April 10, 1993 when Hiten was intentionally crashed into the lunar surface at 34°18′S 55°36′E / 34.3°S 55.6°E between the craters Stevinus and Furnerius.

Nano-JASMINE

Nano-JASMINE (JASMINE: *Japan Astrometry Satellite Mission for INfrared Exploration*) is a 35 kg astrometric microsatellite developed by the National Astronomical Observatory of Japan. The satellite is scheduled to be lanched August 2011 into a sun-synchronous orbit.

Overview

Nano-JASMINE is Japan's first astrometric satellite and is anticipated to be the world's second astrometric satellite, the first being Hipparcos, launched in 1989 by the European Space Agency. It is the first of a planned series of three satellites of increasing size: Nano-JASMINE, Small-JASMINE, and JASMINE. The satellite observes in the infrared, allowing for better observation towards the center of the Galaxy, and has a small, 5 centimeter primary mirror.

The satellite should measure positions with accuracy comparable to Hipparcos, but should be useful to determine the positions of stars whose current positions are poorly known owing to uncertainty in their motion since their previous measurement by Hipparcos. In addition, combining nano-JASMINE data with Hipparcos data should enable the determination of more accurate proper motions.

The development cost of the satellite is approximately 100 million yen. It is scheduled to be lanched in August 2011 by a Tsyklon-4 rocket from the Brazilian Space Agency's launch site in Alcantara, Brazil. The launch has been provided free of charge.

Nano-Jasmine will incorporate the use of star-image extraction (SIE) to cut-down on the amount data sent.

SPICA (spacecraft)

SPICA telescope	
General information	
Organization	JAXA / NASA / ESA
Launch date	2017/18
Launch vehicle	H-IIA
Mission length	5 years (design)
Location	Lagrangian point L2
Wavelength	3.5 to 210 µm (infrared)
Diameter	~3.5 m (11 ft)
Instruments	
SAFARI	Far infrared spectrometer
MIR Coronagraph	Mid IR Coronagraph
Mid IR Camera and Spectrometer	Mid IR Camera and Spectrometer
Website	sci.esa.int/spica

The **Space Infra-Red Telescope for Cosmology and Astrophysics telescope** (**SPICA**), initially called **HII/L2** after the launch vehicle and orbit, is a proposed infrared space telescope, successor of the successful AKARI spacecraft.

Background

The project is led by the Japan Aerospace Exploration Agency (JAXA), and the telescope will be launched on an H-IIA rocket. The Ritchey-Chrétien telescope's 3.5-metre mirror (similar size to that of the Herschel Space Observatory) is to be made of silicon carbide, possibly by the European Space Agency (ESA) given their experience with Herschel. Currently planned to be launched in 2017, the spacecraft's main mission will bet the study of the star and planetary formation. It will be able to detect stellar nurseries of galaxies, protoplanetary discs around young stars, and exoplanets, helped by its own coronograph for the latter two types of objects.

Project plan

It is intended to use a halo orbit around the L2 point; it is intended to use mechanical cryocoolers rather than liquid helium, allowing the mirror to be cooled to 4.5 K (versus the 80 K or so of a mirror cooled only by radiation like Herschel's) which provides substantially greater sensitivity in the 10–100 μm infrared band (IR band); the telescope is intended to observe in longer wavelength infrared than the James Webb Space Telescope.

Intended focal-plane instrumentation

- SAFARI: 30–200 μm imaging spectrometer (to be provided by ESA)
- Coronagraphic instrument for detecting Jupiter-scale exoplanets, working in the 5–20 μm range, also usable as an unobstructed imager.
- High-resolution spectrograph for 4–40 μm
- Low-resolution spectrograph for 10–100 μm

Timeline

The mission has been planned for many years; the launch date as of 2005 was "early 2010s", though as of 2009 a great deal of hardware has been designed but very little built, the SPICA website indicates that in summer 2009 the mission is still at the conference stage, and the 2009 paper says 'within ten years'.

As of 2010, it is expected to be launched in 2018.

Astro-H

Astro-H (also known as **NeXT** for *New X-ray Telescope*) is a planned X-ray astronomy satellite under development by the Japan Aerospace Exploration Agency (JAXA). It is expected to be launched in summer 2013 into the 550 km height orbit around earth. Launch vehicle will be the H-IIA.

With a planned weight of 2.4 t, Astro-H will be the heaviest Japanese astronomy mission so far. When its telescope is extended in orbit, the satellite will be 14 meters length.

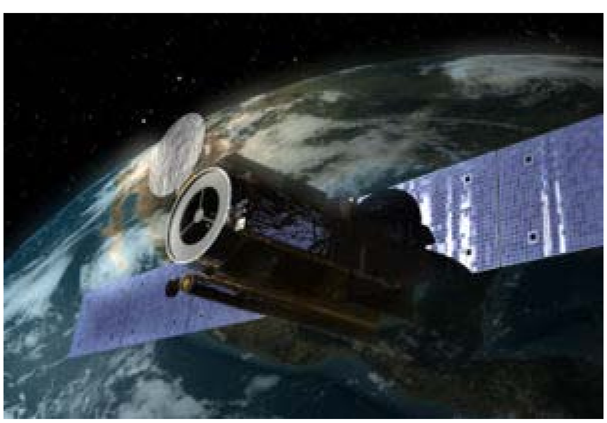
The observatory is designed to extend the research conducted by Advanced Satellite for Cosmology and Astrophysics (ASCA) by investigating the hard X-ray band above 10 keV. NASA is participating with this project by committing the High-Resolution Soft X-Ray Spectrometer (SXS). The Netherlands Institute for Space Research (SRON) will build the filter-wheel and calibration source for the spectrometer. This calibration source corrects for instabilities in the spectrometer.

Instruments

- Hard X-ray Telescope (HXT)
- Soft X-ray Telescope (SXT-S, SXT-I)
- Hard X-ray Imager (HXI)
- Soft X-ray Spectrometer (SXS)
- Soft X-ray Imager (SXI)
- Soft Gamma-ray Detector (SGD)

Hinode

Hinode



Artist's impression of the Hinode spacecraft (then known as Solar-B) in orbit

General information	
NSSDC ID	2006-041A
Organization	JAXA / NASA / PPARC
Launch date	2006-09-22 21:36 UTC
Launched from	Uchinoura Space Center Kimotsuki, Kagoshima, Japan
Launch vehicle	M-V-7 rocket
Mission length	elapsed: 5 years, 1 month, and 24 days
Mass	700.0 kg
Type of orbit	sun-synchronous orbit
Wavelength	optical, X ray, EUV
Instruments	
SOT	Solar Optical Telescope
XRT	X-ray Telescope
EIS	Extreme-Ultraviolet Imaging Spectrometer
Website	JAXA Hinode mission

Hinode, formerly **Solar-B**, is a Japan Aerospace Exploration Agency Solar mission with United States and United Kingdom collaboration. It is the follow-up to the Yohkoh (Solar-A) mission and it was launched on the final flight of the M-V-7 rocket from Uchinoura Space Center, Japan on 22 September 2006 at 21:36 UTC (23 September, 06:36 JST). Initial orbit was perigee height 280 km, apogee height 686 km, inclination 98.3 degrees. Then the satellite maneuvered to the quasi-circular sun-synchronous orbit over the day/night terminator, which allows near-continuous observation of the Sun. On 28 October 2006, the probe's instruments captured their first images.

Mission

Hinode was planned as a three-year mission to explore the magnetic fields of the Sun. It consists of a coordinated set of optical, extreme ultraviolet (EUV), and x-ray instruments to investigate the interaction between the Sun's magnetic field and its corona. The result will be an improved understanding of the mechanisms that power the solar atmosphere and drive solar eruptions. NASA, the space agency of the United States, developed three science instrument components: the Focal Plane Package (FPP), the X-Ray Telescope (XRT), and the Extreme Ultraviolet Imaging Spectrometer (EIS) and shares operations support for science planning and instrument command generation.

Instruments

Hinode carries three main instruments to study the Sun:

SOT (Solar Optical Telescope)

A 0.5 meter Gregorian optical telescope with an angular resolution of about 0.2 arcsecond over the field of view of about 400 x 400 arcsec. At the SOT focal plane, the Focal Plane Package (FPP) built by the Lockheed Martin Solar and Astrophysics Laboratory in Palo Alto, California consists of three optical instruments: the Broadband Filter Imager (BFI) which produces images of the solar photosphere and chromosphere in six wide-band interference filters; the Narrowband Filter Imager (NFI) which is a tunable Lyot-type birefringent filter capable of producing magnetogram and dopplergram images of the solar surface; and the Spectropolarimeter (SP) which produces the most sensitive vector magnetograph maps of the photosphere to date. The FPP also includes a Correlation Tracker (CT) which locks onto solar granulation to stabilize the SOT images to a fraction of an arcsecond. The spatial resolution of the SOT is a factor of 5 improvement over previous space-based solar telescopes (e.g., the MDI instrument on the SOHO).

XRT (X-ray Telescope)

A modified Wolter I telescope design that uses grazing incidence optics to image the solar corona's hottest components (0.5 to 10 Million K) with an angular resolution consistent with 1 arcsec pixels at the CCD. The telescope has an imaging field of view of 34 arcminutes. It is capable of capturing an image of the full sun when pointed at the center of the solar disk. The telescope was designed and built by Smithsonian Astrophysical Observatory (SAO), which, with the Harvard College Observatory (HCO) form the Harvard-Smithsonian Center for Astrophysics (CfA). The camera was developed by NAOJ and JAXA.

EIS (Extreme-Ultraviolet Imaging Spectrometer)

A normal incidence extreme ultraviolet (EUV) spectrometer that obtains spatially resolved spectra in two wavelength bands: 17.0-21.2 and 24.6-29.2 nm. Spatial resolution is around 2 arcsec, and the field of view is up to 560 x 512 arcsec^2. The emission lines in the EIS wavelength bands are emitted at temperatures ranging from 50,000 K to 20 million K. EIS is used to identify the physical processes involved in heating the solar corona.

Hinode Science Data Centre Europe

The Hinode Science Data Centre (SDC) Europe has been developed at the Institute of Theoretical Astrophysics, University of Oslo, through the Norwegian Space Centre, as part of the contribution of the European Space Agency to the Hinode mission. The other part of the contribution is to increase the amount of down linked data by about a factor of four, using ground stations located at Svalbard. The data volumes in the Hinode archive are significant: 2 million compressed fits files with 1.5 terabytes of data after just half a year, and about 20 million images and thumbnails to go with them.

Suzaku (satellite)

***Suzaku* (ASTRO-EII)**

General information

NSSDC ID	2005-025A
Organization	Japan Aerospace Exploration Agency (JAXA)
Major contractors	NASA, MIT
Launch date	2005-07-10, 03:30:00 UTC

Launched from	Uchinoura Space Center Uchinoura, Kagoshima, Japan
Launch vehicle	M-V-6
Mission length	elapsed: 5 years, 7 months, and 12 days
Mass	1706 kg
Type of orbit	Circular
Orbit height	550.0 km (inclination 31°)
Orbit period	96 minutes
Website	www.jaxa.jp/projects/sat/astro_e2

ASTRO-E

The M-V rocket carrying ASTRO-E veering off course after launch on 10 February 2000.

General information

Organization	Institute of Space and Astronautical Science (ISAS)
Launch date	2000-02-10, 01:30:00 UTC
Launched from	Kagoshima Space Center

	Uchinoura, Kagoshima, Japan
Launch vehicle	M-V-4

Suzaku (formerly **ASTRO-EII**) is a Japanese X-ray astronomy satellite launched on 10 July 2005 aboard the M-V-6 rocket. The project was renamed *Suzaku* after its successful launch after the mythical Vermilion bird of the South.

The *Suzaku* spacecraft functioned flawlessly until 29 July 2005 when the first of series of cooling system malfunctions occurred, that ultimately on 8 August 2005 caused the entire reservoir of liquid helium to boil off into space. This effectively shut down the XRS which is the spacecrafts primary instrument. The two other instruments, XIS and HXD, were unaffected by the malfunction, and there are plans to integrate another XRS into the proposed NeXT X-ray observation satellite planned for launch in 2012.

Suzaku instruments

Suzaku is carrying high spectroscopic resolution, very wide energy band instruments for detecting signals ranging from soft X-rays up to gamma-rays (0.3–600 keV). High resolution spectroscopy and wide-band are essential factors to physically investigate high energy astronomical phenomena, such as black holes and supernovae. One such feature, the broad iron K line, may be key to more direct imaging of black holes.

- X-ray Telescope (XRT)
- X-ray Spectrometer (XRS)
- X-ray Imaging Spectrometer (XIS)
- Hard X-ray Detector (HXD)
    - Uses Gadolinium Silicate crystal (GSO), $Gd_2SiO_5(Ce)$
    - Uses Bismuth Germanate crystal (BGO), $Bi_4Ge_3O_{12}$

ASTRO-E

Suzaku is a replacement of **ASTRO-E** which was lost for the failure of launch vehicle. M-V-4 rocket launched on 10 February 2000 at 01:30:00 UTC but experienced a failure 42 seconds later, failed to achieve orbit and crashed with its payload into the ocean.

Hakucho

Hakucho (CORSA-B)

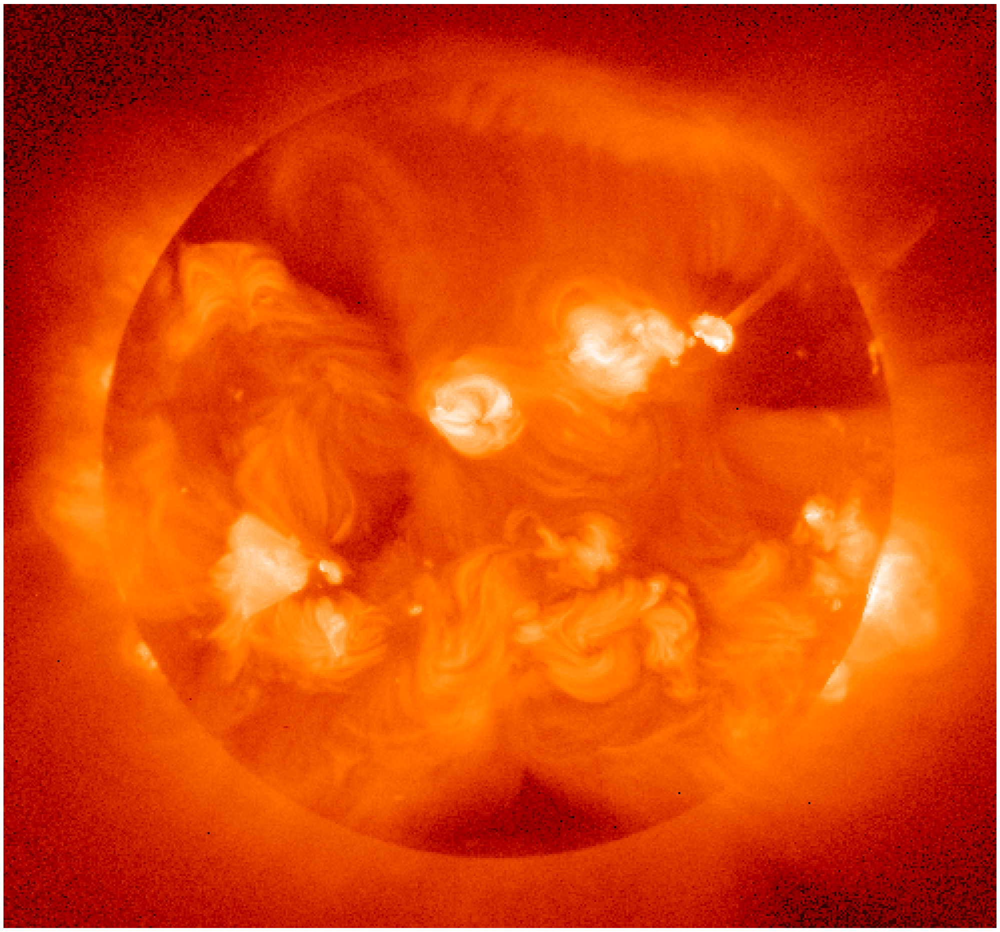
Hakucho (also known as **CORSA-b** before launch) was Japan's first X-ray astronomy satellite, developed by the Institute of Space and Aeronautical Science (then a division of the University of Tokyo). It was launched by the ISAS M-3C-4 rocket on February 21, 1979 and reentered the atmosphere on April 16, 1985 .

It was a replacement for the CORSA satellite which failed to launch due to rocket failure on February 4, 1976 .

Highlights

- Discovery of soft X-ray transient Cen X-4 and Apl X-1
- Discovery of many burst sources
- Long-term monitoring of X-ray pulsar (e.g. Vela X-1)
- Discovery of 2 Hz variability in the Rapid Burster later named Quasi Period Oscillation.

Yohkoh



The X-ray solar corona as viewed by the *Yohkoh* observatory

Yohkoh (ようこう, *Sunbeam* in Japanese), known before launch as **Solar-A**, was a Solar observatory spacecraft of the Institute of Space and Astronautical Science (Japan) with United States and United Kingdom collaboration. It was launched into Earth orbit August 30, 1991 by the M-3S-5 rocket from Kagoshima Space Center.

The satellite was three-axis stabilized and in a near-circular orbit. It carried four instruments: a Soft X-ray Telescope (SXT), a Hard X-ray Telescope (HXT), a Bragg Crystal Spectrometer (BCS), and a Wide Band Spectrometer (WBS). About 50 MB were generated each day and this was stored on board by a 10.5 MB bubble memory recorder.

Because SXT utilized a charge-coupled device (CCD) as its readout device, perhaps being the first X-ray astronomical telescope to do so, its "data cube" of images was both extensive and convenient, and it revealed much interesting detail about the behavior of the solar corona. Previous solar soft X-ray observations, such as those of Skylab, had been restricted to film as a readout device.

The mission ended after more than ten years of successful observation when it went into its "safehold" mode during an annular eclipse on December 14, 2001 after the spacecraft lost lock on the sun. Operational mistakes and other flaws conspired in such a way that its solar panels could no longer charge the batteries, which drained irreversibly; several other solar eclipses had successfully been observed.

On September 12, 2005 the spacecraft burned up during reentry over South Asia. The time of reentry, as provided by the U.S. Space Surveillance Network, was 6:16 pm Japan Standard Time (JST).

Instruments

Yohkoh carries four instruments:

- **Soft X-ray Telescope** (SXT) is an X-ray telescope with glancing incidence X-ray mirror and a CCD sensor. There is also a co-aligned optical telescope using the same CCD, but after the failure of the entrance filter in November 1992 it became unusable.

The CCD is 1024×1024 pixels with pixel angular size of 2.45″×2.45″, point spread function core width (FWHM) is about 1.5 pixels (i.e. 3.7″), field of view is 42′×42′, which is a little larger than the whole solar disk. Typical time resolution is 2 s in flare mode and 8 s in quiet (no flare) mode, the maximum time resolution in 0.5 s.

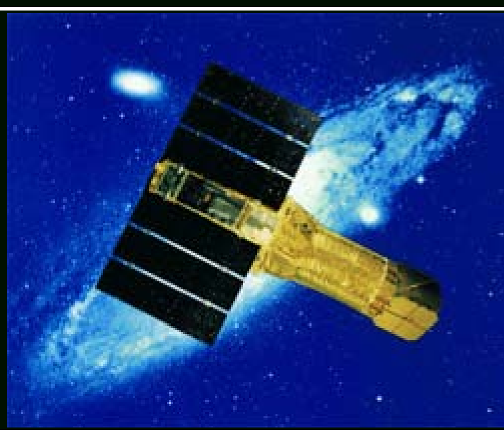
For spectral discrimination, STX employs wide-band filters installed on a filter wheel. There are five usable filter positions: **1265 Å**-thick **Al** filter (2.5 Å–36 Å pass band), **Al/Mg/Mn** filter (2.4 Å–32 Å), **2.52 µm Mg** filter (2.4 Å–23 Å), **11.6 µm Al** filter (2.4 Å–13 Å), **119 µm Be** filter (2.3 Å–10 Å). Before the entrance filter failure in November 1992 three more filter positions were available: no analysis filter (2.5 Å–46 Å), Wide band optical filter (4600 Å–4800 Å), Narrow band optical filter (4290 Å–4320 Å).

- **Hard X-ray Telescope** (HXT) is a Fourier synthesis type X-ray imager. HXT is sensitive to photons with energies from 14 keV to 93 keV, this range is divided into four energy bands (called L, M1, M2, H). The angular resolution is about 5″, image synthesis field of view is 2′×2′, maximum time resolution is 0.5 s.
- **Bragg Crystal Spectrometer** (BCS) is two bent crystal spectrometers sensitive in four spectral lines: the line of ion Fe XXVI (1.76 Å–1.81 Å), ion Fe XXV (1.83 Å–1.90 Å), ion Ca XIX (3.16 Å–3.19 Å), and ion S XV (5.02 Å–5.11 Å). Spectral resolution varies in the range of $\lambda/\Delta\lambda$=3000–8000, typical time resolution in flare mode is 8 s, maximum is 0.125 s. BCS integrates radiation over the whole solar disc.
- **Wide Band Spectrometer** (WBS) has spectroscopic capabilities in a wide energy band from 3 keV to 100 MeV. WBS is a set of four subinstruments, each of them outputs Pulse Count (PC) corresponding to intensity integrated over a band, and Pulse Height (PH) profile which corresponds to spectrum. Time resolution for PC

(0.125 s–4 s for different subinstruments and modes) is 8–16 times better than for PH (1 s–32 s). WBS integrates radiation over the whole Sun and does not resolve source position.

- Soft X-ray Spectrometer (SXS) consists of two proportional gas counters with nominal energy band 5 keV–40 keV, which is divided into two PC channels and 128 PH channels. It was found after the launch that PH to energy relationship was distorted. No energy calibration for WBS PH data was available in 1999.
- Hard X-ray Spectrometer (HXS) is a NaI(Tl) scintillator. The energy band after June 1992 is 24 keV–830 keV. It is dividede into 2 PC channels and 32 PH channels.
- Gamma-ray Spectrometer (GRS) consists of two identical bismuth germanate oxide scintillators. It covers energy range 0.3 MeV–100 MeV, which is divided into 6 PC channels and 128+16 PH channels.
- Radiation Belt Monitor (RBM) unlike the other three isn't aimed at solar flare observations and serves to sound the alarm for radiation belt passage.

Advanced Satellite for Cosmology and Astrophysics

ASCA	
	
The ASCA Spacecraft (credit: ISAS and NASA GSFC)	
Organization	ISAS, NASA
Wavelength regime	X-ray
Orbit Height	500–600 km
Orbit period	95 min
Launch date	20 February 1993
Deorbit date	2 March 2001
Mass	420 kg
Webpage	http://heasarc.gsfc.nasa.gov/docs/asca/
Physical Characteristics	

Telescope Style	Wolter telescope - paired grazing incidence hyperbolic and parabolic foil mirrors
Diameter	1.2m
Collecting Area	1300 cm² @ 1 keV, 600 cm² @ 7 keV
Effective Focal Length	3.5 m
Instruments	
XRT	X-ray telescopes (4)
GIS	Imaging Spectrometer
SIS	Imaging Spectrometer

ASCA (formerly named ASTRO-D) was Japan's fourth cosmic X-ray astronomy mission, and the second for which the United States provided part of the scientific payload. The satellite was successfully launched February 20, 1993. After 8 years of observation, its altitude control was lost in 2000, and it re-entered to atmosphere in 2001.

Highlights

- Broad Fe lines from AGN, probing the strong gravity near the central engine
- Lower than solar Fe abundance in the coronae of active stars
- Spectroscopy of interacting binaries
- Non-thermal X-rays from SN 1006, a site of Cosmic Ray acceleration
- Abundances of heavy elements in clusters of galaxies, consistent with type II supernova origin

Hinotori (satellite)

Hinotori (ASTRO-A)	
Operator	ISAS
Mission type	Orbiter
Satellite of	**Earth**
Launch date	February 21, 1981
Launch vehicle	M-3S
Orbital decay	July 11, 1991
COSPAR ID	1981-017A

Mass	188.0 kg
Orbital elements	
Eccentricity	~0.003952.
Inclination	~31.30 °
Apoapsis	603.0 km
Periapsis	548.0 km
Orbital period	~96.20 min

The **Hinotori (satellite)** (Japanese for "phoenix" or "firebird"), also known as Astronomical Satellite-A or ASTRO-A, was launched on February 21, 1981, at 09:30:00 UTC, using the M-3S vehicle from the Uchinoura Space Center in Japan.

The main objective of the Hinotori mission is the detailed study of solar flares during solar maximum. Principal investigations are (1) imaging of solar flare X-rays in the range 10 to 40 keV by means of rotating modulation collimators and (2) spectroscopy of X-ray emission lines from highly ionized iron in solar flares in the range 0.17 to 0.20 nm by means of a Bragg spectrometer. Wavelength scanning is achieved by the spacecraft revolution, with an offset pointing of the spin axis with respect to the Sun. Investigations (1) and (2) each had a time resolution of 6 s. In addition, the following investigations are included: three solar flare X-ray monitors that recorded the time profile and spectrum of the X-ray flares in the range 2 to 20 keV, a solar flare gamma-ray detector for the range 0.2 to 9.0 MeV, a particle detector that monitored electron flux above 100 keV, and plasma probes for the measurement of electron density and temperature.

Instruments

Hinotori has these eight scientific instruments aboard for specific purposes:

1. solar flare X-ray imager (SXT),
2. solar soft X-ray, bright line spectrum analyzer (SOX),
3. solar soft X-ray monitor (HXM),
4. solar flare monitor (FLM),
5. solar gamma-ray monitor (SGR),
6. particle-ray monitor (PXM),
7. plasma electron density measurement (IMP), and
8. plasma electron temperature measurement (TEL).

The gamma-ray spectrometer (SGR) covering the energy range (0.21 - 6.67 MeV) consists of a phoswich type CsI(Tl) scintillator (8.9 cm dia x 5.1 cm thickness) surrounded by a 0.5 cm thick plastic scintillator.

The hard X-ray spectrometer (HXM) consists of a NaI(Tl) scintillator (8.9 cm dia x 1 cm thick), covering the energy range 17 - 340 keV.

Scientific accomplishments

Each Hinotori instrument has contributed significantly to further understanding of the Sun and solar active regions.

Solar X-ray astronomy

The Hinotori observations of the 1980s pioneered hard X-ray imaging of solar flares.

A new type of X-ray burst which emits thermal hard X-rays with a strong Fe XXVI emission has been found. This thermal burst efficiently forms hot thermal plasma, $T_e = 3 - 5 \times 10^7$K, and becomes dominant after the middle phase of a flare.

Gamma-ray astronomy

Four cosmic gamma-ray bursts were observed between February 1981 and June 1982: on February 21, 1982, lasting 16 s, July 21, 1981, lasting 6 s, February 26, 1982, lasting 32 s, and March 13, 1982, lasting 80 s. Of the four bursts, the first two were also detected by PVO, the second by ISEE-3 and SMM, while the third was corroborated by Venera 14, and the fourth by Venera 13, Venera 14, and SMM.

During solar cycle 21, gamma-ray flares observed by Hinotori and SMM exhibited a 152-158 day periodicity in the occurrence of solar activity. Power-spectrum analyses of daily sunspot areas for the period 1980-1982 show a peak around 159 days, similar to that of solar gamma-ray bursts (GRBs) above 300 keV, soft X-ray bursts (152 d), hard X-ray bursts (158 d) above 30 keV, Hα flare data, microwave bursts (152 d) for the period 1966-1983, but no periodicity in sunspot number, indicating that sunspot area data should be treated as an indicator of solar activity rather than the daily sunspot number.

Eight solar gamma-ray flares observed between April 1981 and June 1982 contained lines at 2.22 MeV and 4.44 MeV produced by particle acceleration where energy spectra do not vary much from flare to flare. The 2.22 MeV line indicates solar surface fusion while the 4.44 MeV line is produced by de-excitation of ^{12}C following the nuclear reactions $^{12}C(p,p'\gamma_{4.438\ MeV})^{12}C$ and $^{12}C(p,2p\gamma_{4.444\ MeV})^{11}B$.

Hayabusa 2

Hayabusa 2 is the follow on mission to the Hayabusa mission as proposed by the Japanese space agency, JAXA. The goal for Hayabusa 2 is to build up on the legacy of the original mission, by strengthening the shown weak points. As of January 2011, the target is asteroid (162173) 1999 JU3 with a proposed launch date July 2014, with backup launch opportunity of December 2014, June and December 2015. Hayabusa 2 would then be expected to arrive to the target in 2018, survey the asteroid for one and a half year, then depart in December 2019, and return to the earth in December 2020. Operations at the asteroid will be similar to the previous Hayabusa, except an explosive device to dig the asteroid surface for fresh sample material.

Funding problems and international cooperation

Hayabusa 2 was agreed by the SAC during 2006 and was announced in a new year interview with JAXA president Keji Tachikawa.

In July 2009, at the 27th ISTS (International Symposium on Space Technology and Science) conference in Japan, presentations were given that elaborated upon the most recent Hayabusa 2 mission concept. The presentation was by Makoto Yoshikawa of JAXA for the paper entitled: "Hayabusa Follow-on Asteroid Sample Return Missions." Dr. Yoshikawa stated that JAXA has a new proposal for Hayabusa 2, namely that they are now proposing the mission have two spacecraft with one specifically being an impactor.

In August 2010, JAXA got the go-ahead from the Japanese government to begin development of Hayabusa 2. The estimated cost of the project is 16.4 billion yen.

Instruments

The French space agency might build an instrument for the Hayabusa 2.