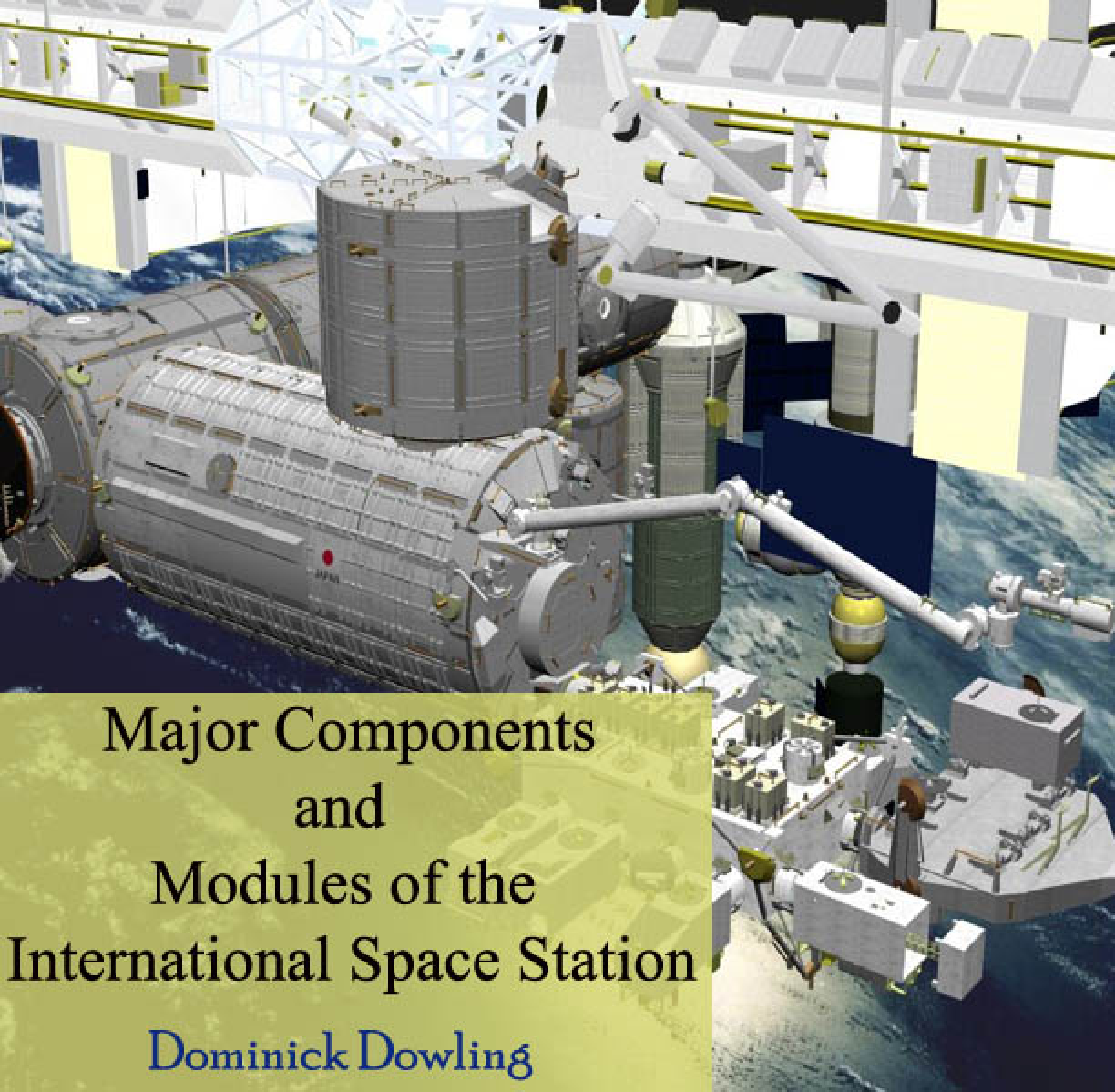

# Major Components and Modules of the International Space Station

Dominick Dowling

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## Chapter- 1

# Zvezda

**ISS Zvezda**

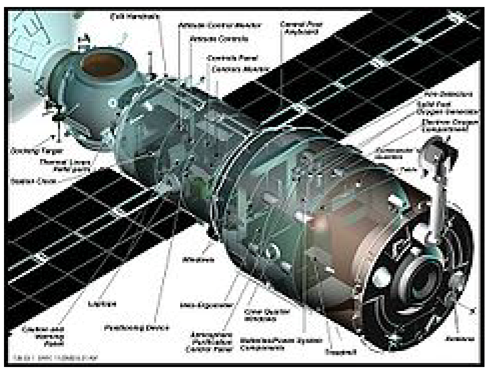
The *Zvezda* service module of the ISS with *Zarya* to the left and a docked Progress spacecraft to the right.


| Station statistics | |
|---|---|
| **Call sign** | International Space Station |
| **Launch** | July 12, 2000<br>Docked with ISS on July 26. |
| **Launch pad** | LC-81/23, Baikonur Cosmodrome, Kazakhstan |
| **Mass** | 19,051 kilograms (42,000 lb) |
| **Length** | 13.1 metres (43 ft) |
| **Width** | 29.7 metres (97 ft) |
| **Diameter** | 4.15 m |
| **Atmospheric pressure** | 101.3 kPa (29.91 inHg) |
| **Perigee** | 319.6 kilometres (172.6 nmi) |
| **Apogee** | 346.9 kilometres (187.3 nmi) |
| **Orbital inclination** | 51.63 degrees |

| | |
|---|---|
| **Typical orbit altitude** | 333.3 kilometres (180.0 nmi) |
| **Average speed** | 27,743.8 kilometres per hour (17,239.2 mph) |
| **Orbital period** | 91.20 minutes |
| **Orbits per day** | 15.79 |
| **Days in orbit** | 2534 days |
| **Days occupied** | 2316 days |
| **Number of orbits** | 40,010 |

Statistics as of June 20, 2007

**Configuration**



On-orbit configuration of the *Zvezda* service module

***Zvezda*** (Russian: Звезда, meaning "star"), DOS-8, also known as the ***Zvezda Service Module***, is a component of the International Space Station (ISS). It was the third module launched to the station, and provides some of the station's life support systems, as well as living quarters for two crew members. It is the structural and functional center of the Russian portion of the station - the Russian Orbital Segment.

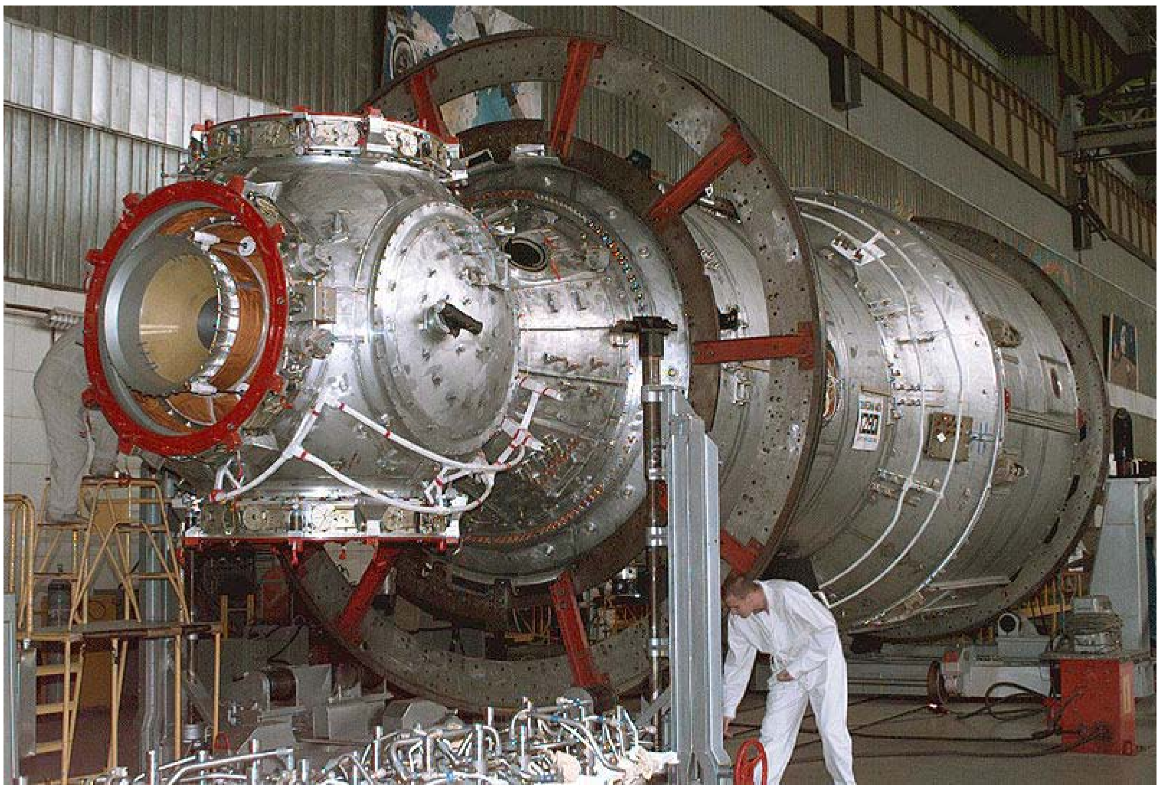
The module was manufactured by S.P. Korolev Rocket and Space Corporation Energia. *Zvezda* was launched on a Proton rocket on July 12, 2000 and docked with the *Zarya* module on July 26. The rocket used for the launch was one of the first to carry advertising; it was emblazoned with the logo of the fast food chain Pizza Hut, for which the company is reported to have paid more than US$1 million.

# Origins

The basic structural frame of *Zvezda*, known as "DOS-8", was initially built in the mid-1980s to be the core of the *Mir-2* space station. This means that *Zvezda* is similar in layout to the core module (DOS-7) of the *Mir* space station. It was in fact labeled as "*Mir*-2" for quite some time in the factory. Its design lineage thus extends back to the original Salyut stations. The space frame was completed in February 1985 and major internal equipment was installed by October 1986.

# Design

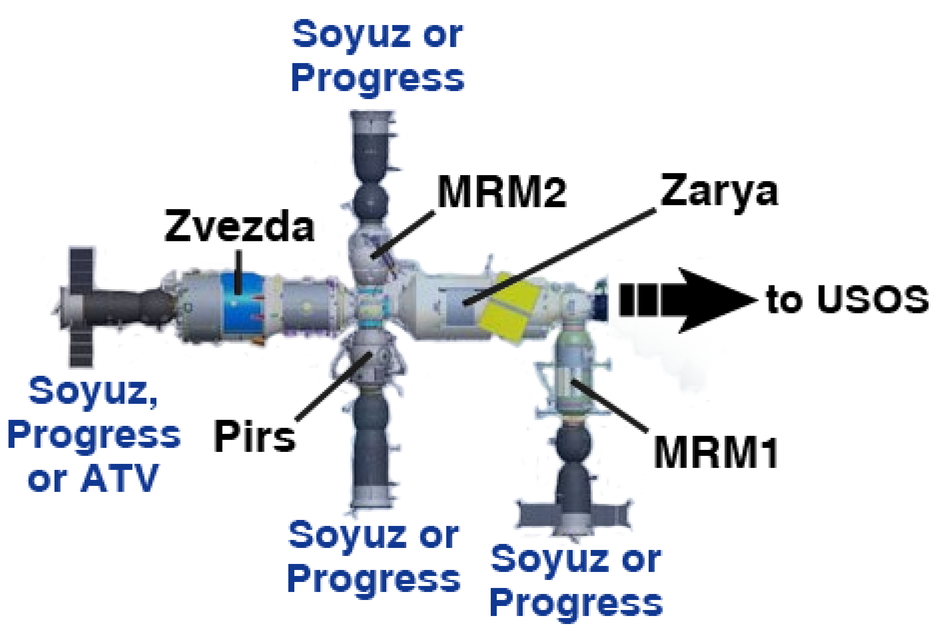
Zvezda consists of a cylindrical "Work Compartment" where the crews work and live, a cylindrical "Transfer Chamber" which has one docking port, an unpressurized "Assembly Compartment" surrounding the Transfer Chamber, and a spherical "Transfer Compartment" with three docking ports. The component weights 18,051 kg (39,800 lb)) and had a length of 13.1 metres (43 ft). The solar panels extend 29.7 metres (97 ft).



*Zvezda* service module under construction

The International Space Station as seen during STS-106, following the arrival of *Zvezda*

Zvezda's toilet.




The location of *Zvezda* on the Russian Orbital Segment.

The "Transfer Compartment" attaches to the *Zarya* module, and has docking ports intended for the Science Power Platform and the Universal Docking Module. Currently the lower port contains the Pirs Docking Compartment and the other contains Mini-Research Module 2. In December 2011, Pirs will be deorbited and replaced by the Multipurpose Laboratory Module.

The "Assembly Compartment" holds external equipment such as thrusters, thermometers, antennas, and propellant tanks.

The "Transfer Chamber" is equipped with automatic docking equipment and is used to service Soyuz and Progress spacecraft.

*Zvezda* contains sleeping quarters for two cosmonauts, a NASA-provided Treadmill with Vibration Isolation System and a bicycle for exercise, toilet and other hygiene facilities and a galley with a refrigerator and freezer. It contains the primary Russian computers for guidance and navigation. It has a total of 14 windows—three 9-inch-diameter (230 mm) windows in the forward Transfer Compartment, a 16-inch window in the Working Compartment, one in each crew compartment, and several more. It also contains the Elektron system that electrolyzes condensed humidity and waste water to provide hydrogen and oxygen. The hydrogen is expelled into space and the oxygen is used for breathing air. The condensed water and the waste water can be used for drinking in an emergency, but ordinarily fresh water from Earth is used. There are 16 small thrusters and two large thrusters for propulsion, and eight batteries for storing power.

The Elektron system has required significant maintenance work, having failed several times and requiring the crew to use Solid Fuel Oxygen Generator canisters (commonly called "Oxygen Candles", which were the cause of a fire on *Mir*) when it has been broken for extended amounts of time. It also contains the Vozdukh, a system which removes carbon dioxide from the air based on the use of regenerable absorbers of carbon dioxide gas. *Zvezda* has been criticized for being excessively noisy and the crew has been observed wearing earplugs inside it.

## Connection to the ISS

On July 26, 2000, *Zvezda* became the third component of the ISS when it docked at the aft port of *Zarya*. (*Zarya* had already been attached to the U.S. *Unity* module.) Later in July, the computers aboard *Zarya* handed over ISS commanding functions to computers on *Zvezda*.

On September 11, 2000, two members of the STS-106 Space Shuttle crew completed final connections between *Zvezda* and *Zarya*; during a 6 hour, 14 minute EVA, astronaut Ed Lu and cosmonaut Yuri Malenchenko connected nine cables between *Zvezda* and *Zarya*, including four power cables, four video and data cables and a fiber-optic telemetry cable. The next day, STS-106 crew members floated into *Zvezda* for the first time, at 05:20 UTC on September 12, 2000.

*Zvezda* provided early living quarters, a life support system, a communication system (*Zvezda* introduced a 10Mbit/s Ethernet network to the ISS ), electrical power distribution, a data processing system, a flight control system, and a propulsion system. These quarters and systems have since been supplemented by additional ISS components.

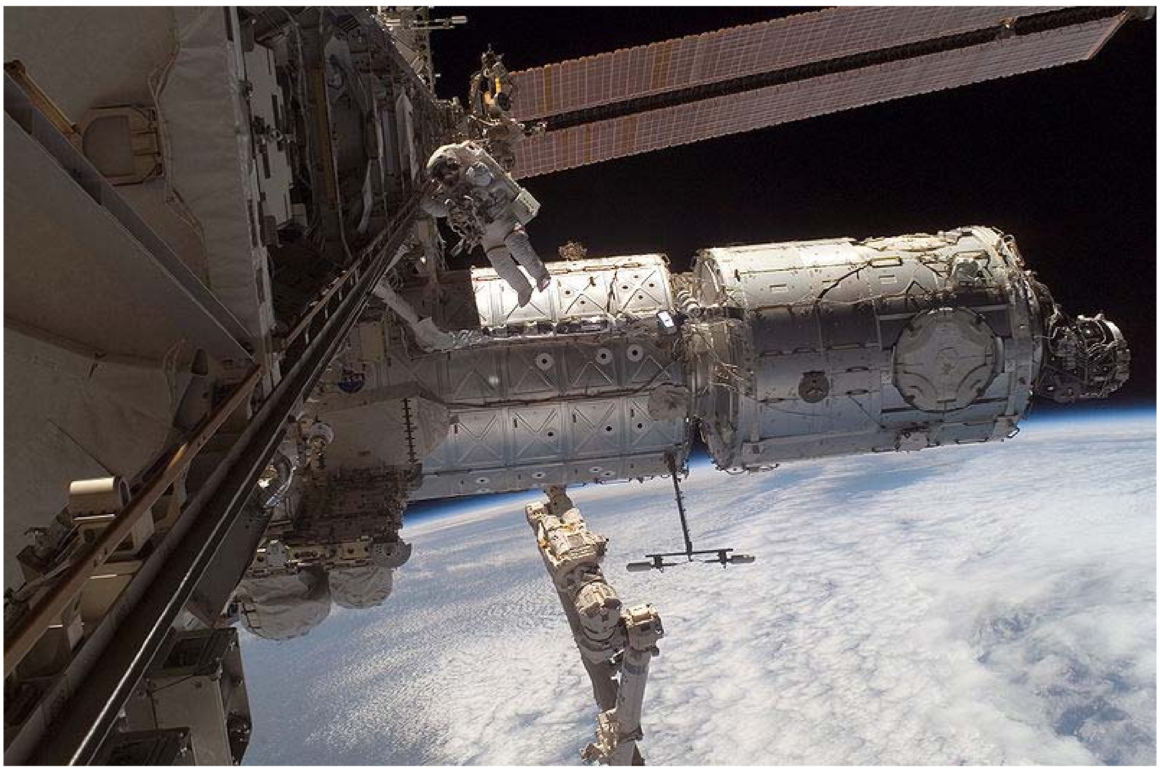
The two main engines on *Zvezda* can be used to raise the station's altitude. This was done on April 25, 2007. This was the first time the engines had been fired since *Zvezda* arrived in 2000.

## Launch risks

Due to Russian financial problems, *Zvezda* was launched with no backup and no insurance. Due to this risk, NASA had constructed an Interim Control Module in case it was delayed significantly or destroyed on launch.

## Chapter- 2

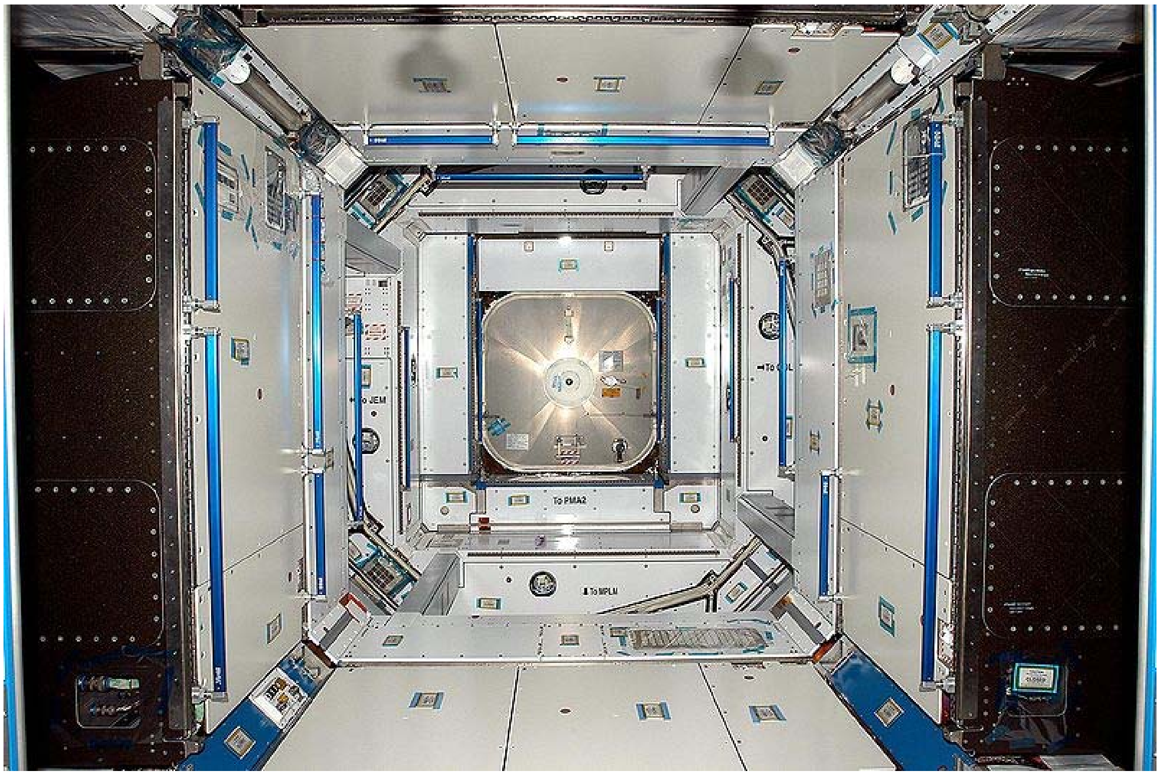
# Harmony



Harmony on the Destiny Laboratory Module. (NASA)

***Harmony***, also known as ***Node 2***, is the "utility hub" of the International Space Station. The hub contains four racks that provide electrical power, plus electronic data, and act as a central connecting point for several other components via its six Common Berthing Mechanisms (CBMs). *Harmony* added 2,666 cubic feet (75 cubic meters) to the station's living volume, an increase of almost 20 percent, from 15,000 cubic feet (425 $m^3$) to 17,666 cubic feet (500 $m^3$) The successful installation of *Harmony* meant that from NASA's perspective, the station was "U.S. Core Complete". *Harmony* was successfully launched into space aboard Space Shuttle flight STS-120 on October 23, 2007. After temporarily being attached to the port side of the Unity node, it was moved to its permanent location on the forward end of the *Destiny* laboratory on November 14, 2007.

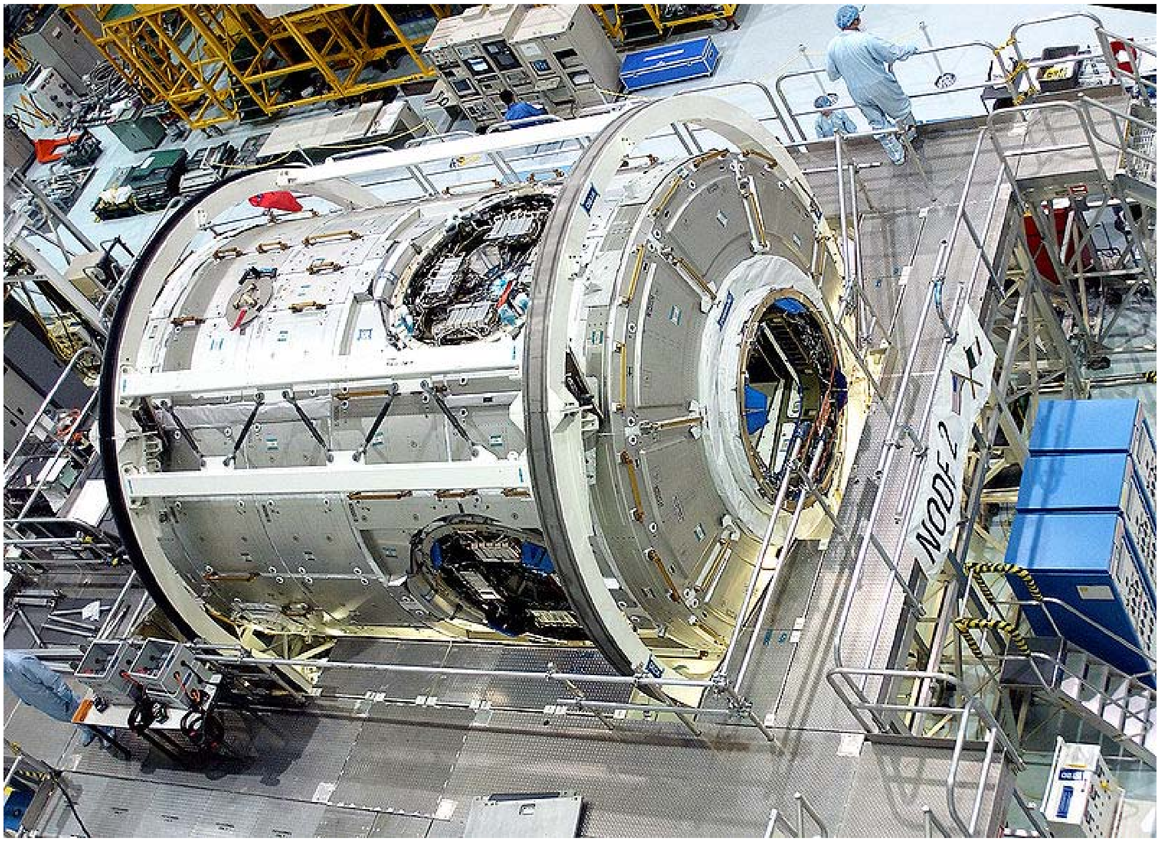
## Origin of name



Interior of Harmony.

The unit formerly known as *Node 2* was renamed *Harmony* in March 2007. The name was chosen from a competition involving more than 2,200 kindergarten through high school students from 32 states. The *Node 2 Challenge* required students to learn about the space station, build a scale model, and write an essay explaining their proposed name for the module, which will serve as a central hub for science labs.

## Specifications




Harmony under assembly. (NASA)

Weighing approximately 14,288 kilograms (31,500 lb), *Harmony* is the second of three connectors between the major ISS modules. The design is based on the existing Multi-Purpose Logistics Module, as well as the European Space Agency's Columbus Module. *Harmony* is managed by NASA's Marshall Space Flight Center in Huntsville, Alabama. Its deployment expanded the Space Station, allowing it to grow from the size of a three-bedroom house, to the space equivalent of a typical five-bedroom house, once the Japanese *Kibō* and European *Columbus* laboratories are attached. The Space Station robotic arm, Canadarm2, is able to operate from a powered grapple fixture on the exterior of *Harmony*. The node measures 7.2 meters (24 ft) in length, and it has a diameter of 4.4 meters (14 ft).

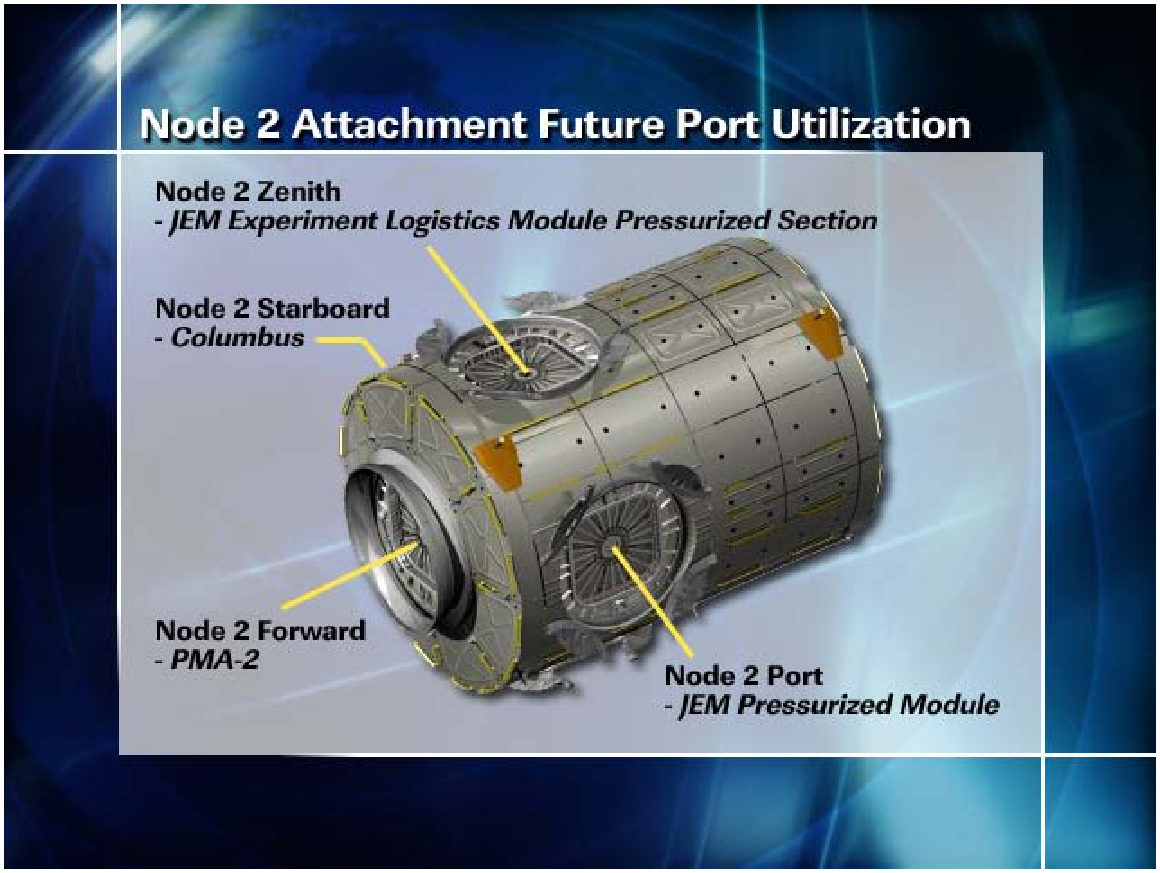
## Construction agreement

In an agreement between NASA and the European Space Agency the Rome-based company Thales Alenia Space built *Harmony* at its facility in Turin, Italy. *Harmony* arrived on June 1, 2003 at the Kennedy Space Center in Florida after its flight in an Airbus Beluga oversize cargo vehicle. Following post transportation inspection, the Italian Space Agency formally handed over *Harmony* to the European Space Agency

(ESA). From there, ESA formally transferred ownership of *Harmony* to NASA on June 18, 2003, taking place in the Space Station Processing Facility of the Kennedy Space Center. The handover of *Harmony* completed a major element of the barter agreement, between ESA and NASA, that was signed in Turin on October 8, 1997.

Paolo A. Nespoli, an ESA astronaut born in Milan, Italy, accompanied the *Harmony* module aboard STS-120 as a mission specialist.

## Launch




Graphic showing the connecting ports of *Harmony*.

*Harmony* being prepared to be taken out of Space Shuttle Discovery's payload bay.

*Harmony* was launched October 23, 2007 aboard STS-120, as the primary component of assembly mission ISS-10A.

On October 26, the station's Space Station Remote Manipulator System (SSRMS) removed *Harmony* from the shuttle cargo bay and temporarily mated it to the port side of Unity and, on October 27, the crew entered *Harmony*. After the Space Shuttle departed *Harmony* was relocated to the forward dock of the *Destiny laboratory*. It required three EVAs by the station crew to complete the installation.

The Expedition 16 crew moved the Pressurized Mating Adapter (PMA-2) on November 12, 2007 from the *Destiny* Laboratory to the forward berth of *Harmony*. The combined PMA-2/Harmony unit was subsequently berthed to its final destination at the forward end of the *Destiny* Laboratory on November 14, 2007.

## Connecting modules

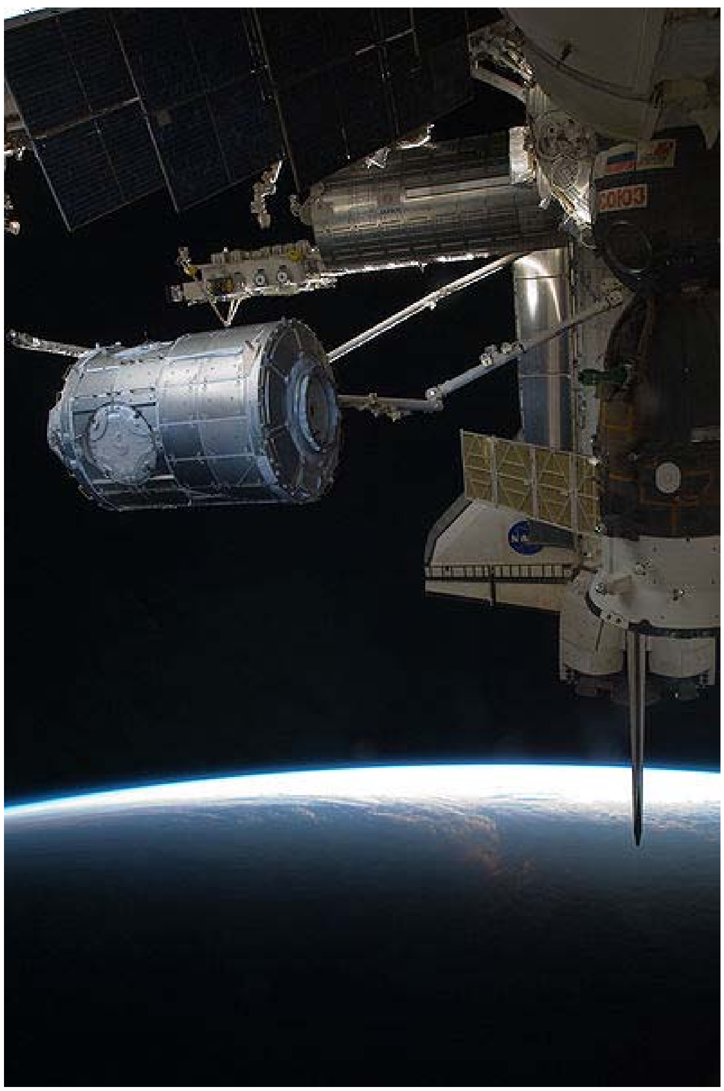
*Harmony* was the first permanent living space enlargement to the ISS after the Pirs docking compartment was added in 2001. On February 11, 2008, ESA's Columbus laboratory was attached to the starboard hatch of the *Harmony* module during space shuttle mission STS-122. On March 14, 2008 the *Experiment Logistics Module Pressurized Section* (ELM-PS) of Kibō was attached to its interim location: the zenith hatch of *Harmony*. During STS-124 a Space Shuttle mission flown by Space Shuttle

*Discovery*, the *Pressurized Module* of Kibō was added to the port side of *Harmony* and the ELM-PS was moved, leaving the zenith hatch empty. The zenith hatch was originally intended to be the permanent docking connector for the now canceled Centrifuge Accommodations Module (CAM).

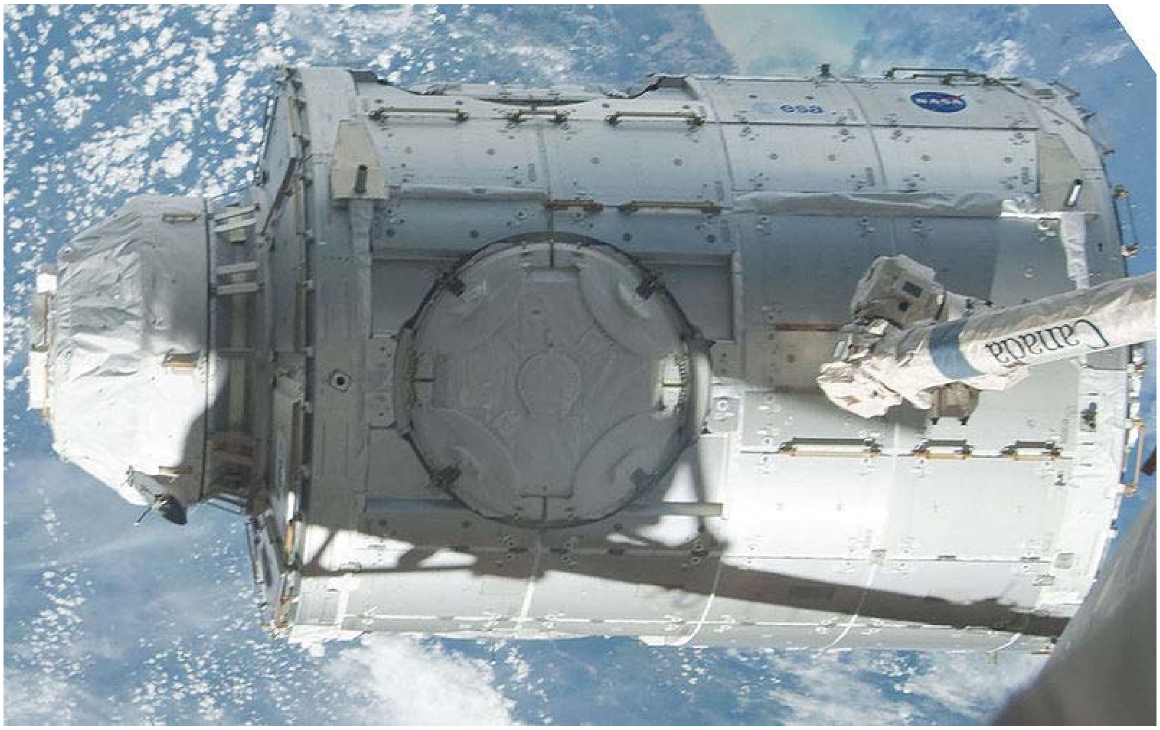
If the shuttle flies the Multipurpose Logistics Modules to the station, then such a module will be temporarily berthed to the nadir hatch of *Harmony*.

## Chapter- 3

# Tranquility



Tranquility photographed just before being installed to Unity node



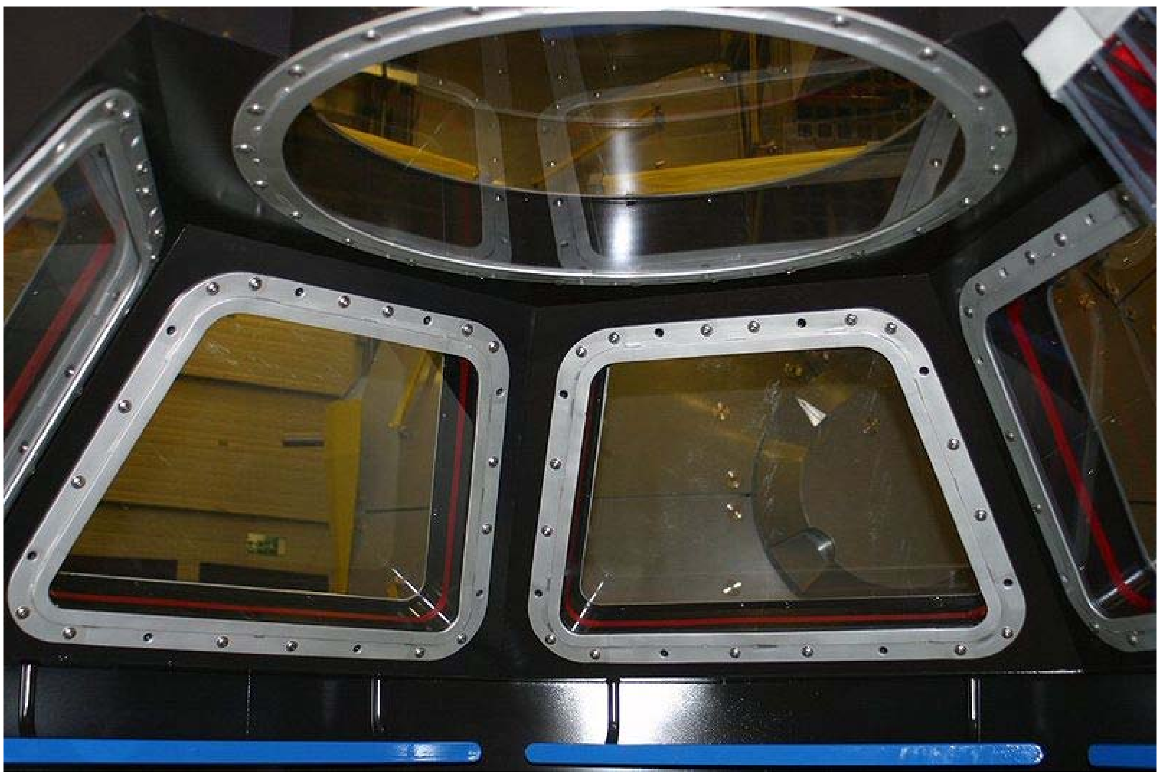
Tranquility with Cupola


Tranquility

***Tranquility***, also known as **Node 3**, is a module of the International Space Station (ISS). ESA and the Italian Space Agency had Tranquility built by Thales Alenia Space. A ceremony on November 20, 2009 transferred ownership of the module to NASA. On February 8, 2010, NASA launched the module on the Space Shuttle's STS-130 mission.

The module provides six berthing locations, however three of those locations are disabled as modules originally planned to be attached to *Tranquility* were canceled. STS-130 also brought the Cupola, a large window module and robotics work station to the ISS which will be attached to the nadir-side of *Tranquility*. The module also includes various ISS systems, including additional life support systems.

## Design

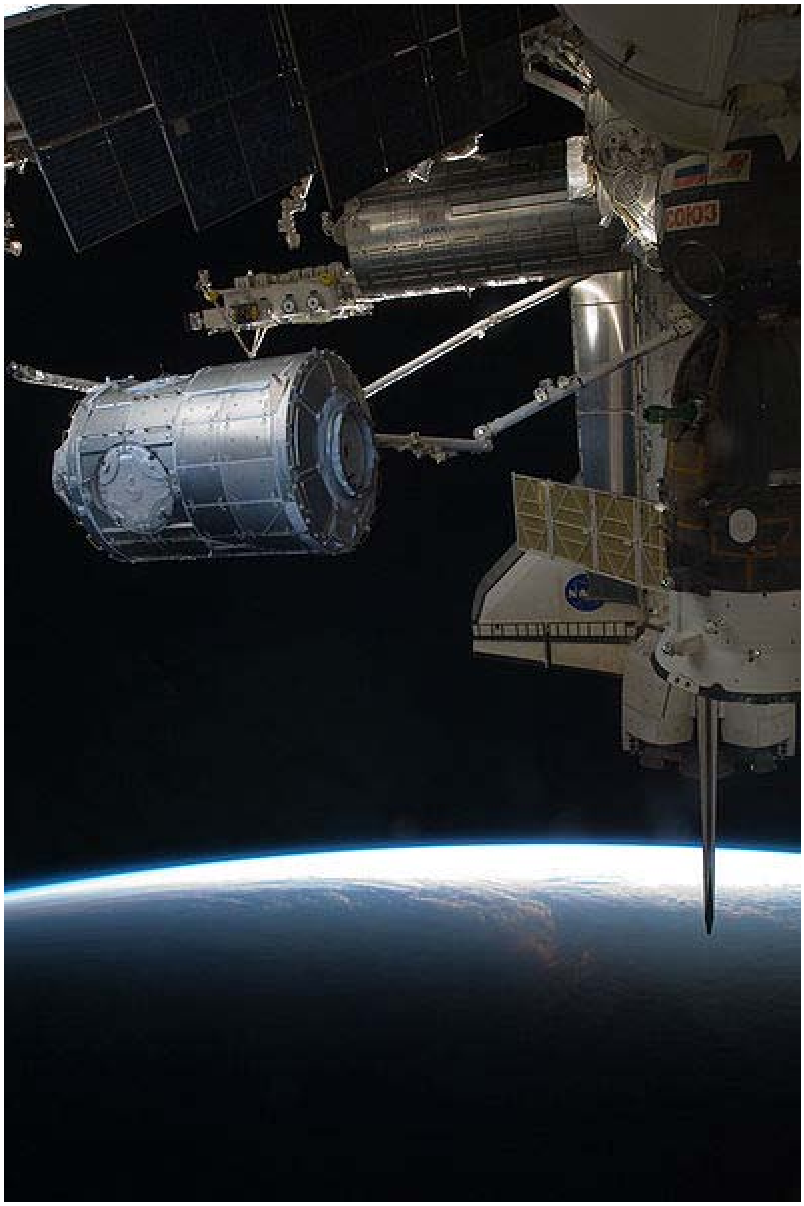


View from inside the Cupola

*Tranquility* was built within the ESA-NASA ISS bartering system. ESA committed to build and fund both *Harmony* and *Tranquility* as well as the ATV in order to use NASA ISS facitilies, fly astronauts on the Shuttle and for other ISS services. ESA teamed up with the Italian Space Agency ASI to build both *Harmony* and *Tranquility* at Thales Alenia Space in Turin.

*Tranquility* provides six berthing locations with power, data and commanding, thermal and environmental control, and crew access for more attached habitable volumes or for crew transportation vehicles or stowage, or an appropriate combination of all of these. One of the berthing locations is used by *Cupola*, which houses a Robotic Work Station inside it to assist in the assembly/maintenance of the ISS as well as offer a window for earth observations. *Tranquility* was launched with the Cupola attached to mating adapter earthward facing port. After mating *Tranquility* with the port Common Berthing Mechanism of *Unity*, the *Cupola* was transferred to the nadir facing port of *Tranquility* where it will stay. The module has three redundant ports that are currently not scheduled to be used. Because the current ISS configuration requires *Tranquility* to be docked to the port berthing location of *Unity*, the three unused berthing locations of *Tranquility* have been disabled and would mostly be blocked by the station's other segments in any event. The docking module PMA-3 has been relocated to the port berthing location of *Tranquility*. The move of PMA-3 to the port location of *Tranquility* was required because NASA decided to leave the MPLM Leonardo permanently attached to the ISS, which will be located at the nadir side of *Unity*.

The Tranquility node during pre-processing.



Tranquility during its move from Endeavour to the install position on the Unity node.


Cupola just after installation at Earth-facing port on Tranquility.

In 2001, NASA considered changing the design of the module. This idea for an extended or "stretched" module, was a result of the deferral/deletion of the Habitation module. The stretched module would have held 16 racks compared with the baseline capacity of eight racks. This modification was not funded and the plans were abandoned.

## Purpose

The module will contain the most advanced life support systems ever flown in space. These systems will recycle waste water for crew use and generate oxygen for the crew to breathe. In addition, *Tranquility* will contain an atmosphere revitalization system to remove contaminants from the atmosphere and monitor/control the atmosphere constituents of the ISS. *Tranquility* will also contain a Waste and Hygiene Compartment (toilet) for supporting the on-board crew.

*Tranquility* will primarily be used for exercise, storage, and robotics work in connection with Cupola.

## Status

*Tranquility* in the SSPF.

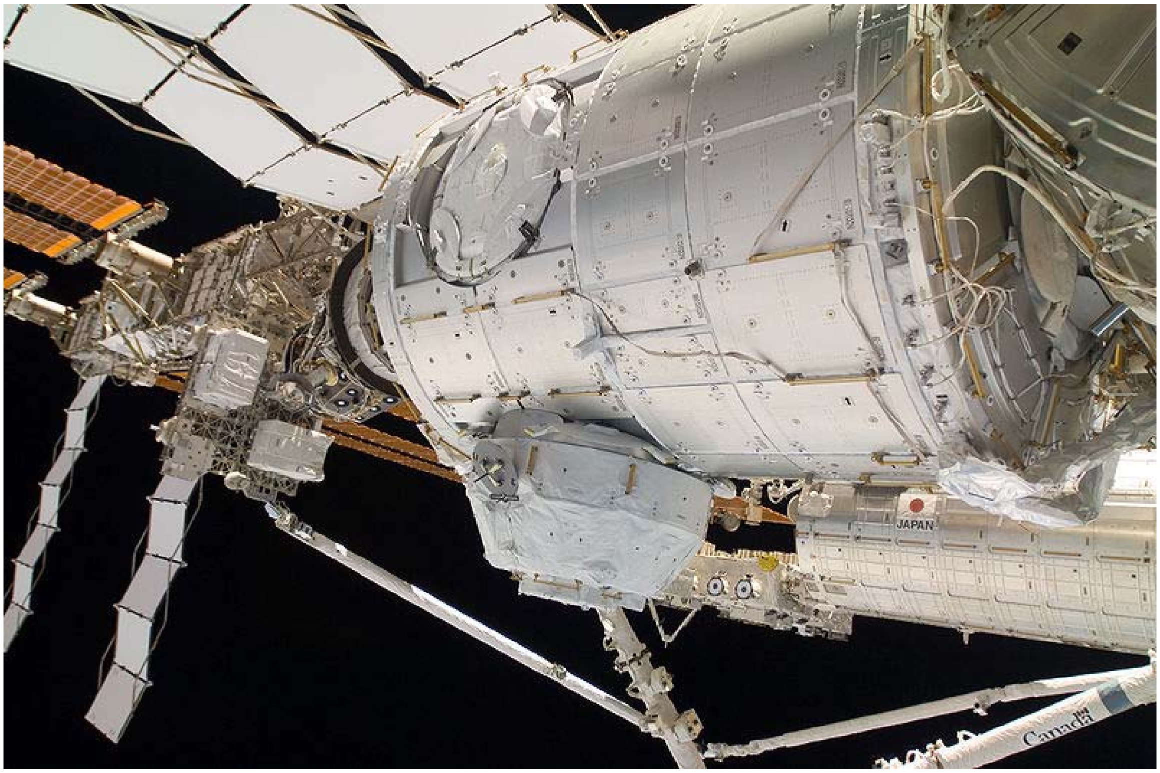
*Tranquility* was located in the clean room at the Thales Alenia Space Turin site until 2009. It was shipped to Kennedy Space Center (KSC) on May 17 and arrived in Florida on May 20, 2009. It was officially welcomed to KSC on June 8, 2009.

*Tranquility* was launched on February 8, 2010 onboard the STS-130 mission flown by Endeavour. It was berthed to the port side of *Unity* on February 12, 2010.

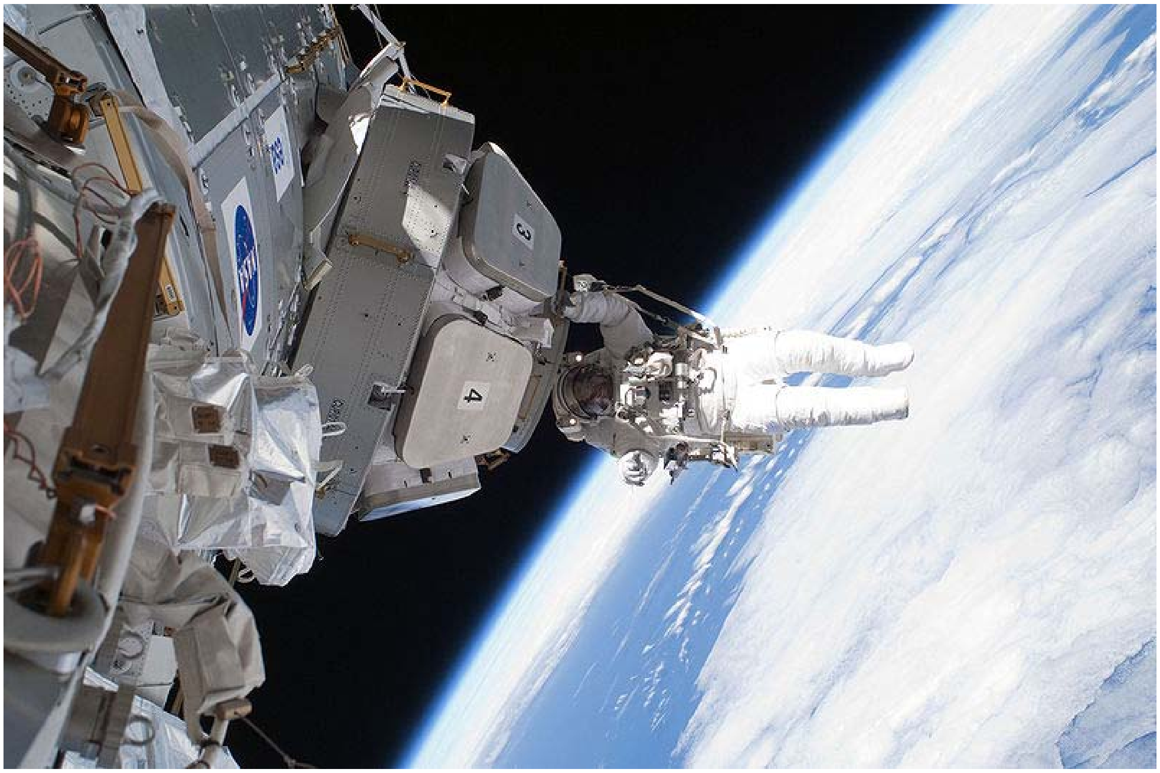
## Naming contest

NASA held an online poll to name Node 3. Users were allowed to choose from among four provided names (Earthrise, Legacy, Serenity, and Venture), or to suggest their own. In early voting, fans of the science fiction TV series *Firefly* boosted "Serenity", also the name of the show's film and eponymous spacecraft, to the top with 86%. On the March

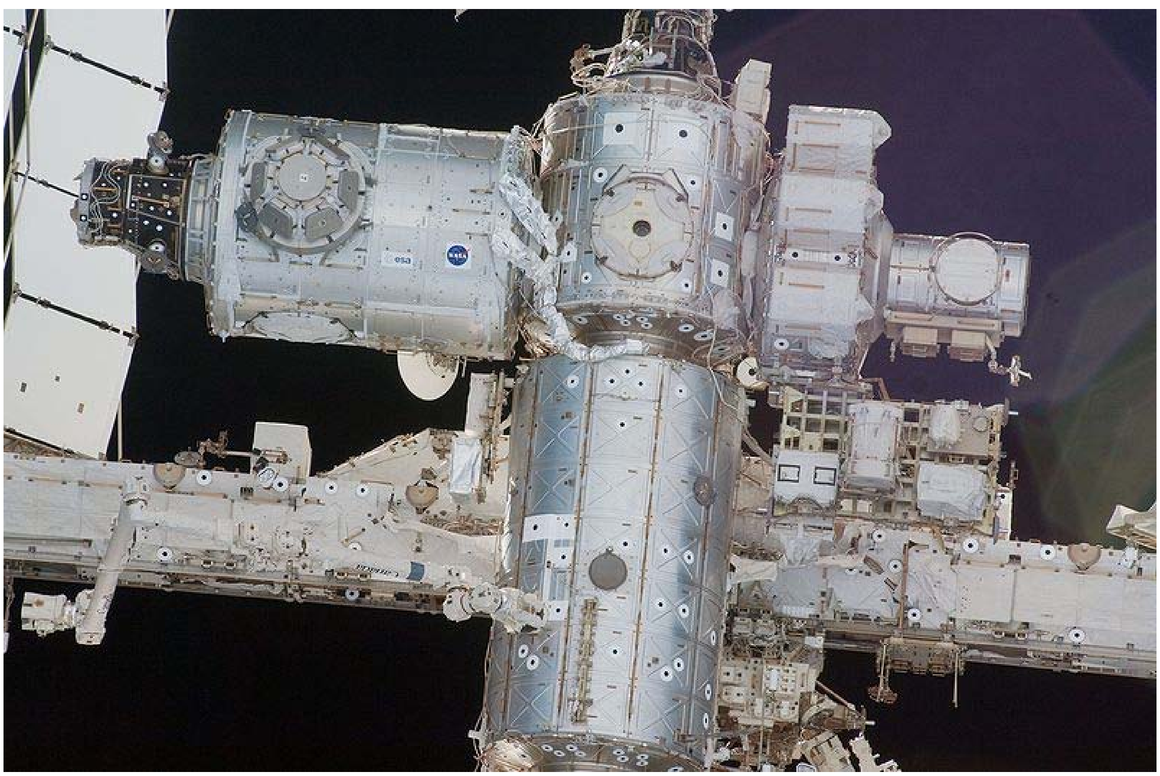
3, 2009, episode of *The Colbert Report*, host Stephen Colbert instructed his viewers to suggest "Colbert" as the name for Node 3 in the online poll.




PMA-3 is moved to the end of Tranquility. Cupola is seen on top with it protective launch cover still attached.



Astronaut Nicholas Patrick hanging on to Cupola after insulation has been removed.



Tranquility seen top left corner with Cupola and PMA-3.

Following Colbert's call to have the node named after him, several other groups attempted to influence the vote. For example, a number of different environmental groups promoted the name "Amazonia", after the Amazon Rainforest. They argued that the name was more appropriate given that Node 3 will include the station's environmental control systems. Humorist Dave Barry urged readers of his blog to name the node "Buddy", which finished as the sixth most popular user-suggested name. Gaia Online asked its users to "Send Gaia to Space" by naming the node "Gaia", referring to the Greek goddess of the planet Earth, and "Gaia" finished third among the user-suggested names. Other popular user suggestions included "myYearbook", "SocialVibe", "Ubuntu", and the name of Scientology's galactic overlord: "Xenu".

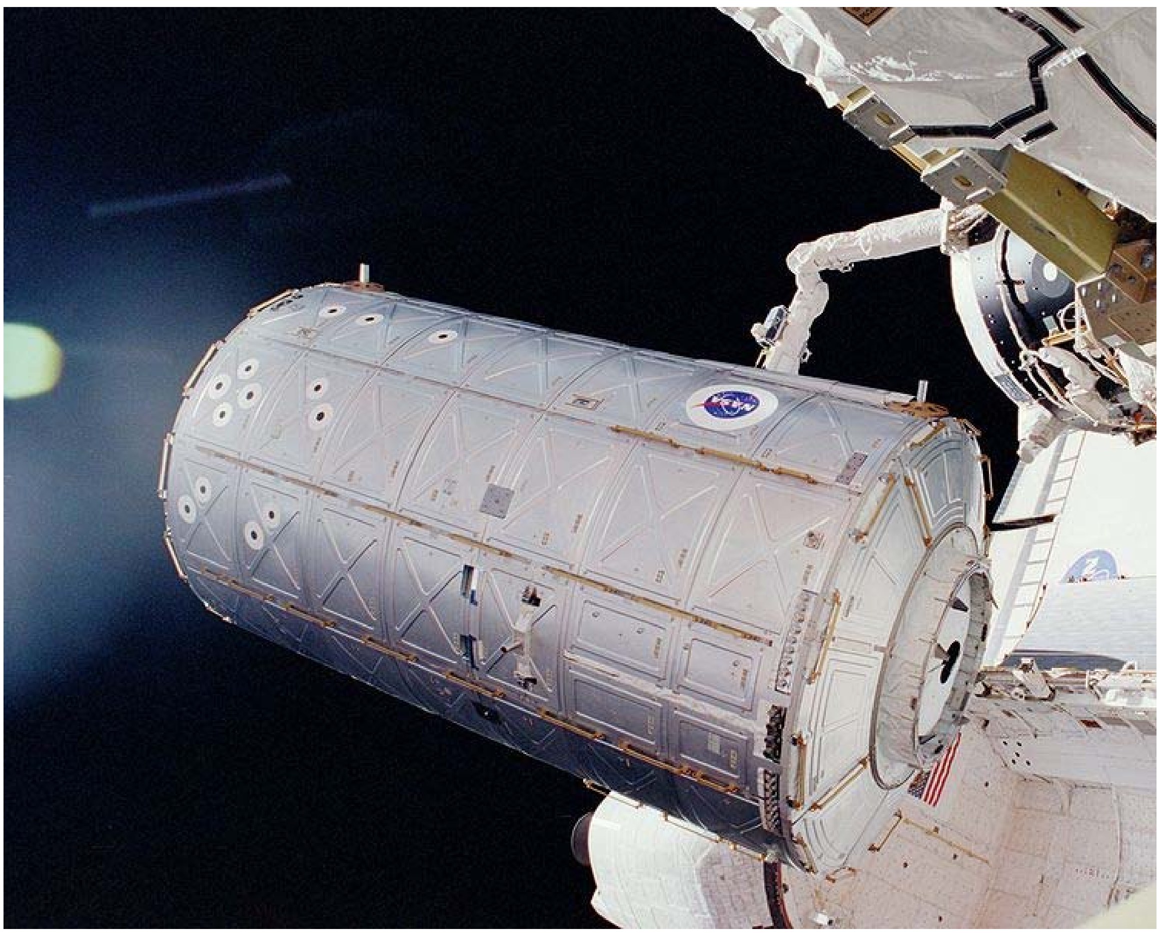

Colbert urging his viewers on the March 3, 2009 airing of *The Colbert Report* to vote for the node to be named after him.

On March 23, 2009, NASA announced that the overall vote winner was "Colbert", with 230,539 votes. Nearly 1.2 million votes were cast in total. "Serenity" was the top choice among the NASA-provided names, with 70% of the vote, but finished second overall, losing to "Colbert" by more than 40,000 votes. The naming contest rules, however, state that although the poll results will be taken into account, NASA has ultimate discretion in choosing an appropriate name for the node. On April 6, 2009, Stephen Colbert, in jest, threatened a lawsuit if the node was not named after him. In addition, United States Congressman Chaka Fattah stated that he believes that paying attention to democracy and voting results should not be limited to earthbound organizations so he planned to use congressional power to force NASA to honor the winning Colbert write-in votes.

On April 14, 2009, astronaut Suni Williams appeared on *The Colbert Report*, and announced the name of the node would be *Tranquility*. The name was chosen in honor of the 40th Anniversary of the first lunar landing of Apollo 11 on the Sea of Tranquility. However, the treadmill the astronauts use for exercise will be named "C.O.L.B.E.R.T." for "Combined Operational Load Bearing External Resistance Treadmill" and will be located in *Tranquility.* Colbert was thrilled and happily accepted this offer. The treadmill traveled to space aboard Space Shuttle mission STS-128 on August 28, 2009, for eventual installation in the *Tranquility* node during STS-130.

**Chapter- 4**

# Destiny



The *Destiny* Laboratory Module (NASA) being installed on the International Space Station.

The ***Destiny*** module is the primary operating facility for U.S. research payloads aboard the International Space Station (ISS). It was berthed to the *Unity* module and activated over a period of five days in February, 2001. *Destiny* is NASA's first permanent operating orbital research station since Skylab was vacated in February 1974.

The Boeing Company began construction of the 16 ton (14.5 tonne), state-of-the art research laboratory in 1995 at the Marshall Space Flight Center in Huntsville, Alabama. *Destiny* was shipped to the Kennedy Space Center in Florida in 1998, and was turned over to NASA for pre-launch preparations in August 2000. It launched on February 7, 2001 aboard the Space Shuttle Atlantis on STS-98.

Astronauts work inside the pressurized facility to conduct research in numerous scientific fields. Scientists throughout the world will use the results to enhance their studies in medicine, engineering, biotechnology, physics, materials science, and Earth science.

## Laboratory structure

Astronaut Susan J. Helms, Expedition Two flight engineer, views the Earth from the *Destiny* module window.

The aluminum U.S. laboratory module is 28 feet (8.5 m) long and 14 feet (4.3 m) wide. It comprises three cylindrical sections and two endcones that contain the hatch openings through which astronauts enter and exit the module. The aft port of *Destiny* is connected to the forward port of the *Unity* node, and the forward port of *Destiny* is connected to the aft port of the *Harmony* module. A 20-inch (510 mm)-diameter window is located on one side of the center module segment.

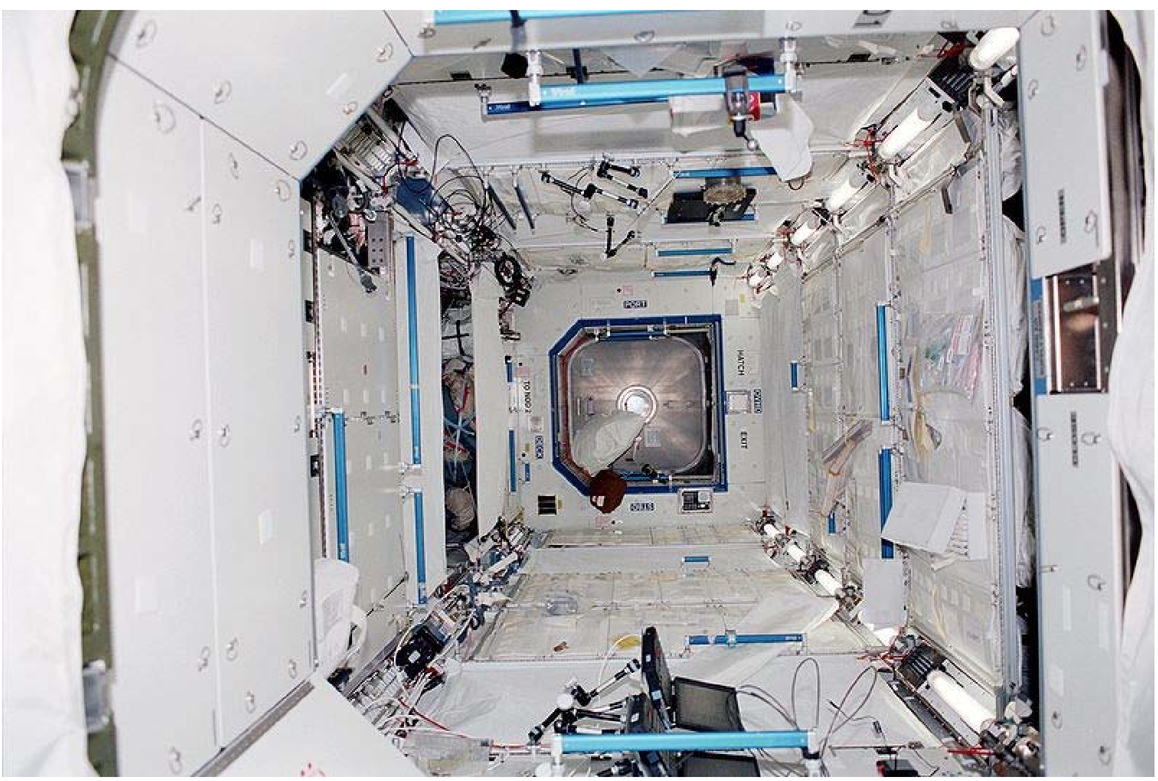
Each of the two berthing ports on *Destiny* contains a hatch. Both hatches are normally open, and remain open unless a situation arises requiring a module to be isolated. Each hatch has a window. The hatches can be opened or closed from either side. The hatches have a pressure interlock feature, which prevents the hatch from being opened if there is a negative pressure across the hatch (higher pressure on the outside of the hatch).

*Destiny* has a 20-inch (510 mm) optically pure, telescope-quality glass window located in an open rack bay used primarily for Earth science observations. Station crewmembers use very high quality video and still cameras at the window to record Earth's changing landscapes. A window shutter protects the window from potential micrometeoroid and orbital debris strikes during the life of the ISS. The crew manually opens the shutter to use the window.

Imagery captured from *Destiny's* window has given geologists and meteorologists the chance to study floods, avalanches, fires and ocean events such as plankton blooms in a way never seen before, as well as given international scientists the opportunity to study features such as glaciers, coral reefs, urban growth and wild fires.

## Specifications

- Length: 8.53 m (28 ft)
- Diameter: 4.27 m (14 ft)
- Mass: 14,520 kg (32,000 lb)
- Pressurized Volume: 106 $m^3$ (3,743.354 $ft^3$)



The *Destiny* laboratory as it looked following installation in 2001.

## Equipment

*Destiny* arrived at the station pre-configured with five racks housing electrical and life support systems that provide electrical power, cooling water, air revitalization, and temperature and humidity control. Seven additional racks were flown to *Destiny* in the *Leonardo* Multi-Purpose Logistics Module by STS-102, and ten more were delivered on subsequent missions. *Destiny* can hold up to 13 payload racks with experiments in human life science, materials research, Earth observations and commercial applications. The laboratory has a total of 24 racks inside the laboratory, six on each side.

Astronaut Kenneth Cockrell, STS-98 commander, emerges from behind a rack curtain in *Destiny*.

Joan E. Higginbotham and Sunita L. Williams work the controls of the Space Station Remote Manipulator System in the Destiny laboratory.

As with the European and Japanese laboratories of the station, payloads inside *Destiny* are configured around International Standard Payload Racks (ISPRs), that can be removed or reconfigured for various experiments and equipment. Made out of a graphite composite shell, each rack weighs about 1,200 pounds (540 kg), and is about 73 inches high, and 42 inches (1,100 mm) wide. The eight rack bays are equipped with curtains that provide around 290 cubic feet (8.2 $m^3$) of temporary stowage space when not occupied by experiments.

Internal to the laboratory are racks, rack stand-offs, and vestibule jumpers. The lab racks house the system hardware in removable modular units. The stand-offs provide space for electrical connections, data management systems cabling for computers, air conditioning ducts, thermal control tubes and more, all of which support the space station's equipment racks. The racks interface to the piping and wiring in the standoff via outlets and ports located in the standoffs at the base end of each rack location.

Jumpers in the vestibule, the area between *Unity* and *Destiny*, connect the piping and wiring between the two. Grounding straps between *Unity* and *Destiny* will be installed. One side of the grounding strap will be connected to the Active Common Berthing Mechanism (ACBM) on *Unity*, while the other end will be connected to the Passive Common Berthing Mechanism (PCBM) on *Destiny*.

Some of the mechanisms on *Destiny* are the CBMs (passive and active), hatches, and the laboratory window shutter. The ACBM is in the forward port of the laboratory. It is attached to the *Harmony* node. The PCBM on *Destiny* is located in the laboratory's aft port. The ACBM in *Unity's* forward port is latched to the laboratory's PCBM to berth *Destiny* to *Unity*.

## Science equipment

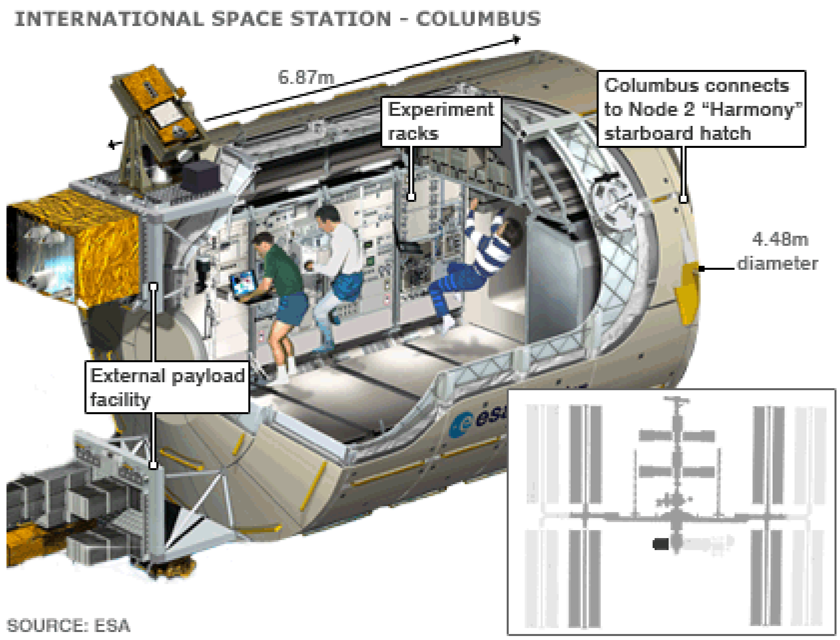
*Destiny* also contains the Minus Eighty Degree Laboratory Freezer for ISS (MELFI), transported to the Space Station on STS-121. The freezer is used both to store samples and reagents on the station, and to transport them to and from the space station in a temperature controlled environment.

Currently installed at the main observation window of *Destiny* is the Agricultural Camera (AgCam). It is a multi-spectral imaging system built and primarily operated by students and faculty at the University of North Dakota. Its purpose is to take frequent images, in visible and infrared light, of vegetated areas on the Earth and promises to deliver a greater effectiveness for in-season agriculture applications research and operational decision support than current satellite systems such as Landsat.

## Chapter- 5

# Columbus

The Columbus Module on the International Space Station.




A cut-away illustration of the Columbus laboratory.


Hans Schlegel is working on outfitting *Columbus*.

***Columbus*** is a science laboratory that is part of the International Space Station (ISS) and is the largest single contribution to the ISS made by the European Space Agency (ESA).

Like the *Harmony* and *Tranquility* modules, the *Columbus* laboratory was constructed in Turin, Italy by Rome based Alcatel Alenia Space with respect to structures and thermal control. The functional architecture (including software) of the lab was designed by EADS in Germany where it was also integrated before being flown to the Kennedy Space Center (KSC) in Florida in an Airbus Beluga. It was launched aboard Space Shuttle *Atlantis* on February 7, 2008 on flight STS-122. It is designed for ten years of operation. The module is controlled by the Columbus Control Centre, located at the German Space Operations Centre, part of the German Aerospace Center in Oberpfaffenhofen near Munich, Germany.

The European Space Agency has spent €1.4 billion (about US$2 billion) on building *Columbus*, including the experiments that will fly in it and the ground control infrastructure necessary to operate them.

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## Description

The laboratory is a cylindrical module with two end cones. It is 4,477 mm (15 ft) in external diameter and 6,871 mm (23 ft) in overall length, excluding the projecting external experiment racks. Its shape is very similar to that of the Multi-Purpose Logistics Modules (MPLMs), since both were designed to fit in the cargo bay of a Space Shuttle orbiter. The starboard end cone contains most of the laboratory's on-board computers. The port end cone contains the Common Berthing Mechanism.

## Construction

ESA chose EADS Astrium Space Transportation as prime contractor for *Columbus*. The Columbus flight structure, the micro-meteorite protection system, the active and passive thermal control, the environmental control, the harness and all the related ground support equipment were designed and qualified by Alcatel Alenia Space in Turin, Italy as defined by the PICA - Principle; the related hardware was pre-integrated and sent as PICA in September 2001 to Bremen. The lab was then fully integrated and qualified on system level at the EADS Astrium Space Transportation facilities in Bremen, Germany.


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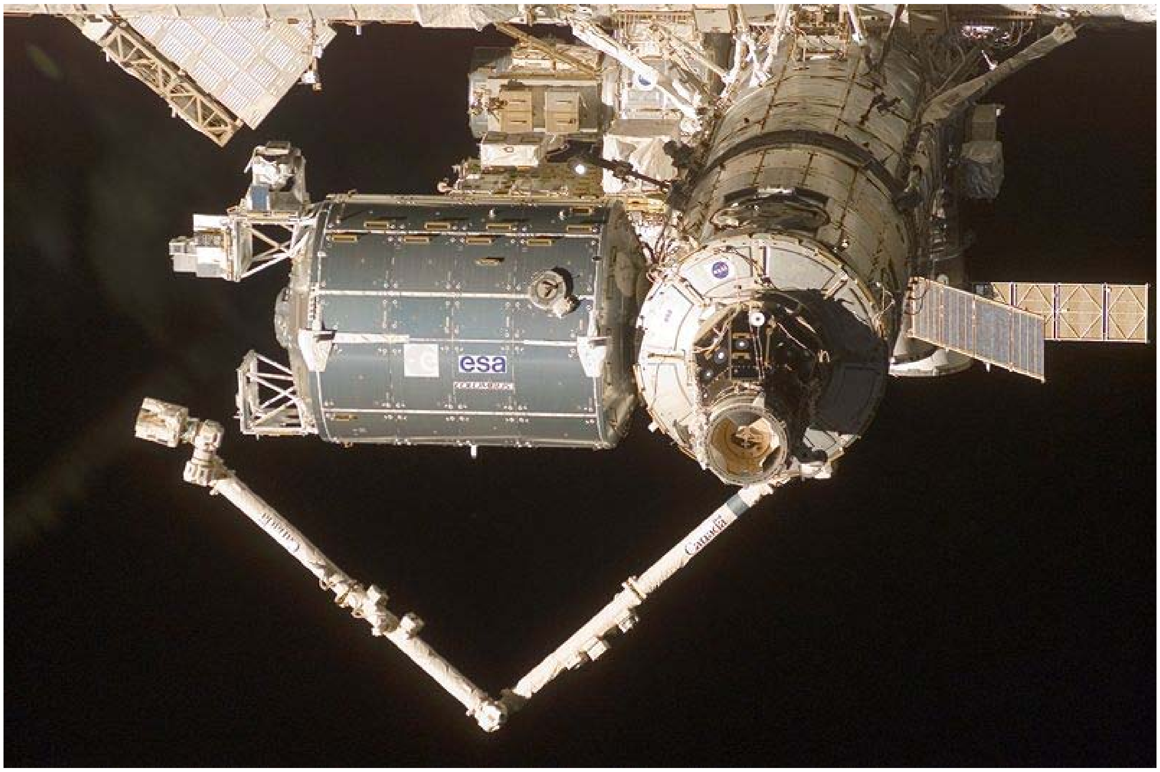
## Launch, berthing and outfitting


Columbus installed in *Atlantis's* payload bay in preparation for launch.


Columbus docked to the starboard side of Harmony.

In November 2007, *Columbus* was moved out of the KSC Space Station Processing Facility, and installed into the payload bay of the *Atlantis* orbiter for launch on ISS assembly flight 1E. During cryo-filling of the space shuttle External Tank (ET) with liquid hydrogen and liquid oxygen prior to the first launch attempt on December 6, 2007, two of four LH2 ECO sensors failed a test. Mission rules called for at least three of the four sensors to be in working order for a launch attempt to proceed. As a result of the failure, the Launch Director Doug Lyons postponed the launch, initially for 24 hours. This was later revised into a 72 hour delay, resulting in a next launch attempt set for Sunday December 9, 2007. This launch attempt was scrubbed when one of the ECO sensors again failed during fuelling.

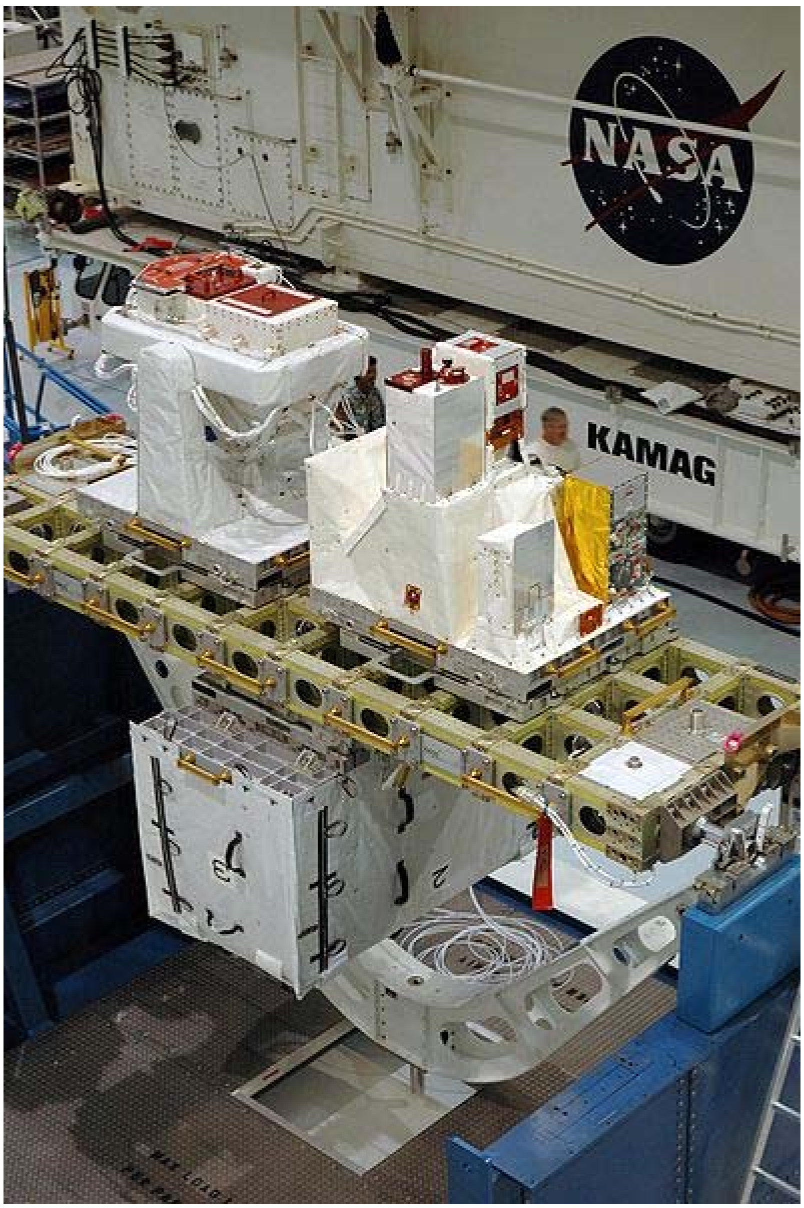
The ECO sensors external connector was changed on the space shuttle external tank, causing a two month delay in the launch. Columbus was finally launched successfully on the third attempt at 2:45pm EST, February 7, 2008. Once at the station, Canadarm2 removed Columbus from the docked shuttle's cargo bay and attached it to the starboard hatch of *Harmony* (also known as Node 2), with the cylinder pointing outwards on February 11, 2008.

## Research activities and payloads

Activities in the lab are controlled on the ground by the Columbus Control Centre (at DLR Oberpfaffenhofen in Germany) and by the associated User Support Operations Centres throughout Europe.

The laboratory can accommodate ten active International Standard Payload Racks (ISPRs) for science payloads. Agreements with NASA allocate to ESA 51% usage of the Columbus Laboratory. ESA is thus allocated five active rack locations, with the other five being allocated to NASA. Four active rack locations are on the forward side of the deck, four on the aft side, and two are in overhead locations. Three of the deck racks are filled with life support and cooling systems. The remaining deck rack and the two remaining overhead racks are storage racks.

In addition, four un-pressurized payload platforms can be attached outside the starboard cone, on the Columbus External Payload Facility (CEPF). Each external payload is mounted on an adaptor able to accommodate small instruments and experiments totalling up to 230 kilograms (507 lb).



External payloads SOLAR and EuTEF installed on LCC-lite cargo carrier prior to launch on shuttle mission STS-122.

The following European ISPRs have been initially installed inside Columbus:

1. Fluid Science Laboratory (FSL)
2. European Physiology Modules (EPM)
3. Biolab
4. European Drawer Rack (EDR)
5. European Storage Rack

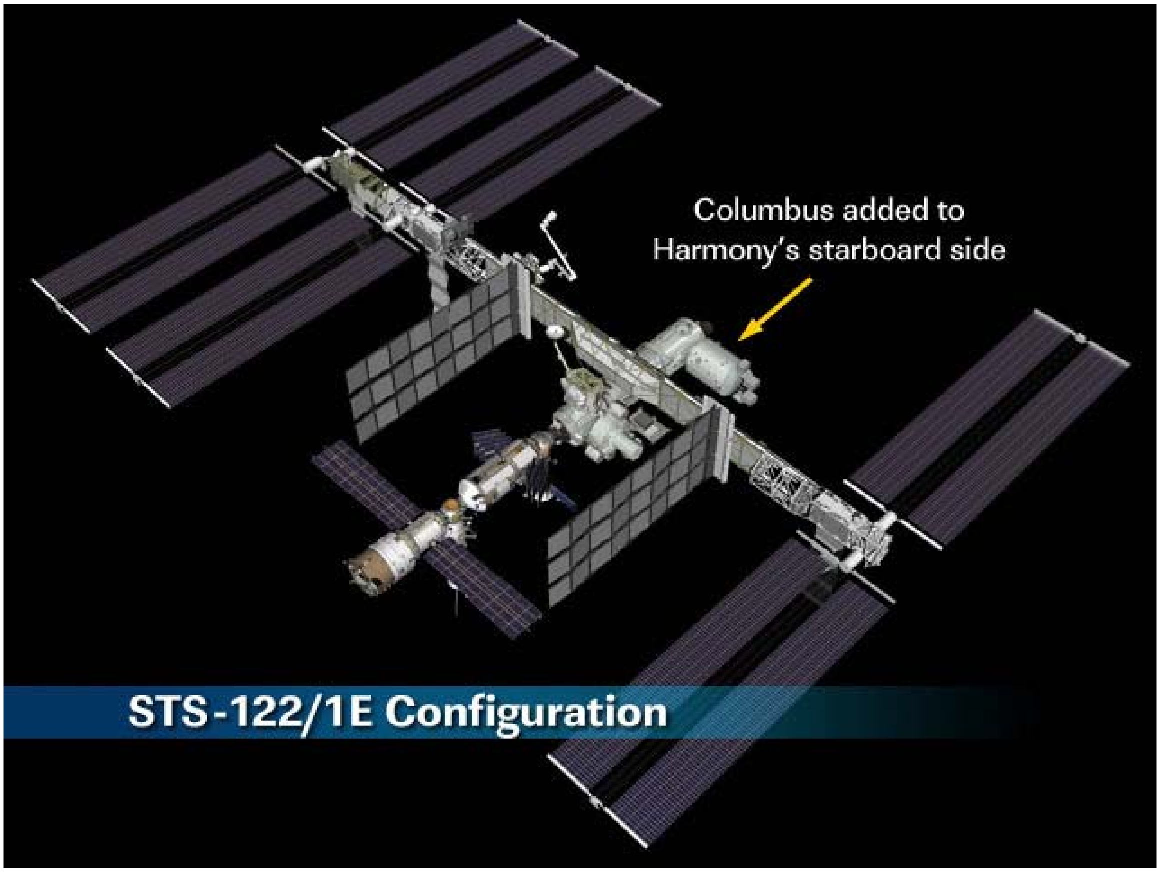
The first external payloads were mounted on Columbus by crew members of the mission STS-122 mission. The three payloads mounted are:

1. European Technology Exposure Facility (EuTEF) platform, which accommodates nine instruments: TRIBOLAB, PLEGPAY, MEDET, EUFIDE, DEBIE-2, FIPEX, EUTEMP, EXPOSE, DOSTEL, and the Earth Viewing Camera.
2. Solar Monitoring Observatory (SOLAR)
3. MISSE-6 (NASA payload)

Planned additional external payload:

1. Atomic Clock Ensemble in Space (ACES)
2. EXPORT
3. Atmosphere-Space Interaction Monitor (ASIM)

## History



Columbus's position on the ISS.

ESA's Board of Directors approved the Columbus program in 1985. From then on, numerous studies and proposals were made.

Like the MPLMs and the ATV resupply craft Columbus traces its origins to Spacelab.

Initially the Columbus program included three flight configurations: a *Man-tended Free-Flyer* (MTFF) element serviced by the Hermes shuttle and flying periodically to the station for maintenance and reconfiguration, an *Attached Pressurized Module* (APM), and a Polar Platform (*PPF*). For development cost saving and optimization of spares provisioning during the operational phase commonality was foreseen between the flight configurations and to the space station (e.g. same computers used for all three elements, video and comms units identical to station equipment).

When the complete phase C/D proposal (Fixed Price) was delivered end 1989 by the prime contractor MBB-ERNO it turned out that the costs were much higher than expected by ESA.

The Columbus logo.

After several budget cuts (and cancellation of the CNES-led Hermes program), all that remained in the Columbus program was the APM, renamed to Columbus Orbital Facility (Note: later it was renamed to just *Columbus* being the present formal name); the polar platform was contracted separately with commonality to the French satellite HELIOS.

When only the APM was left in the program there were not enough tasks for the two main contributors Germany and Italy represented by MBB-ERNO and Alenia respectively. As compromise the PICA (Pre Integrated Columbus APM) - Principle was invented meaning a split systems engineering responsibility where Alenia as a Co-prime is responsible for the overall Columbus configuration, the mechanical and thermal/life support systems, HFE and harness design/manufacturing whereas EADS Astrium Space Transportation is responsible for the overall Columbus design and all Avionics systems including electrical harness design and software.  Splitting off systems engineering responsibility and harness design under separate fixed-price contracts was found not to be advantageous with respect to efficiency and fast decision making as financial reasonings were pre-dominant in the last phase of development and verification.

Loading of Columbus at the Bremen airport into an Airbus Beluga.

On May 27, 2006 Columbus was flown from Bremen, Germany to Kennedy Space Center on board an Airbus Beluga.

The structure used is based on the MPLM module built for NASA by Thales Alenia Space. In 2000 the pre-integrated module (structure including harness and tubing) was delivered to Bremen in Germany by the Co-prime contractor Alenia. The final integration and system testing was performed by the overall prime contractor EADS Astrium Space Transportation, after that the initial Payload was integrated and the overall complement checked-out.

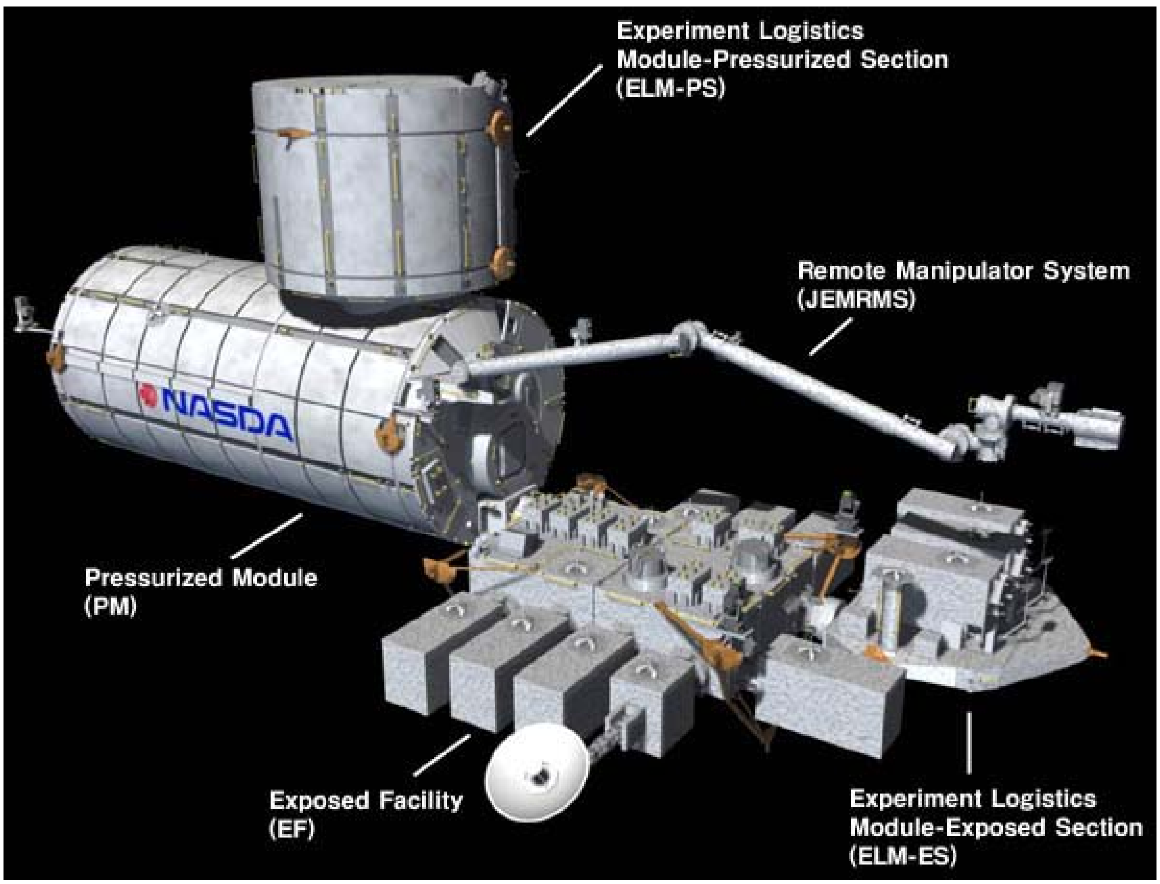
The final schedule was much longer than originally planned due to development problems (several caused by the complex responsibility splitting between the Co-prime and the Overall prime contractor) and design changes introduced by ESA but being affordable due to the Shuttle problems delaying the Columbus launch for several years. The main design change was the addition of the *External Payload Facility* (EPF), which was driven by the different European Payload organizations being more interested in outer space than internal experiments. Also the addition of a terminal for direct communications to/from ground, which could have been used also as back-up for the *ISS* system, was studied but not implemented for cost reasons.

## Specifications

- Length: 7 m (23 ft)
- Diameter: 4.5 m (15 ft)
- Total mass: 10,300 kg (22,708 lb)
- Total payload mass 2,500 kg (5,512 lb)
- Total on-orbit mass 12,800 kg (28,219 lb)

Chapter- 6

# Japanese Experiment Module



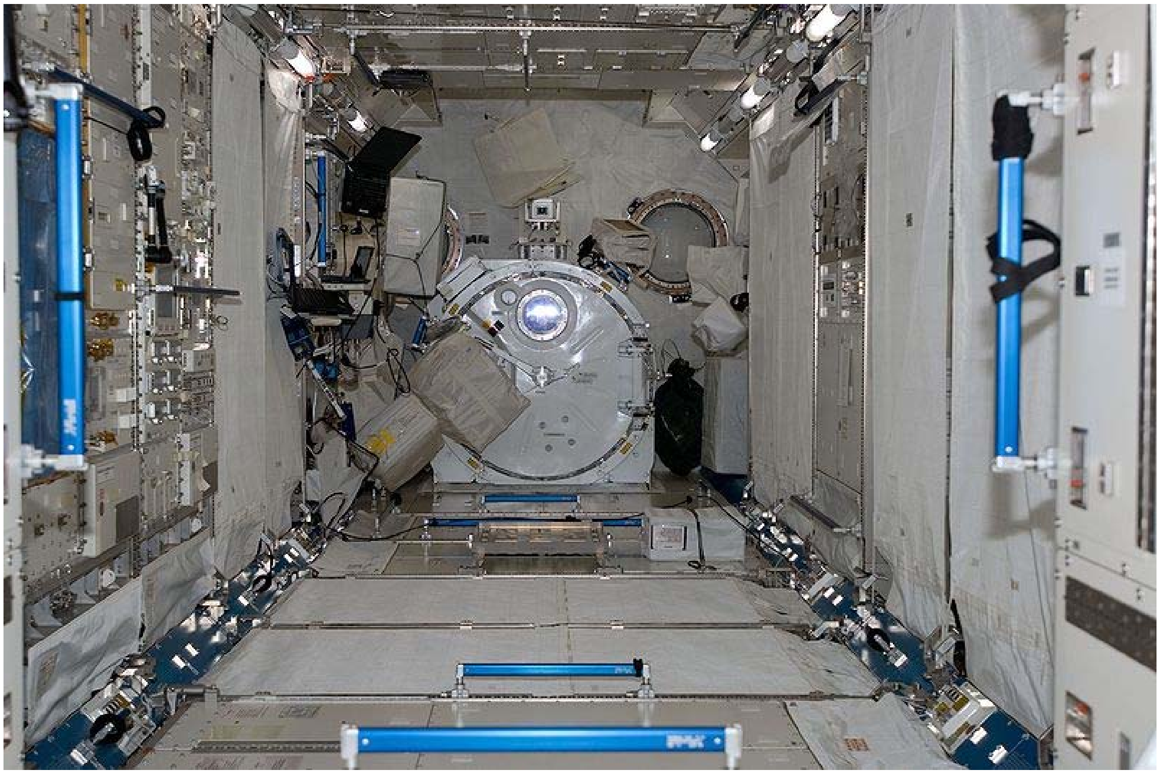

ISS JAXA JEM module

The **Japanese Experiment Module** (JEM), also known with the nickname **Kibo** (きぼう *Kibō*?, Hope), is a Japanese science module for the International Space Station (ISS) developed by JAXA. It is the largest single ISS module. The first two pieces of the module were launched on space shuttle missions STS-123 and STS-124. The third and final components were launched on STS-127.

## Components

*Kibō* consists of four primary components:

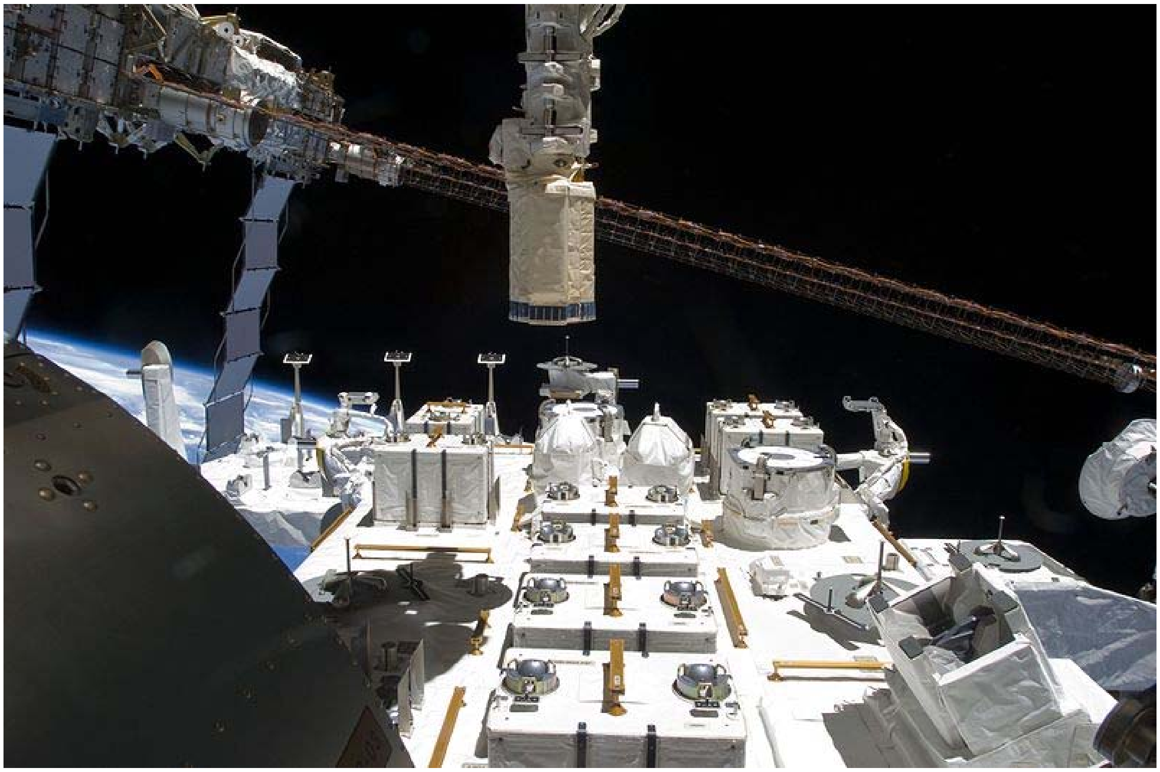
### Pressurized Module



The interior of the Pressurized Module.

The *Pressurized Module* (PM) is the core component connected to the port hatch of the Node 2 Module. It is a cylindrical shape and contains twenty-three International Standard Payload Racks (ISPRs), ten of which are dedicated to science experiments while the remaining 13 are dedicated to Kibo's systems and storage. The racks will be placed 6-6-6-5 among the four walls of the module. The end of the JEM-PM has an airlock and two window hatches. The three components: Exposed Facility, Experiment Logisitics Module and the Remote manipulator all connect to the pressurized module.

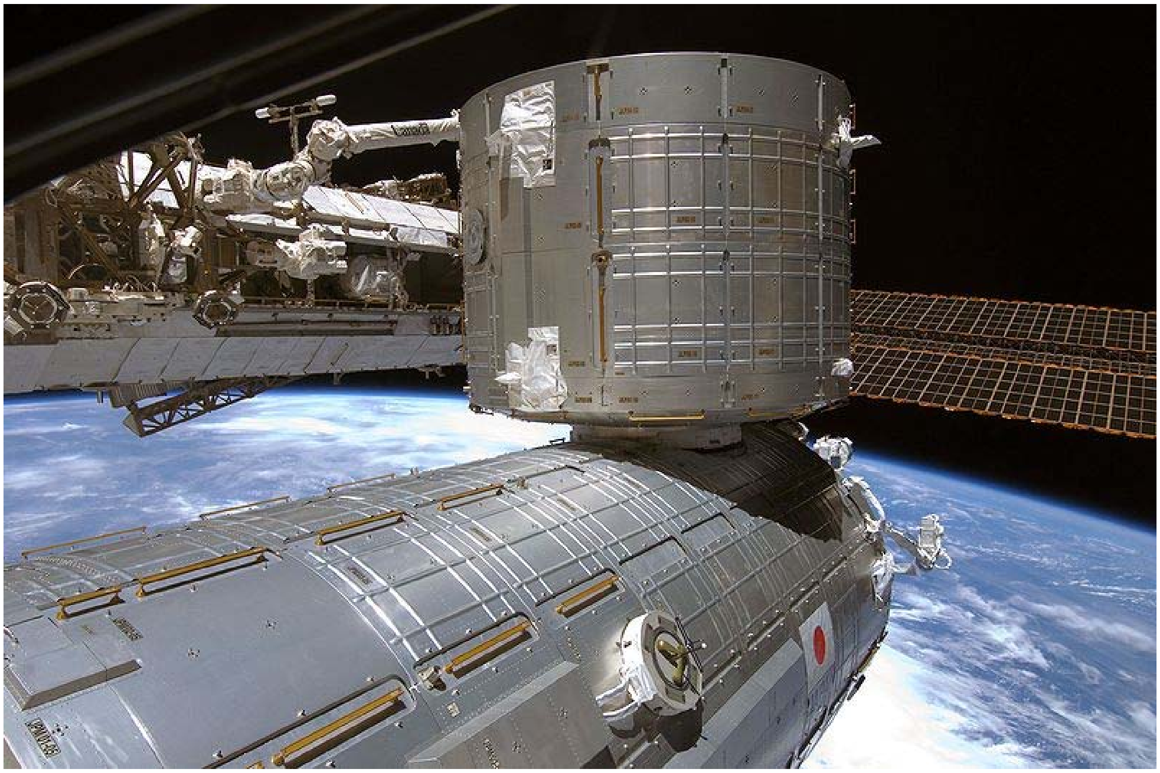
### Exposed Facility



The Exposed facility as seen from Kibo.

The *Exposed Facility* (EF), also known as "Terrace", is located outside the port cone of the PM (which is equipped with an airlocked hatch). The EF has 12 EFU (Exposed Facility Unit) Ports that attach to PIU (Payload Interface Unit) Connectors on EF-EEUs (EF-Equipment Exchange Units). All experiment payloads are fully exposed to the space environment. For Proper functioning of these experiments, the payload requires an ORU (Orbital Replacement Unit) which consists of the EPS (Electrical Power System), CT (Communications & Tracking) and the TCS (Thermal Control System). Of the 12 ORUs, 8 are replaceable by the JEMRMS while the other 4 are EVA replaceable.

## Experiment Logistics Module



The exterior of the Experiment Logistics Module, Pressurized Section (top) and the Pressurized Module (bottom).

The *Experiment Logistics Module* (ELM), is now on orbit and includes two sections:

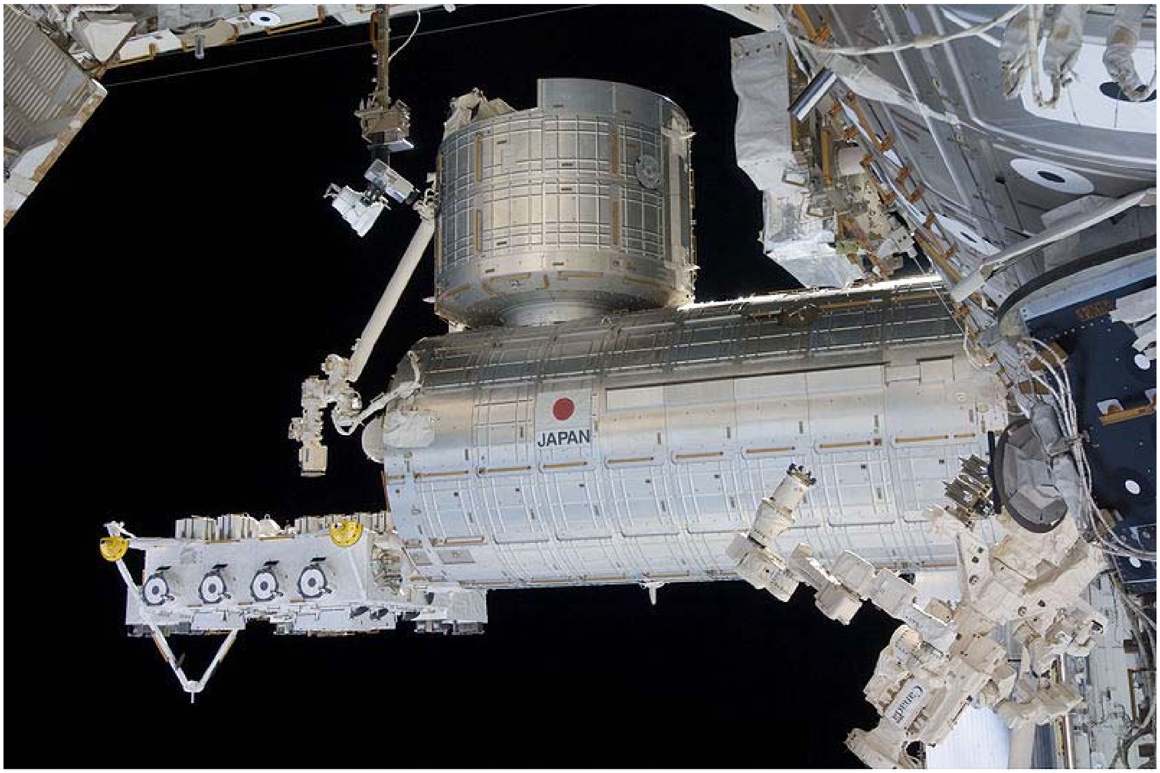
- The Japanese Experiment Logistics Module, Pressurized Section (ELM-PS) –- also called the JLP –- is a pressurized addition to the PM. The module is a storage facility that provides storage space for experiment payloads, samples and spare items.
- The unpressurized (external) section (ELM-ES) will serve the EF. It is intended as a storage and transportation module.

## Remote Manipulator System

Technicians work on the Remote Manipulator System in the Kennedy Space Center.

The *Remote Manipulator System* (JEMRMS) is a robotic arm, mounted at the port cone of the PM, intended to service the EF and to move equipment from and to ELM. The RMS control console was launched in the ELM-PS. The main arm was launched with the PM. The "Small Fine Arm", which attaches to the end effector of the main arm, was launched aboard HTV-1.

## Launch sequence




A view of the completed Kibo module.

NASA launched the JEM complex over three flights:

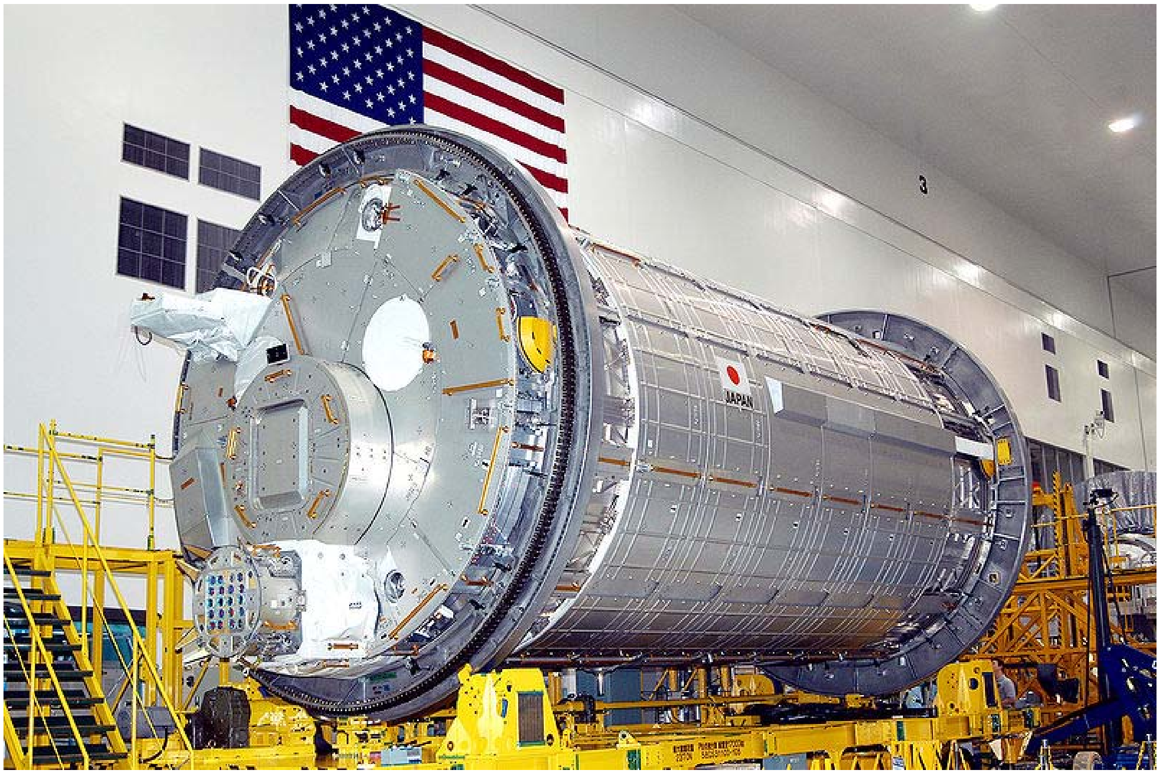
- On 12 March 2007 the *Experiment Logistics Module Pressurized Section* (ELM-PS) arrived in Kennedy Space Center (KSC) from Japan. It was stored in the Space Station Processing Facility until launched into orbit aboard Space Shuttle *Endeavour* as part of the STS-123 mission. At first the ELM-PS was connected to a temporary location into Harmony Module (Node 2) and later, on 6 June 2008, was moved to its final destination into the PM's upper section.
- On 30 May 2003 the *Pressurized Module* (PM) arrived in KSC from Japan. It was stored in the Space Station Processing Facility until launched into orbit aboard Space Shuttle *Discovery* as part of the STS-124 mission. On 3 June 2008 the PM was connected to the Harmony Module.

EF and ELM-ES arrive at KSC.

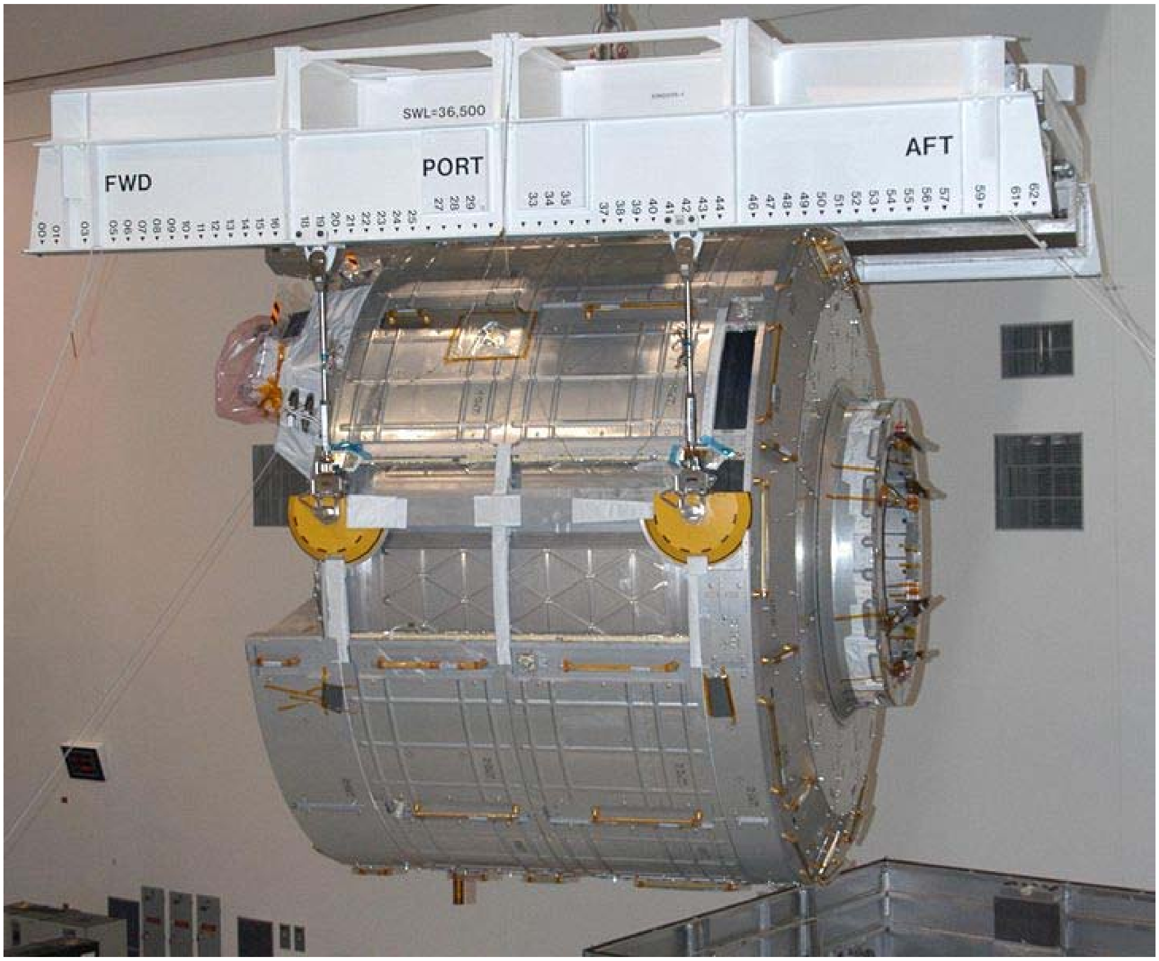
- The EF and ELM-ES arrived at KSC on 24 September 2008.

The *Exposed Facility* (EF) and ELM-ES were launched on STS-127, on 15 July 2009. The ELM-ES will be brought back to Earth at the end of the mission. The assembly of the EF was completed during the fifth spacewalk.

## Specifications



JEM PM module in assembly.



JEM ELM module in assembly.

Kibō is the largest single ISS module.

- *Pressurized Module*
    - Length: 11.19 m (36.7 ft)
    - Diameter: 4.39 m (14.4 ft)
    - Mass: 14,800 kg (32,600 lb)

- *Experiment Logistics Module*
    - Length: 4.21 m (13.8 ft)
    - Diameter: 4.39 m (14.4 ft)
    - Mass: 8,386 kg (18,488 lb)

# Current external experiments on Kibo

- **MAXI** X-ray astronomy from 0.5 to 30 keV
- **SMILES** observes and monitors very weak sub-millimeter wave emission lines of trace gas molecules in the stratosphere

- **SEDA-AP** (Space Environment Data Acquisition equipment-Attached Payload) measures neutrons, plasma, heavy ions, and high-energy light particles in ISS orbit.
- **HREP** (Hyperspectral Imager for the Coastal Ocean (HICO) & Remote Atmospheric & Ionospheric Detection System (RAIDS) Experimental Payload)

## Planned external experiments on Kibo

- **CALET** Observation for high energy. Launch 2012 through H-II Transfer Vehicle, Mass: 2500 kg

## Current internal experiments on Kibo

Japanese:

- **RYUTAI Rack** Fluid Physics Experiment Facility (FPEF), Solution Crystallization Observation Facility (SCOF), Protein Crystallization Research Facility (PCRF), Image Processing Unit (IPU)
- **SAIBO Rack** Cell Biology Experiment Facility (CBEF), Clean Bench (CB)

American:

- **EXPRESS Rack 4** Biotechnology Specimen Temperature Controller (BSTC), Gas Supply Module (GSM), Space Acceleration Measurement System-II (SAMS-II), Biotechnology Specimen Temperature Controller (BSTC)
- **EXPRESS Rack 5**
- **MELFI-1**

## Planned internal experiments on Kibo

- **KOBAIRO Rack** Gradient Heating Furnace (GHF)
- **MPSR** Multi-Purpose Small payload Rack

## Chapter- 7

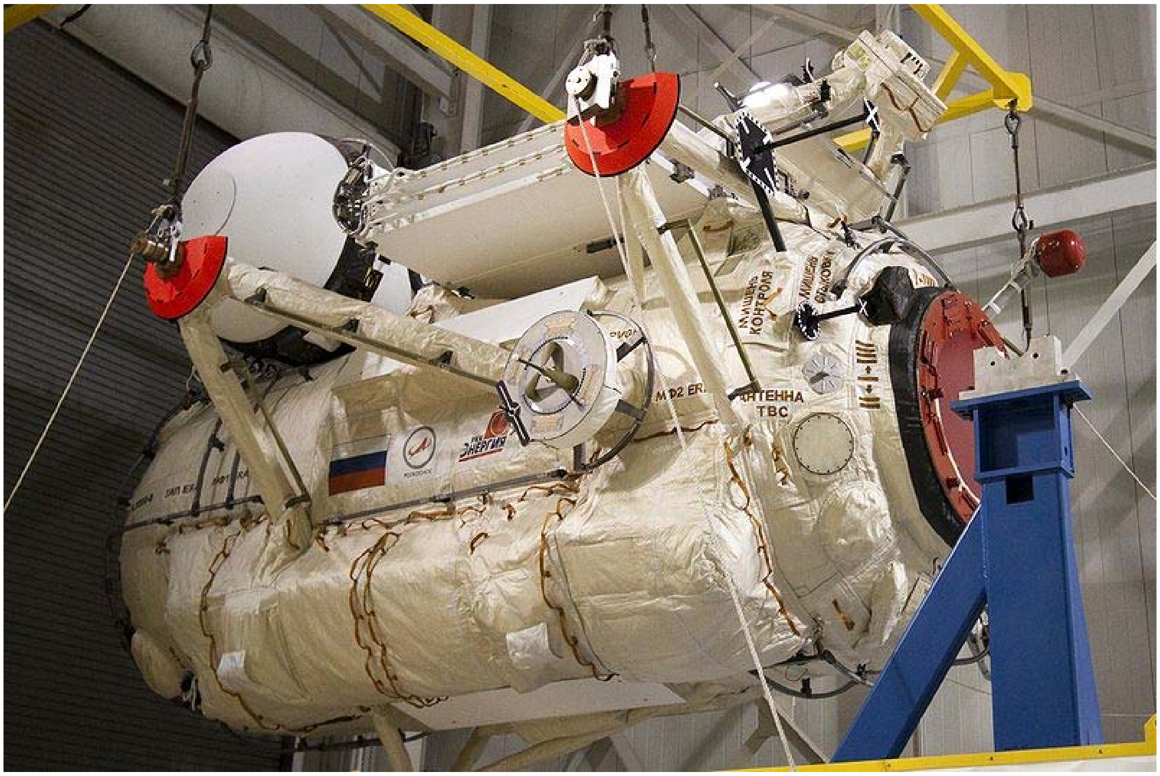
# Rassvet

MRM1 Rassvet as seen from the Cupola module during STS-132.

***Rassvet*** (Russian: Рассве́т; lit. "dawn"), also known as the **Mini-Research Module 1** (**MRM 1**) (Russian: Малый исследовательский модуль, МИМ 1) and formerly known as the **Docking Cargo Module** (**DCM**), is a component of the International Space Station (ISS). *Rassvet* will be primarily used for cargo storage and as a docking port for visiting spacecraft. It was flown to the ISS on STS-132 aboard Space Shuttle *Atlantis* on May 14, 2010, and was connected to the ISS on May 18. The hatch connecting Rassvet with the ISS was opened on May 20.

On 28 June 2010 the Soyuz TMA-19 spacecraft performed the first docking with the module.

## Details



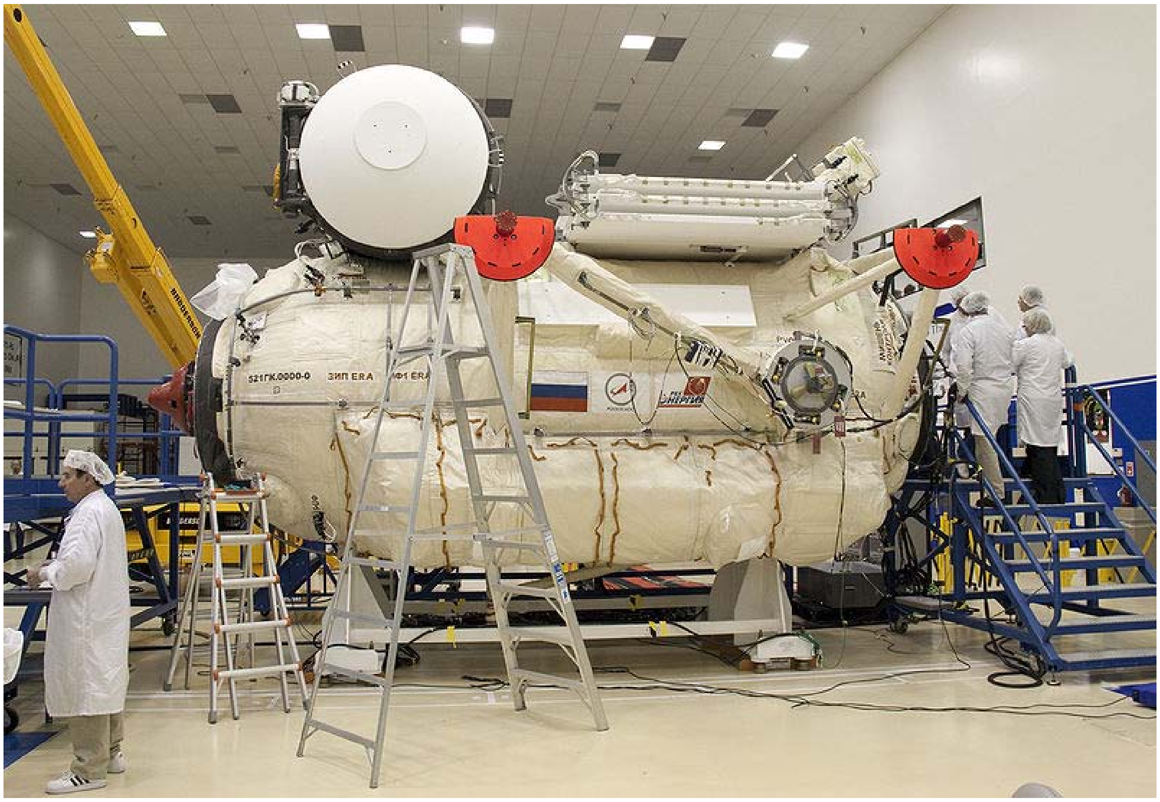
Rassvet in the Space Station Processing Facility (SSPF) at Kennedy Space Center in Florida

*Rassvet* was docked to the nadir port of *Zarya* with help from the SSRMS. *Rassvet* carried externally attached outfitting equipment from NASA for the *Nauka* Multipurpose Laboratory Module (MLM), a spare elbow joint for the European Robotic Arm, and a radiator. Delivering *Rassvet* thus enabled NASA to fulfill its promise to ship 1.4 metric tons to equip the MLM.

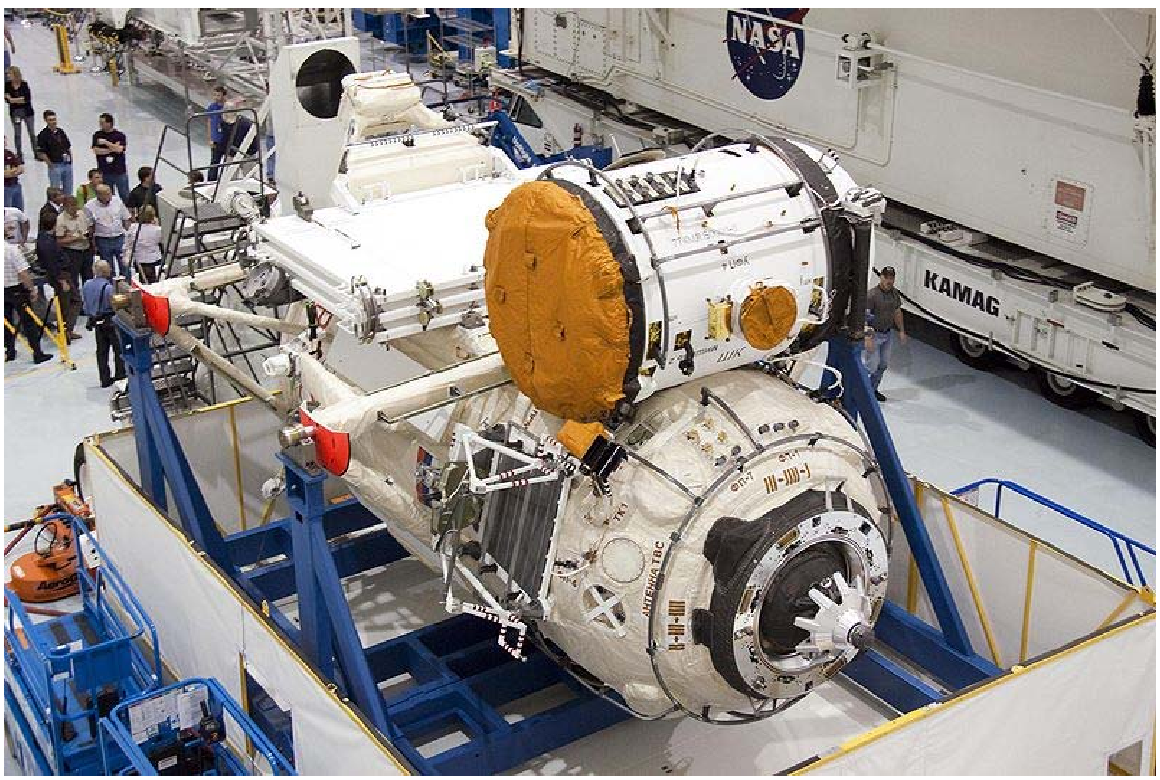
*Rassvet* has two docking units: one to attach to the nadir port of the *Zarya* module, and one to provide a docking port for a Soyuz or Progress spacecraft. It implements the role of the Docking and Stowage Module from the original ISS design. Russia announced the cancellation of the last of the two planned Russian Research Modules when it announced the plans for *Rassvet*.

## Initial planning

In the initial ISS plan there was a **Docking and Stowage Module (DSM)**. This module was a planned Russian element of the International Space Station that was intended to provide facilities for stowage and an additional docking port. The **Docking and Stowage Module** would have been used for additional stowage and to support Soyuz docking, and would have been launched to the International Space Station on a Proton launch vehicle. The DSM would have been mounted to Zarya's nadir (Earth-facing) docking port. It was similar in size and shape to the Zarya module.



MRM1 at the Astrotech Facility.




This ISS module was canceled due to budget constraints by Russia for some time, but according to the current schedule the design of the module is modified into the **Docking and Cargo Module** (MRM 1 *Rassvet*) that will connect to the same *Zarya* location and will provide stowage space and docking port. During the cancellation period it was a proposal that a **Multi Purpose Module (MPM)** called *Enterprise* should be docked at its location and afterwards the **Multipurpose Laboratory Module** was expected to be located there, but according to current plans *Enterprise* is not approved and MLM will be docked to *Zvezda's* nadir port instead.

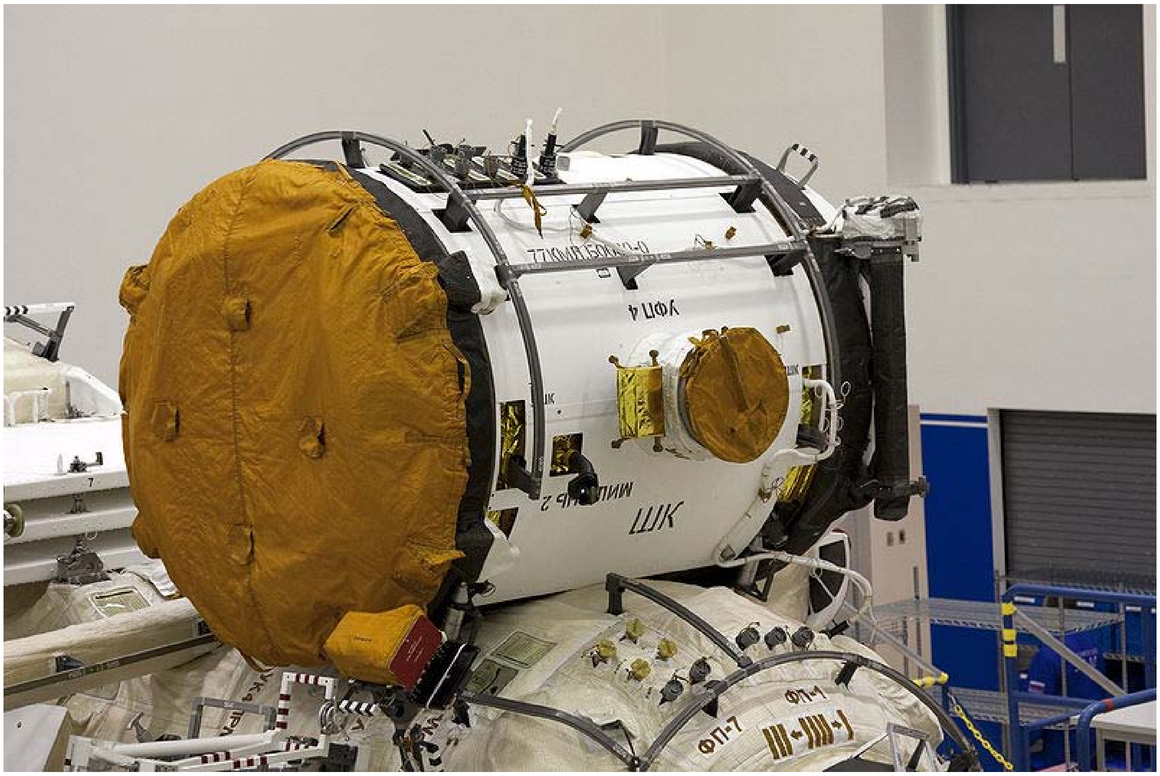
## Benefits

*Rassvet* came to exist out of two requirements that needed to be fulfilled by the ISS partners:

1. NASA is under contract to carry the MLM outfitting equipment into space.
2. The overlapping missions of the Progress, Soyuz, and ATV spacecraft highlight the need of having four Russian docking ports available on the ISS. The cancellation of both Russian Research Modules meant that the ISS would be left with just three such docking ports after the installation of the Pressurized Multipurpose Module, which makes the nadir port of *Zarya* unusable.

The new MRM solves both of these issues. NASA will not need to add another payload flight to accommodate the MLM outfitting equipment, as it can attach the hardware to the exterior of MRM 1; the ISS will have 4 docking ports available (the aft port of *Zvezda*, the port of *Pirs* (later MLM) on the nadir port of *Zvezda*, the port of MRM 2 on the zenith port of *Zvezda*, and the port on MRM 1 on the nadir port of *Zarya*); and Russia's cancellation of the Research Module is of less consequence for the ISS program as a whole.

# Design and construction



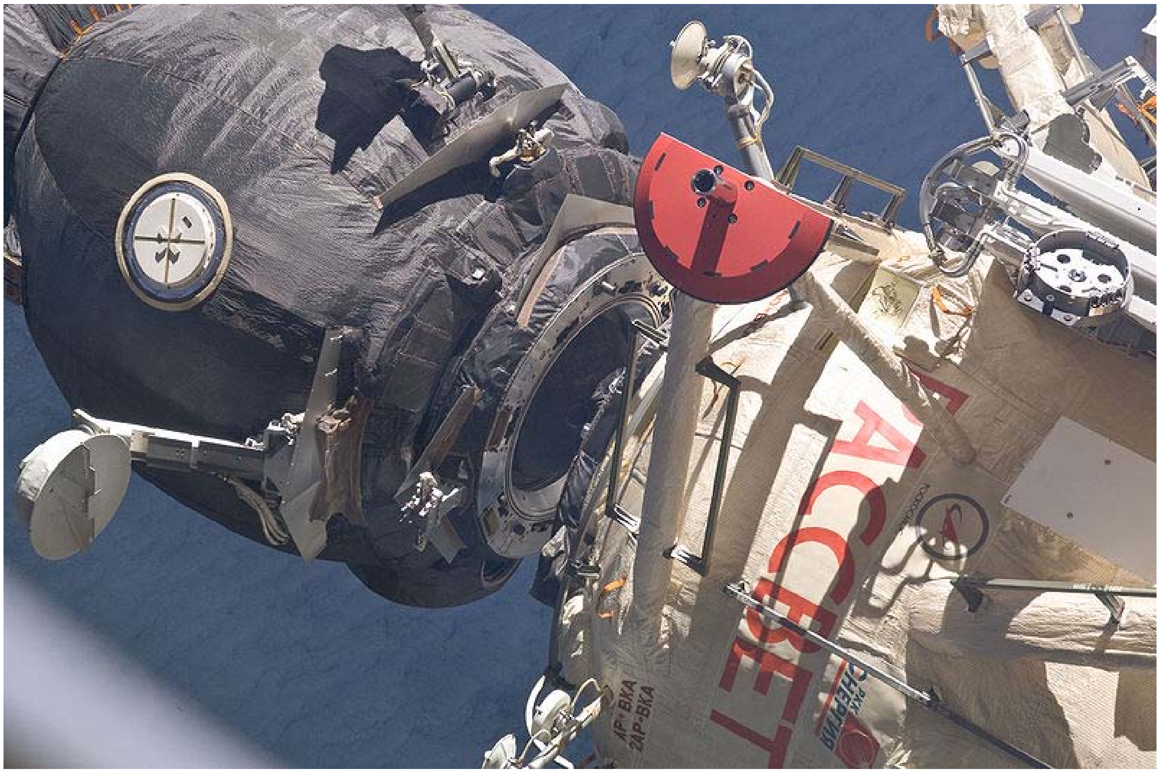

The Experiment Airlock of the Rassvet module.

The module was designed and built by S.P. Korolev RSC Energia, from the already-made pressurized hull of the mock-up for dynamic tests of the canceled Science Power Platform .

On December 17, 2009 airplane AN-124 carrying the *Rassvet* Module and ground process equipment kit arrived at the Kennedy Space Center . Upon unloading, the equipment was delivered to prelaunch processing facility run by the Astrotech. Energia specialists and technicians continued their work at the SPPF facility of the Astrotech on the processing of the *Rassvet* Module and completed stand-alone electrical tests and leak tests of the module and the airlock. They also prepared the airlock and the radiative heat exchanger for installation onto Rassvet. The module was moved to NASA's Space Station Processing Facility on April 2, 2010. After completing the final touches, it was placed into the shuttle payload transporter on April 5, 2010. The payload canister containing the *Rassvet* Module arrived at Launch Pad 39A on April 15, 2010.

Engineers at Launch Pad 39A preparing space shuttle *Atlantis* had noticed paint peeling from the MRM 1 module. Although the problem was declared to have no impact on the operation of MRM 1, it holds a potential threat of releasing debris on orbit.

## Basic specifications



The Soyuz TMA-19 spacecraft docks to the Rassvet Mini-Research Module 1.

MRM 1 basic specifications:

| | |
|---|---|
| Module launch mass | 5075 kg |
| Total Launch mass | 8015 kg |
| Maximum hull diameter | 2.35 m |
| Hull length between docking assembly planes | 6 m |
| Pressurized volume | 17.4 $m^3$ |
| Habitable volume | 5.85 $m^3$ |

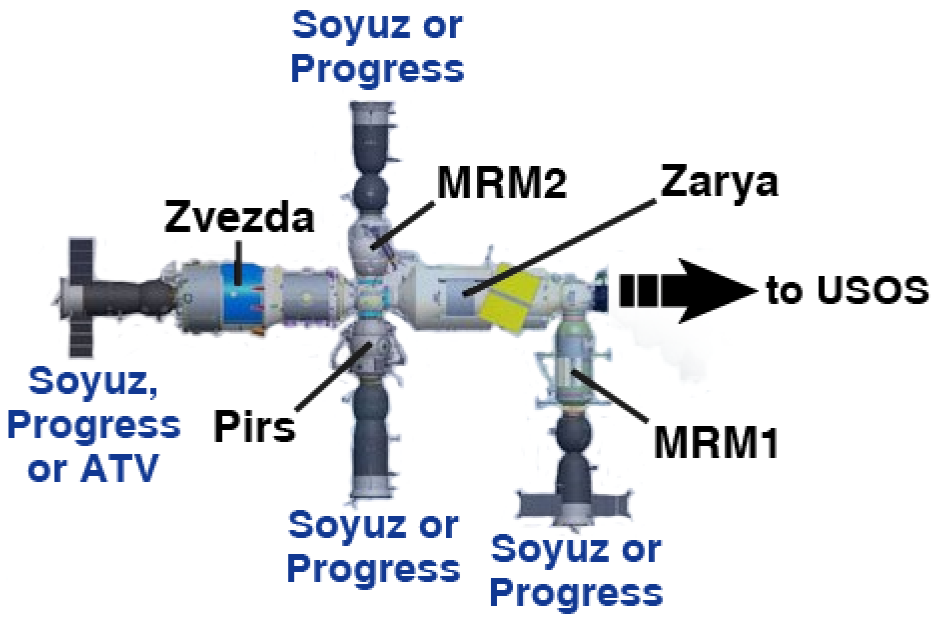
Chapter- 8

# Poisk

*Poisk* docking module at the Space Station.

**Poisk** (Russian: По́иск; lit. *Search*), also known as the **Mini-Research Module 2** (**MRM 2**), *Малый исследовательский модуль 2*, or *МИМ 2*, is a docking module of the International Space Station. Its original name was **Docking Module 2** (*Stykovochniy Otsek 2* (SO-2)), as it is almost identical to the Pirs Docking Compartment. *Poisk* was the first major Russian addition to the International Space Station since 2001.

## Details




The location of MRM-2 on the Russian Orbital Segment.

*Poisk* arrives at the ISS for docking in 2009.

*Poisk* docked to the zenith port of the *Zvezda* module on November 12, 2009, and will serve as an additional docking port for Soyuz and Progress spacecraft and as an airlock for spacewalks. *Poisk* will also provide extra space for scientific experiments, and provide power-supply outlets and data-transmission interfaces for two external scientific payloads to be developed by the Russian Academy of Sciences.

Two spacewalks conducted from the ISS in June 2009, successfully completed activities anticipating *Poisk* module's future berthing.

On 5 June 2009, during Russian Orlan EVA-22 spacewalk Expedition 19/20 Commander Gennady Padalka and Flight Engineer Michael Barratt installed two Kurs docking antennas, a docking target and electrical connectors on the exterior of Zvezda's Service Module.

On June 10, 2009, during Russian Orlan EVA-23 spacewalk Padalka and Barratt replaced a flat hatch cover in the forward section of *Zvezda* with a standard conical docking cone cover to allow for Poisk's docking.

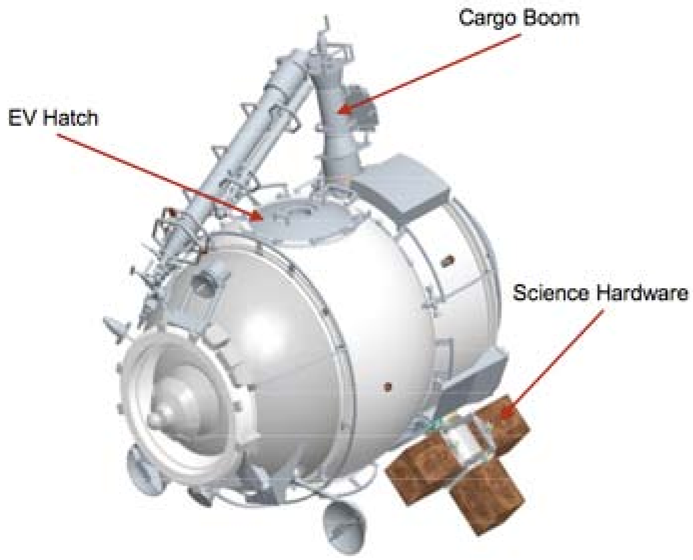



Diagram of the *Poisk* docking module

Astronaut Jeffrey Williams and cosmonaut Maksim Suraev inspecting the *Poisk* module

*Poisk* approaching the ISS for docking

On January 14, 2010, cosmonauts Oleg Kotov and Maksim Suraev conducted a spacewalk to outfit the *Poisk* module to prepare for receiving Soyuz and Progress ships in the future . They deployed antennas and a docking target, installed two handrails and plugged the new module's Kurs antennas into the Kurs docking system circuitry . The spacewalk lasted five hours and 44 minutes.

On January 21, 2010, the module was first used when cosmonaut Suraev and Expedition 22 Commander Jefferey Williams relocated their Soyuz TMA-16 spacecraft from the aft port of the *Zvezda* module to the zenith-facing port of the *Poisk* module . The Soyuz TMA-16 spacecraft undocked from the aft end of the *Zvezda* service module at 10:03 UTC and backed away to a distance of about 100 feet from the space station. Undocking occurred as the station flew about 213 miles high off the southwest coast of Africa. Re-docking occurred at 10:24 UTC after Suraev fired the *Soyuz* maneuvering thrusters to fly halfway around the orbiting space station and line up with the *Poisk* module.

## Design and construction

The module was designed and built by S.P. Korolev RSC Energia , the leading organization engaged in the development and operational use of the ISS Russian segment.

## Launch in 2009

The propulsion compartment of the *Poisk* module departs the Space Station.

The module was launched on November 10, 2009, 2:22 p.m. GMT attached to a modified Progress spacecraft, called Progress M-MIM2, on a Soyuz-U rocket from Launch Pad 1 at the Baikonur Cosmodrome in Kazakhstan. The occasion also marked the 1750th launch of a Soyuz rocket in its various configurations. About eight minutes after launch, the three-stage Soyuz rocket delivered *Poisk*, to a low-altitude injection orbit. According to NASA *Poisk* carried about 1800 pounds of cargo to the ISS including new Russian Orlan spacesuits, life support equipment, medical supplies and crew hygiene items.

The Progress space tug provided electrical power and propulsion for the *Poisk* module during its two-day journey to the space station. On 12 November, Progress began its automated final approach to the station on a Kurs rendezvous radar system and at 15:41 UTC *Poisk* docked to the *Zvezda* module's zenith port. The docking happened as the space station sailed more than 220 miles over northern Kazakhstan.

Cosmonauts Maksim Suraev and Roman Romanenko entered the module for the first time by opening the hatch leading into *Poisk* at 12:17 UTC on 13 November 2009.

The jettisoning of the Progress ship from the *Poisk* module happened around 8 December 2009. The Progress was destroyed during re-entry into the atmosphere.

## Specifications


*Poisk* after arriving at the Space Station on November 12, 2009.

| | |
|---|---|
| Designation | 240GK No. 2L |
| Launch mass | 3670 kg ± 50 kg |
| Maximum hull diameter | 2.55 m |
| Hull length between docking assembly planes | 4.049 m |
| Pressurized volume | 14.8 $m^3$ |
| Habitable volume | 10.7 $m^3$ |
| Number of egress hatches (open inward) | 2 |
| Egress hatch diameter | 1 m |
| Mass of delivered cargoes | up to 1000 kg |

## False depressurization alarm

False alarms woke the crews aboard space shuttle *Atlantis* and the Space Station at 01:36 UTC on 20 November 2009 and once again at 02:53 UTC on 21 November. An erroneous indication of a rapid depressurization led to the automatic shutdown of ventilation fans throughout the station, which stirred up dust and led to a false smoke detection alarm in the European Space Agency's Columbus laboratory. Mission control Capcom Frank Lien in Houston told Expedition 21 Commander Frank De Winne it might have originated with the *Poisk* module.

## Visited spacecraft

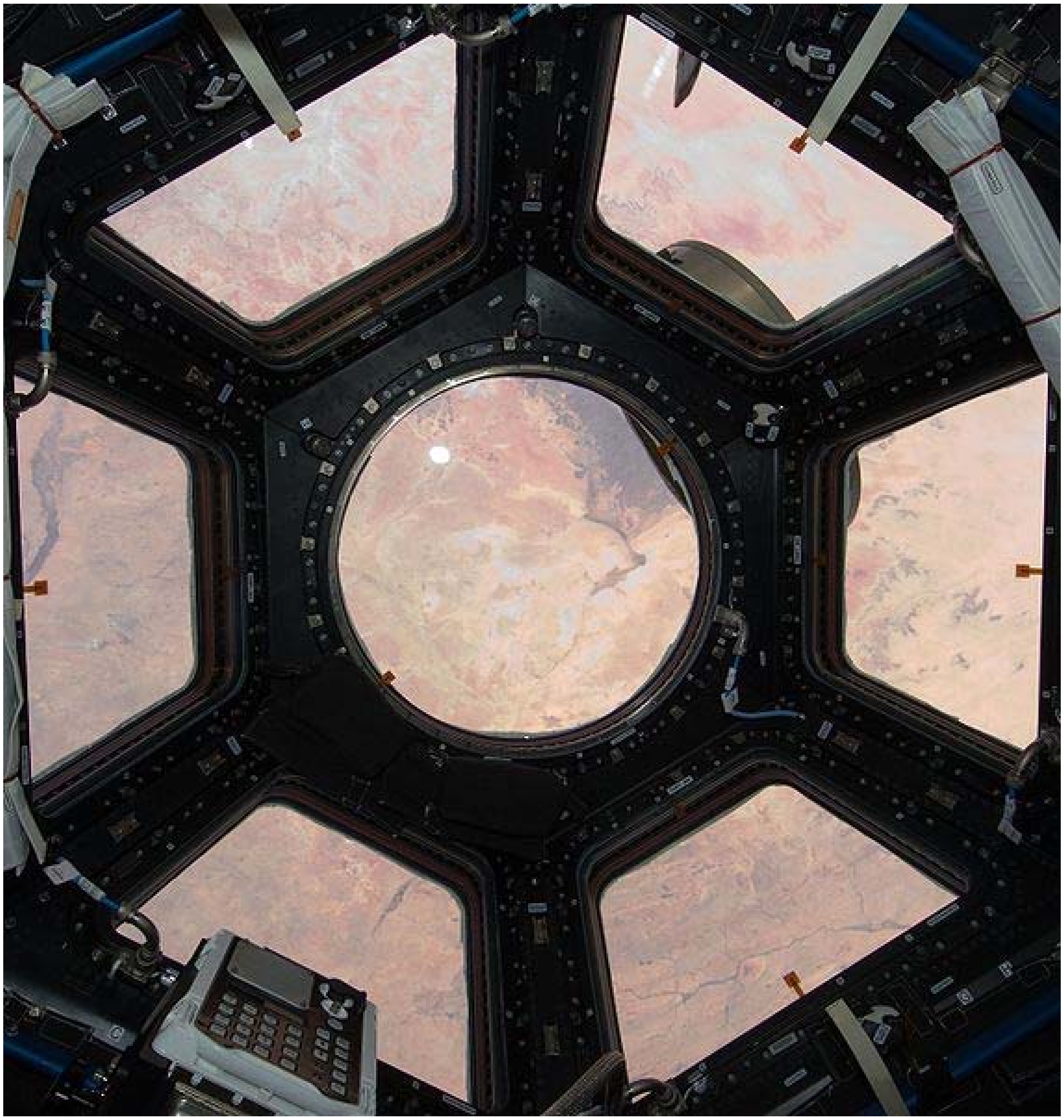
The following Table shows the spacecraft that have linked up with the Poisk Module

| Spacecraft | Docking | Undocking |
|---|---|---|
| Soyuz TMA-16 | January 21, 2010<br>5:24 a.m. EST | March 18, 2010<br>8:03 UTC |
| Soyuz TMA-18 | April 4, 2010<br>5:25 UTC | September 25, 2010<br>02:02 UTC |
| Soyuz TMA-01M | October 10, 2010<br>00:01 UTC | March 16, 2011<br>Planned |

# Chapter- 9

# Cupola

Tracy Caldwell Dyson in the Cupola module of the International Space Station observing the Earth below.



The Sahara desert viewed through the Cupola with its shutters open.

The **Cupola** is an ESA-built observatory module of the International Space Station (ISS). Its seven windows are used to conduct experiments, dockings and observations of Earth. It was launched aboard Space Shuttle mission STS-130 on 8 February 2010 and attached to the *Tranquility* (Node 3) module. With the Cupola attached, ISS assembly reached 85 percent completeness. The Cupola is the largest window ever used in space.

## Overview

External view of the Cupola with window shutters open.

The Cupola provides an observation and work area for the ISS crew giving visibility to support the control of the space station remote manipulator system and general external viewing of Earth, celestial objects and visiting vehicles. Its name derives from Italian word *cupola*, which means "dome". The Cupola project was started by NASA and Boeing, but canceled due to budget cuts. A barter agreement between NASA and the ESA resulted in the Cupola's development being resumed in 1998 by the ESA. It is extremely important to the ISS astronauts , as previously they have been confined to looking out of small portholes or at best the 20-inch (50 cm) window in the US *Destiny* laboratory. The Cupola is berthed onto the down-facing port of Node 3—the final of three modules, including Node 1 and Node 2.

## Design and construction


Doug Wheelock in the Cupola.

The International Space Station Cupola was first conceived in 1987 by Space Station Man-Systems Architectural Control Manager Gary Kitmacher as a workstation for operating the station's robotic arm, maneuvering vehicles outside of the station, and observing and supporting spacewalks. He likened the use as similar to that of the Shuttle Orbiter Aft Flight Deck. There were to have been 2 Cupolas, one on either end of the racetrack shape formed by the station modules and nodes. It was initially named the "windowed workstation", to discriminate it from other computer-based workstations inside of the station and from which the crew could operate the station's systems. Once the idea was initially accepted, a number of people went to work. Human factors specialist Frances Mount began to develop the rationale and operational scenarios for the Cupola, and got considerable support from Chief Astronaut John Young and Shuttle Commander Gordon Fullerton. Charles Wheelwright, who had defined the specifications for every window on every prior US manned spacecraft, began to define the design specs of the Cupola windows. Laurie Weaver, who had just started with NASA as a co-op, began to work on a series of different configurations for the Cupola. She started with Kitmacher's idea based on the Shuttle Aft Flight Deck, in this case two Aft Flight Decks mounted back to back, placed atop a short cylinder. An inexpensive mock-up made of PVC tubes was built and tested underwater where critical dimensions could be measured to ensure that two crew members in zero-g would have adequate access. Then she built a series of small cardboard models, looking at a variety of different alternative shapes. The different configurations and their positive and negative attributes were presented at a series of Crew Station Reviews over the next year in which participants rated each. The Cupola that evolved was octagonal in shape, with eight similar windows around the periphery, four quadrant windows overhead, and mounted on a cylinder. The module was designed to fully contain at least two crewmembers ‘floating’ side by side in zero-g neutral body posture. About this time, Kitmacher and Designer Jay Cory applied the term Cupola for the first time. Kitmacher wrote the requirements and the name into the Man-Systems Architectural Control Document and into the RFPs for Work Package 1 at MSFC and Work Package 2 at JSC. Later Kitmacher went on to lead the Man-Systems group leading the first lunar outpost and moonbase studies and the Cupola reappeared on several of his rover and module designs.

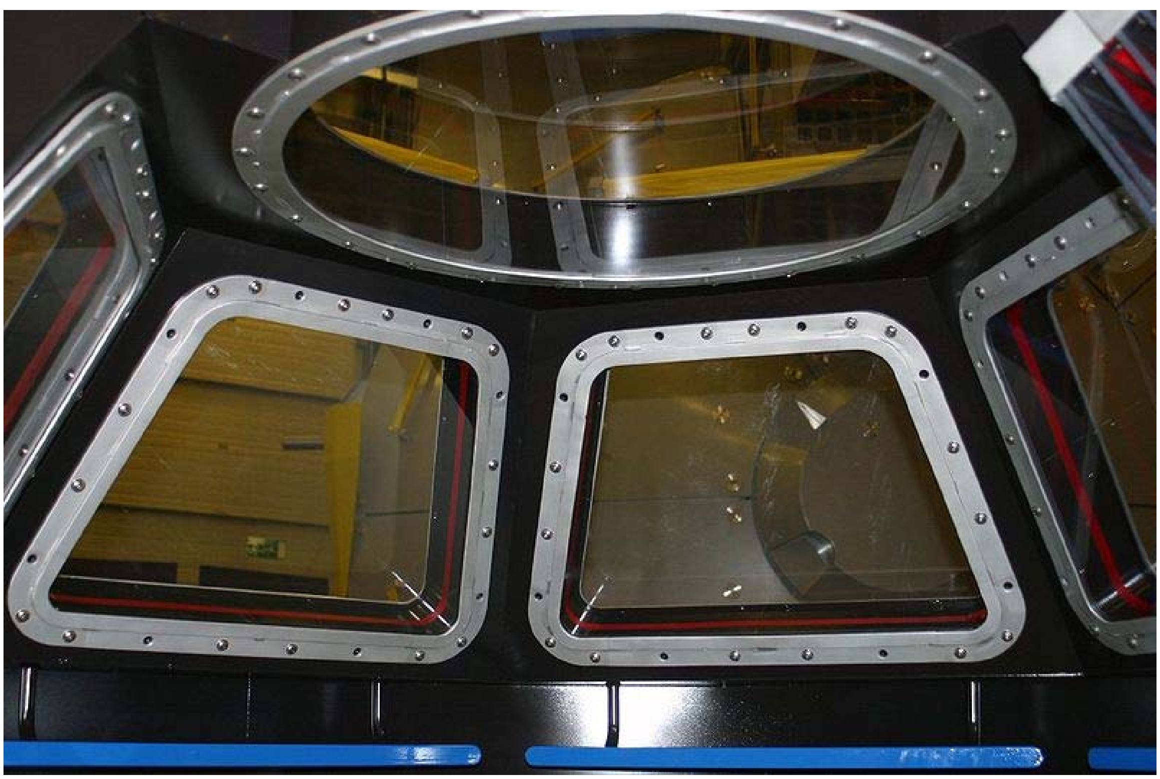
Cupola being aligned...

Cupola getting mated...

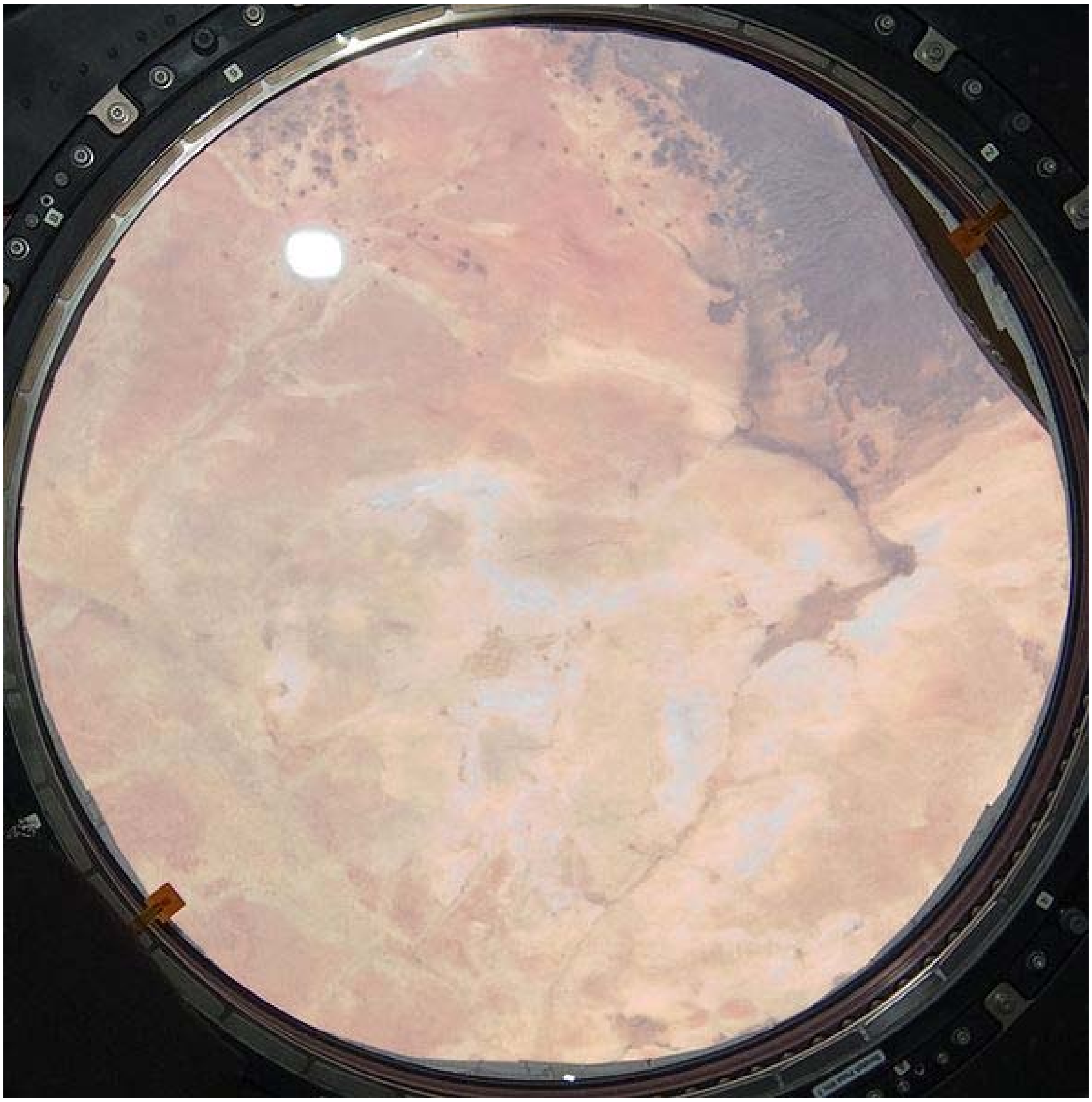

Cupola-artists rende...

Cupola-close-up-iss0...

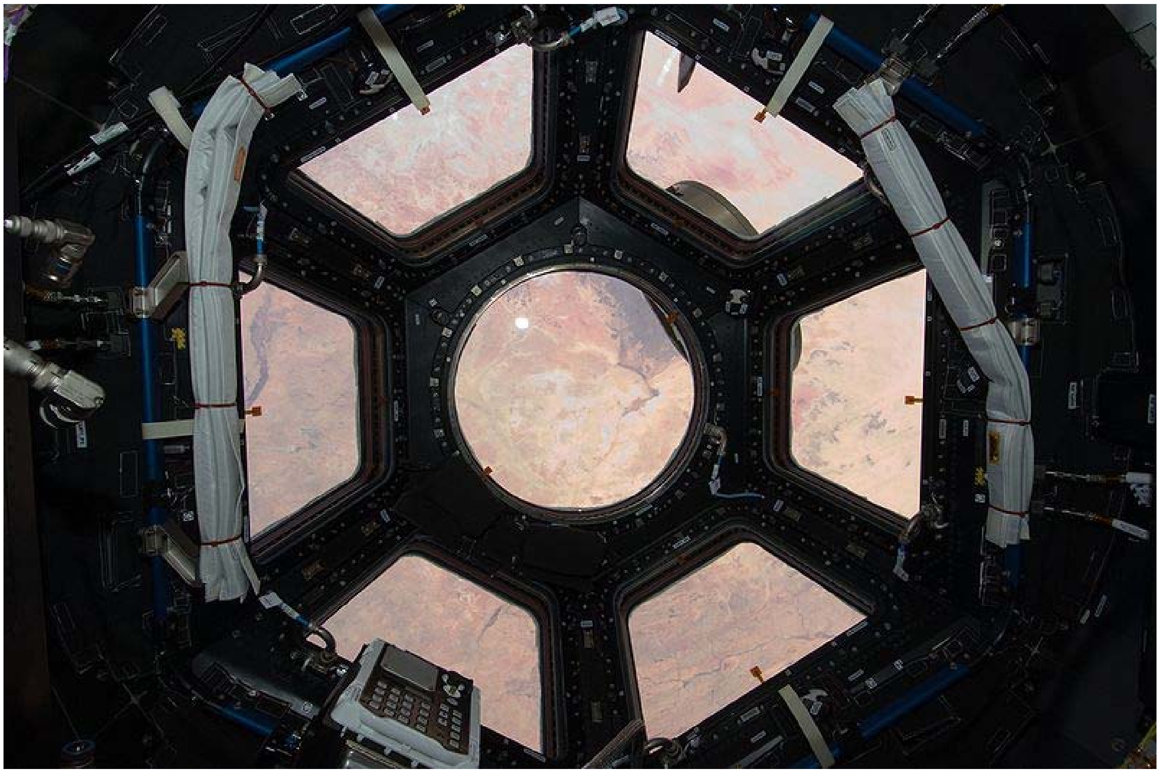
Canadarm2 Cupola Rel...



Copola-innen



Cupola ISS open shut...

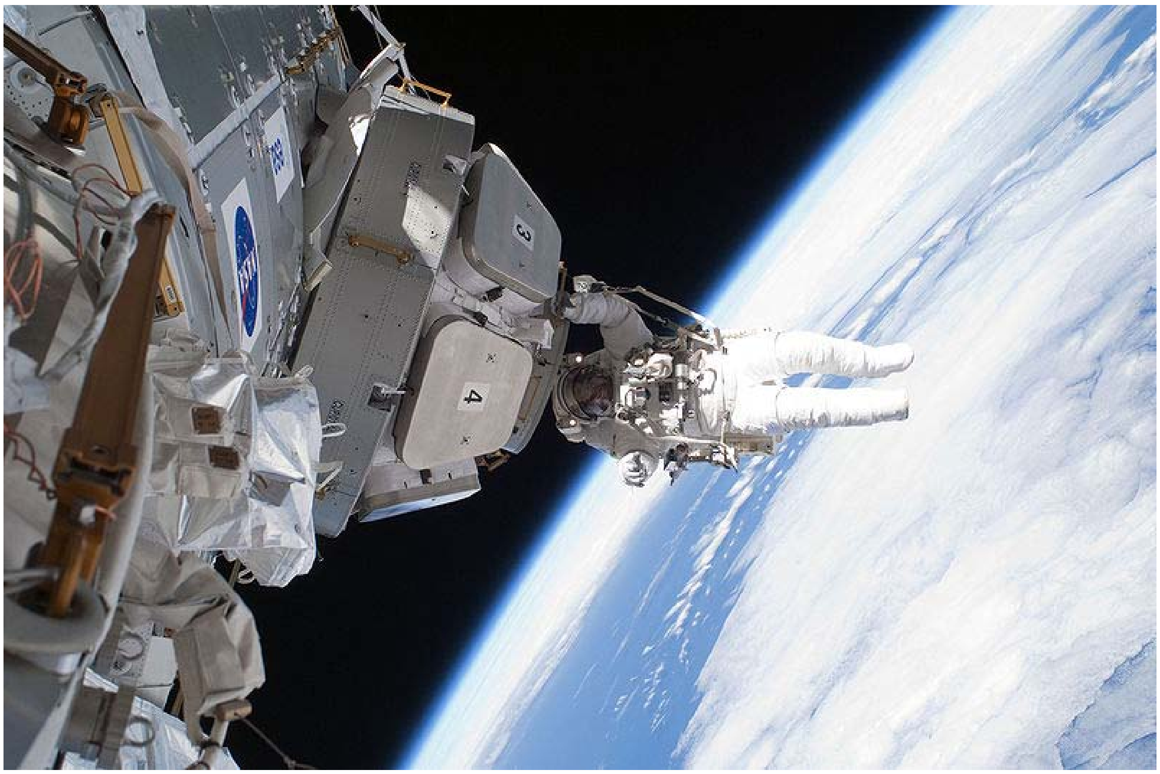

Cupola ISS open shut...

Cupola ISS open shut...

Because of confusion between the responsibilities of the two contracts, both Boeing, which won Work Package 1, and McDonnell-Douglas, which won Work Package 2, bid to build the Cupola. The McDonnell-Douglas design was basically the same as NASA's but Boeing's was smaller; a hexagon, with a single large circular overhead window, and a much shorter cylinder; this design had been considered but previously discarded because it was unable to accommodate two crew members completely and would instead require the crew to dangle their legs and bodies in the Node to which the Cupola would be attached. This design was the one ultimately built. Components of the Cupola were initially fabricated in California, and the windows in New York in the late 1980s. But as budgets were cut, the Cupola was a favorite target. Several times it was fought back into the program only to be cut again as not technically required. More than once the responsibilities for fabrication were bartered to one international partner and then another in exchange for Shuttle launch services and resources that the US would provide on-board the station in orbit. The Cupola made the rounds to Brazil and then finally wound up with ESA and the Italians in 1998, who did complete it back in 2003. Even then the launch of the Cupola was repeatedly delayed until it finally made it into orbit in February, 2010.

With final design and assembly by the Italian contractor Alenia Spazio (now Thales Alenia Space), it is approximately 2 metres in diameter and 1.5 metres tall. It has six side windows and a top window, all of which are equipped with shutters to protect them from damage by micrometeorites and orbital debris. It features a thermal control system, audio, video and MIL-STD-1553 bus interfaces, as well as the connections needed for installing one of the two identical robotic workstations that control the Canadarm2 into it.

## Installation



Astronaut Nicholas Patrick hanging on to Cupola

The Cupola was launched aboard the Space Shuttle on mission STS-130, on February 8, 2010. It was berthed to the forward port of the Tranquility module for launch, and was later transferred to the nadir-facing port of Tranquility by the Canadarm2, once Tranquility had been berthed to the Unity Module of the ISS. The installation of the Cupola, along with Tranquility, marks one of the last main components to be added to the International Space Station.

## Specifications

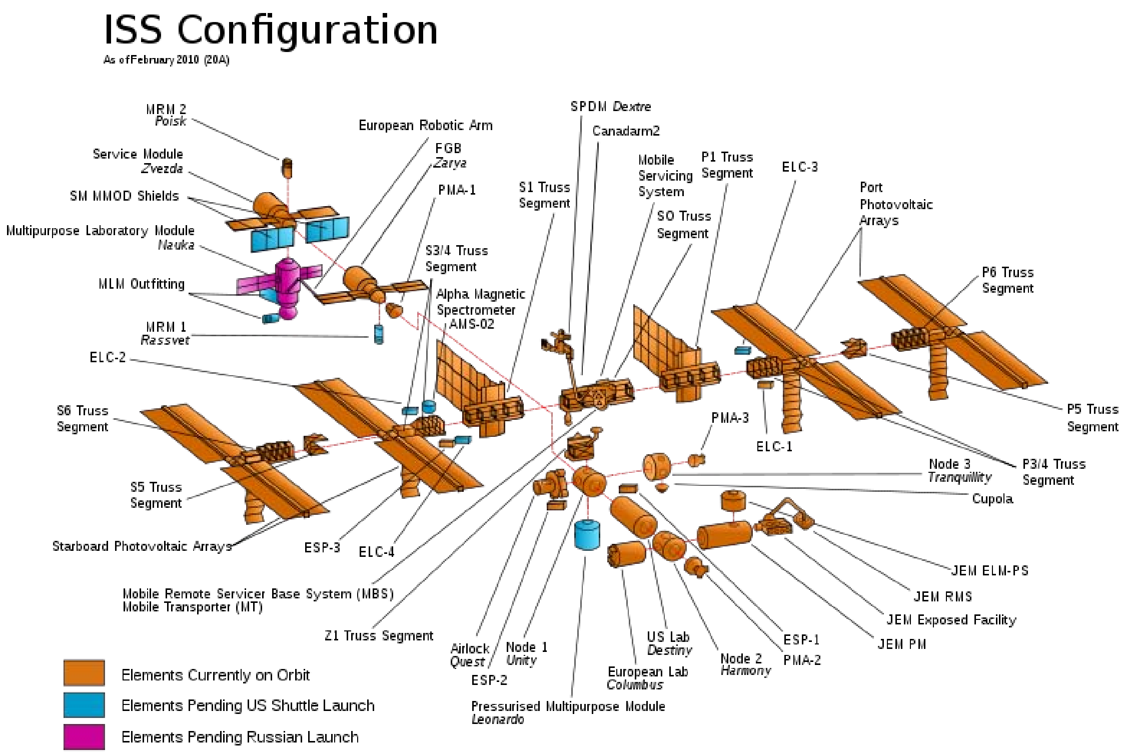
- Overall Height: 1.5-metre (4.9 ft)
- Maximum Diameter: 2.95-metre (9.68 ft)
- Launch Mass: 1,805-kilogram (3,979 lb)
- On Orbit Mass: 1,880-kilogram (4,145 lb)
- Dome: Forged Al 2219-T851

- Skirt: Al 2219-T851
- Windows: Fused Silica and Borosilicate Glass
- MDPS Shutters: Kevlar/Nextel sheets
- Electrical Power: Node 120 V Interface

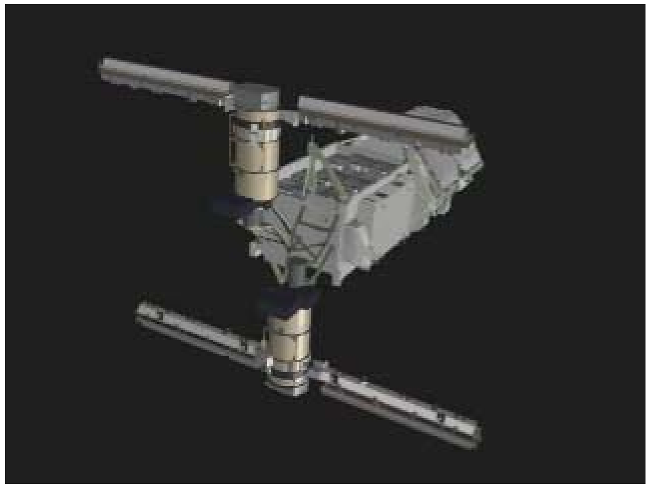
- Top Window: 80-centimetre (31 in) Diameter
- Thermal Control: Goldised Kapton Multi-Layer Insulation Blanket

## Chapter- 10

# Integrated Truss Structure




ISS elements as of February 2010



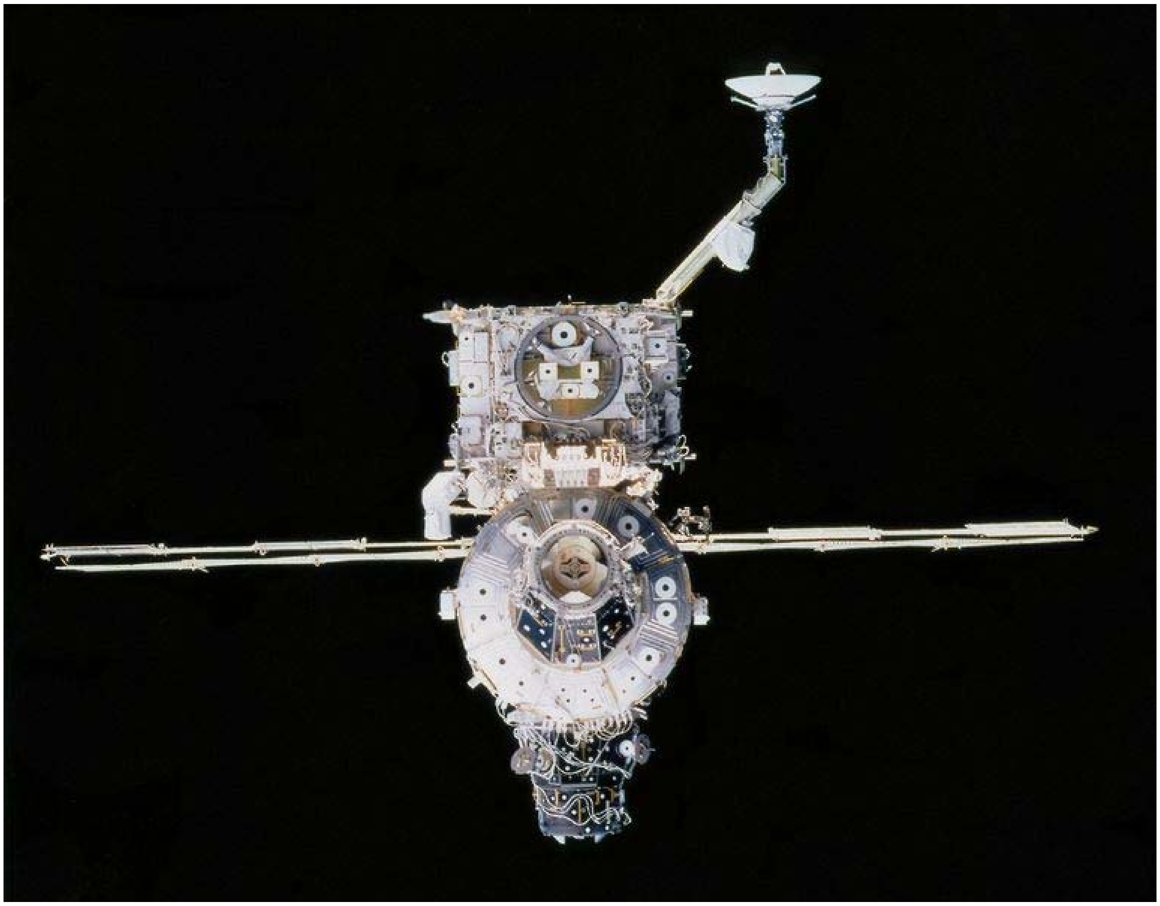
The components and the unfolding of the P3/P4 Truss in Detail (Animation)

The **Integrated Truss Structure** forms the backbone of the International Space Station, with mountings for unpressurized logistics carriers, radiators, solar arrays, and other equipment.

In the initial Space Station Freedom plans, a variety of designs for the truss were used, all of them intended to be shipped up as girders where they would be assembled and their equipment installed by astronauts on spacewalks once it had been launched. After the 1991 redesign, NASA switched to shorter, prefabricated pieces that were easier to install.

# Truss components

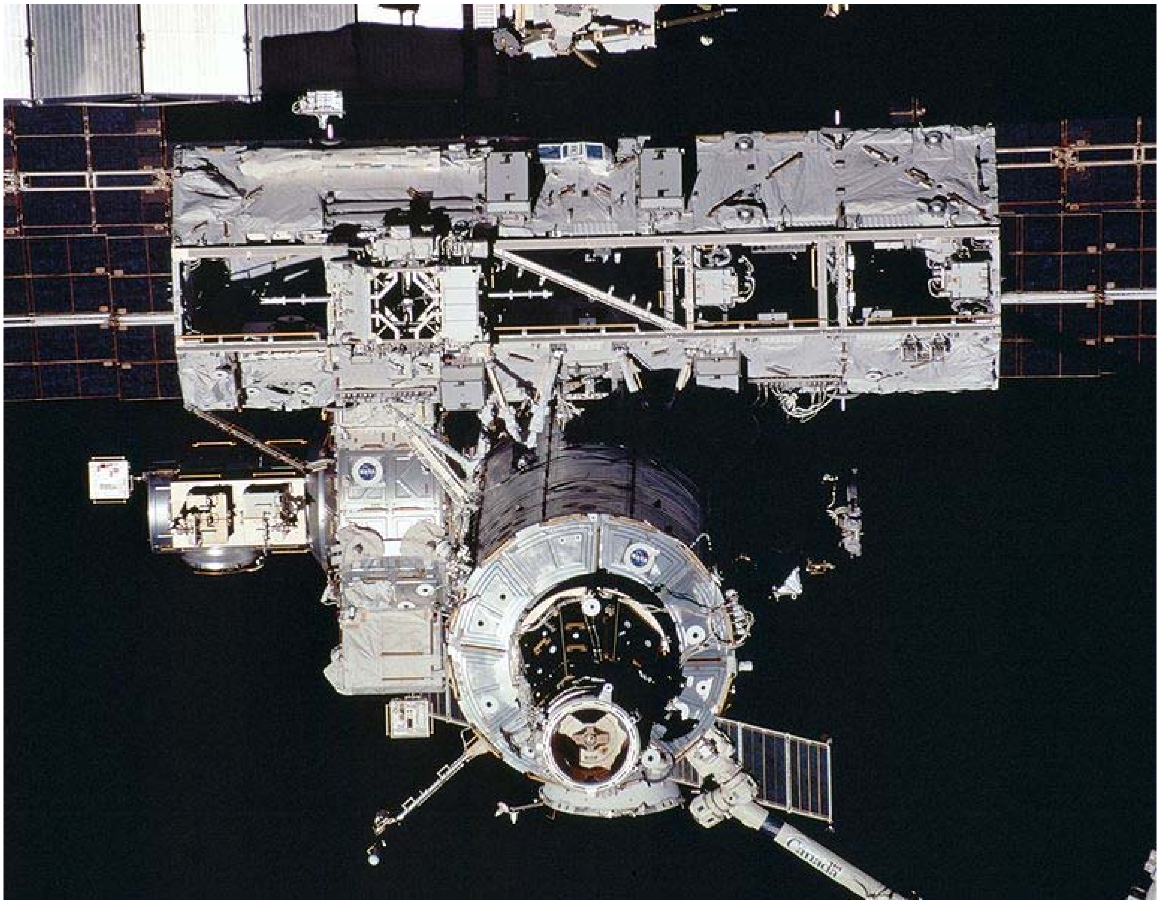
## Z1 truss



**Z1 truss** (above) and Unity Module (below) from STS-92 in October 2000

The first truss piece, the Z1 truss, launched aboard STS-92 in October 2000 was used as a temporary mounting position for the P6 truss and solar array until its relocation to the end of the P5 truss during STS-120. Though not a part of the main truss, the Z1 truss was the first permanent lattice-work structure for the ISS, very much like a girder, setting the stage for the future addition of the station's major trusses or backbones. It contains the control moment gyroscope (CMG) assemblies, electrical wiring, communications equipment, and two plasma contactors designed to neutralize the static electrical charge of the space station. It is unpressurized (with the exception of a small vestibule ), but features two Common Berthing Mechanism docking ports for easy connecting and data communications. One port (nadir) is used to connect the Z1 truss to the zenith port of *Unity*. The other port (forward) was used to temporarily berth PMA-2 during the placing of the *Destiny* lab onto the *Unity* node during STS-98. In October 2007, the P6 was moved to its permanent position next to P5, and the Z1 truss is now not used for connecting other elements, but solely to house the CMGs, communications equipment and the plasma contactors.

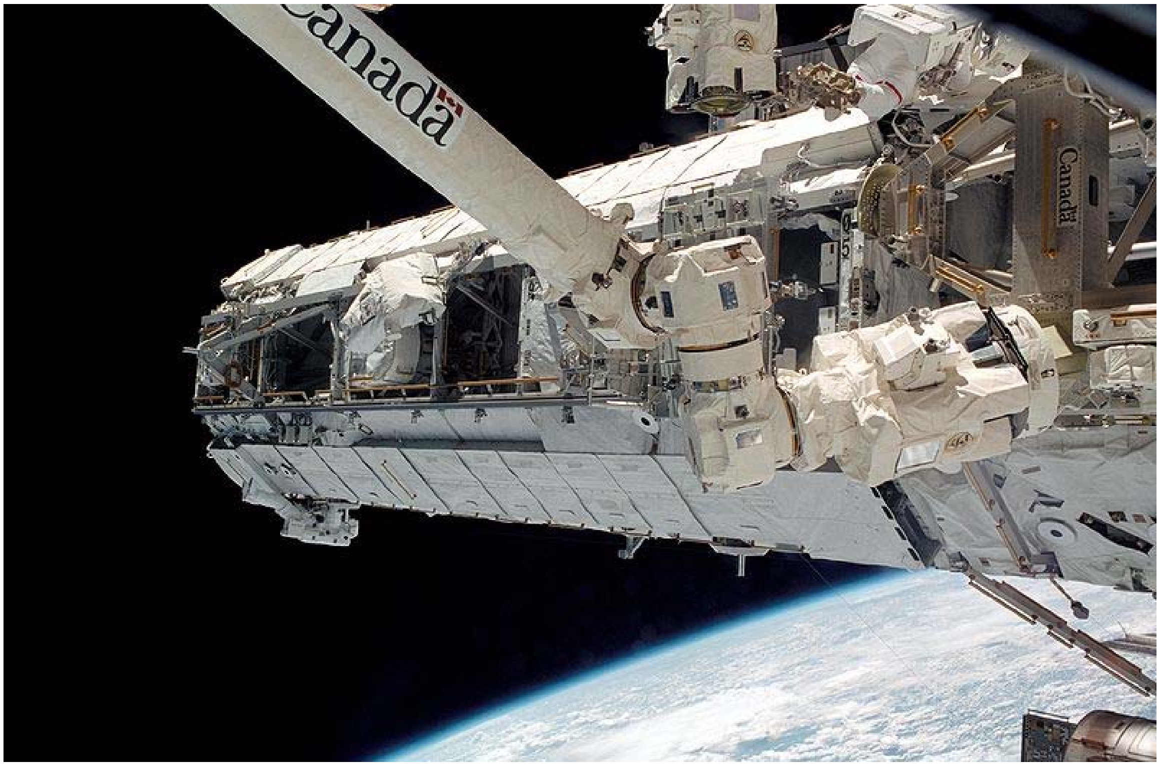
## S0 truss



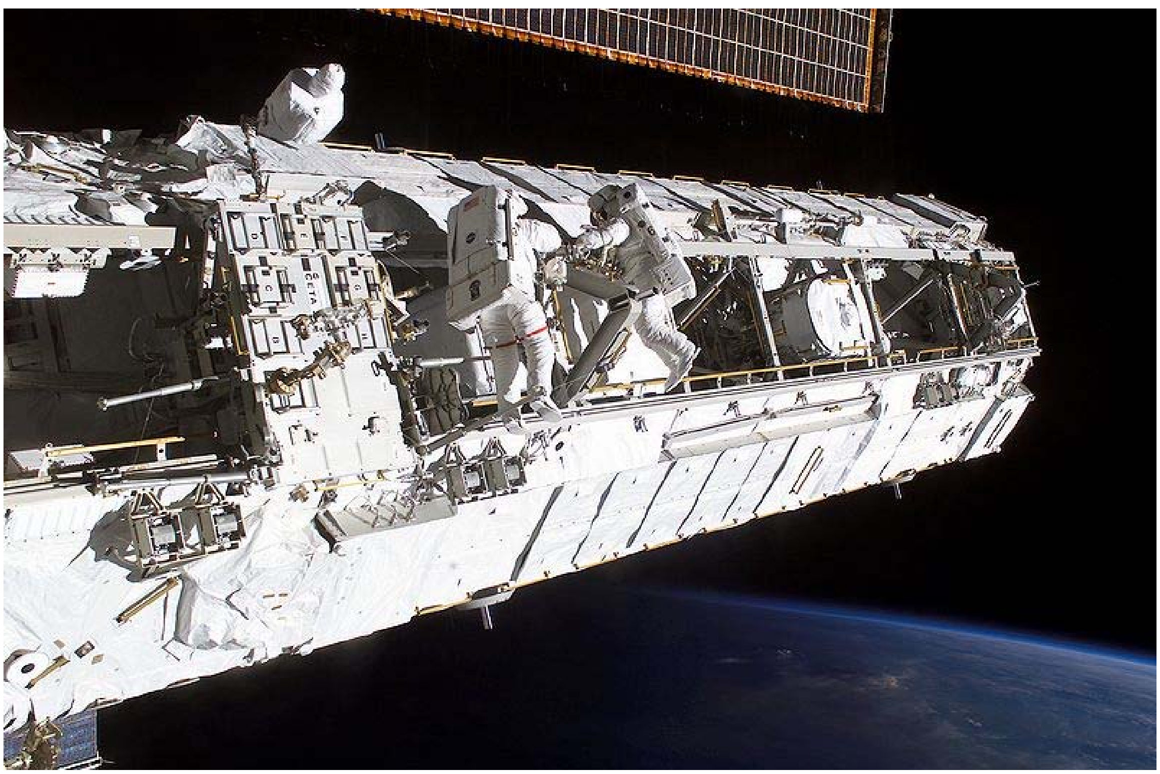
The **S0 truss** (above) from STS-110 April 17, 2002

The S0 truss, (also called the *Center Integrated Truss Assembly Starboard 0 Truss*) forms the center backbone of the Space Station. It was attached on the top of the Destiny Laboratory Module during STS-110 in April 2002. S0 is used to route power to the pressurized station modules and conduct heat away from the modules to the S1 and P1 Trusses. The S0 truss is not docked to the ISS, but is connected with four Module to Truss Structure (MTS) struts.

**P1, S1 trusses**




ISS **S1 truss** element being installed on STS-112 October 10, 2002



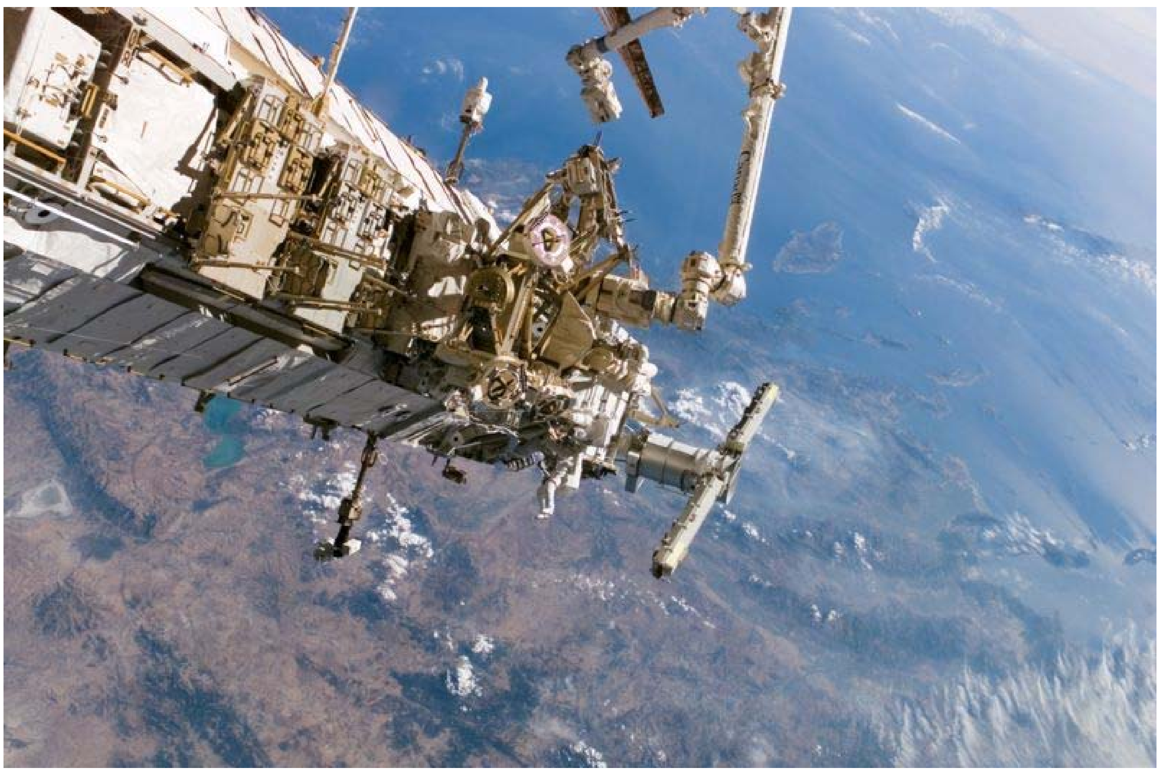
ISS **P1 truss** element being installed on STS-113 November 28, 2002

The P1 and S1 trusses (also called the *Port and Starboard Side Thermal Radiator Trusses*) are attached to the S0 truss, and contain carts to transport the Canadarm2 and astronauts to worksites along the space station. They each flow 290 kg (637 lb) of anhydrous ammonia through three heat rejection radiators. The S1 truss was launched on STS-112 in October 2002 and the P1 truss was launched on STS-113 in November 2002. Detailed design, test and construction of the S1 and P1 structures was conducted by McDonnell Douglas (now Boeing) in Huntington Beach, CA. First parts were cut for the structure in 1996, and delivery of the first truss occurred in 1999.

## P2, S2 trusses

The P2 and S2 trusses were planned as locations for rocket thrusters in the original design for Space Station Freedom. Since the Russian parts of the ISS also provided that capability, the reboost capability of the Space Station Freedom design was no longer needed at that location. So P2 and S2 were canceled.

## P3/P4, S3/S4 truss assemblies



The **P3/P4 truss assembly** being installed during STS-115 September 13, 2006. Astronauts give scale to the image.

The newly installed **S3/S4 truss assembly** during the first EVA of mission STS-117 on June 11, 2007.

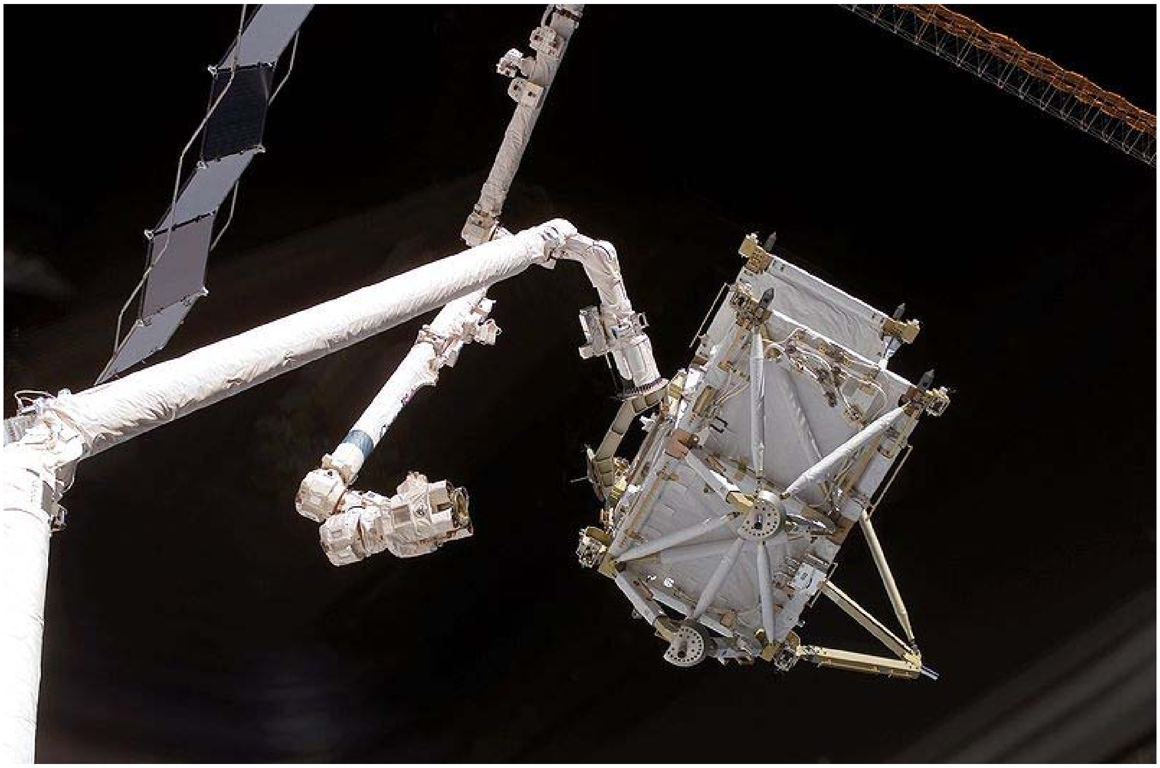
The P3/P4 truss assembly was installed by the Space Shuttle *Atlantis* STS-115 mission, launched September 9, 2006, and attached to the P1 segment. The P3 and P4 segments together contain a pair of solar arrays, a radiator and a rotary joint that will aim the solar arrays, and connects P3 to P4. Upon its installation, no power was flowing across the rotary joint, so the electricity generated by the P4 solar array wings was only being used on the P4 segment, and not the rest of the station. Then in December 2006 a major electrical rewiring of the station by STS-116 routed this power to the entire grid. The S3/S4 truss assembly—a mirror-image of P3/P4—was installed on June 11, 2007 also by Space Shuttle *Atlantis* during flight STS-117, mission 13A and mounted to the S1 truss segment.

Major P3 and S3 subsystems include the Segment-to-Segment Attach System (SSAS), Solar Alpha Rotary Joint (SARJ), and Unpressurized Cargo Carrier Attach System (UCCAS). The primary functions of the P3 truss segment are to provide mechanical, power and data interfaces to payloads attached to the two UCCAS platforms; axial indexing for solar tracking, or rotating of the arrays to follow the sun, via the SARJ; movement and work site accommodations for the Mobile Transporter. The P3/S3 primary structure is made of a hexagonal shaped aluminum structure and includes four bulkheads and six longerons. The S3 truss also supports EXPRESS Logistics Carrier locations, first to be launched and installed in the 2009 time frame.

Major subsystems of the P4 and S4 Photovoltaic Modules (PVM) include the two Solar Array Wings (SAW), the Photovoltaic Radiator (PVR), the Alpha Joint Interface

Structure (AJIS), and Modified Rocketdyne Truss Attachment System (MRTAS), and Beta Gimbal Assembly (BGA).

## P5, S5 trusses



Space Shuttle *Discovery*'s Canadarm-1 robotic arm hands off the P5 truss section to the International Space Station's Canadarm-2 during shuttle mission STS-116 in December, 2006.

Space Shuttle *Endeavour* approaches the International Space Station during mission STS-118 with the S5 truss section ready to be installed.

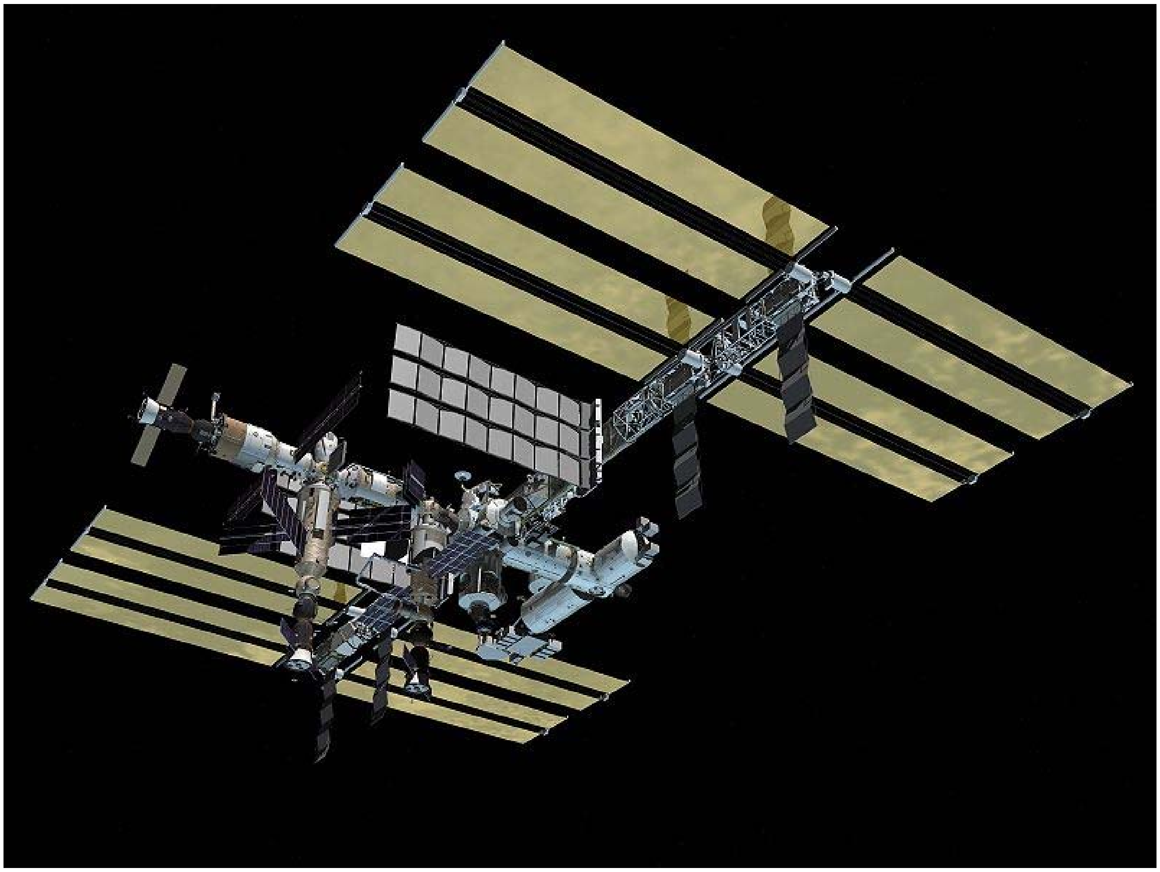
The P5 and S5 trusses are connectors which support the P6 and S6 trusses, respectively. The P3/P4 and S3/S4 truss assemblies' length was limited by the cargo bay capacity of the Space Shuttle, so these small connectors are needed to extend the truss. The P5 truss was installed on December 12, 2006 during the first EVA of mission STS-116. The S5 truss was brought into orbit by mission STS-118 and installed on August 11, 2007.

## P6, S6 trusses

The P6 truss was the second truss segment to be added, because it contains a large Solar Array Wing (SAW) that generated essential electricity for the station, prior to activation of the SAW on the P4 truss. It was originally mounted to the Z1 truss and had its SAW extended during STS-97, but SAW was folded, one half at a time, to make room for the SAWs on the P4 and S4 trusses, during STS-116 and STS-117 respectively. Shuttle mission STS-120 (assembly mission 10A) detached the P6 truss from Z1, remounted it on the P5 truss, redeployed its radiator panels and attempted to redeploy its SAWs. One SAW (2B) was deployed successfully but the second SAW (4B) developed a significant tear that temporarily stopped deployment at around 80%. This was subsequently fixed and the array is now fully deployed. A later assembly mission (the out of sequence STS-119) mounted the S6 truss on the S5 truss, which provided a fourth and final set of solar arrays and radiators.

## Truss subsystems

International Space Station on November 5, 2007 after relocation of the P6 truss assembly (far right) by STS-120

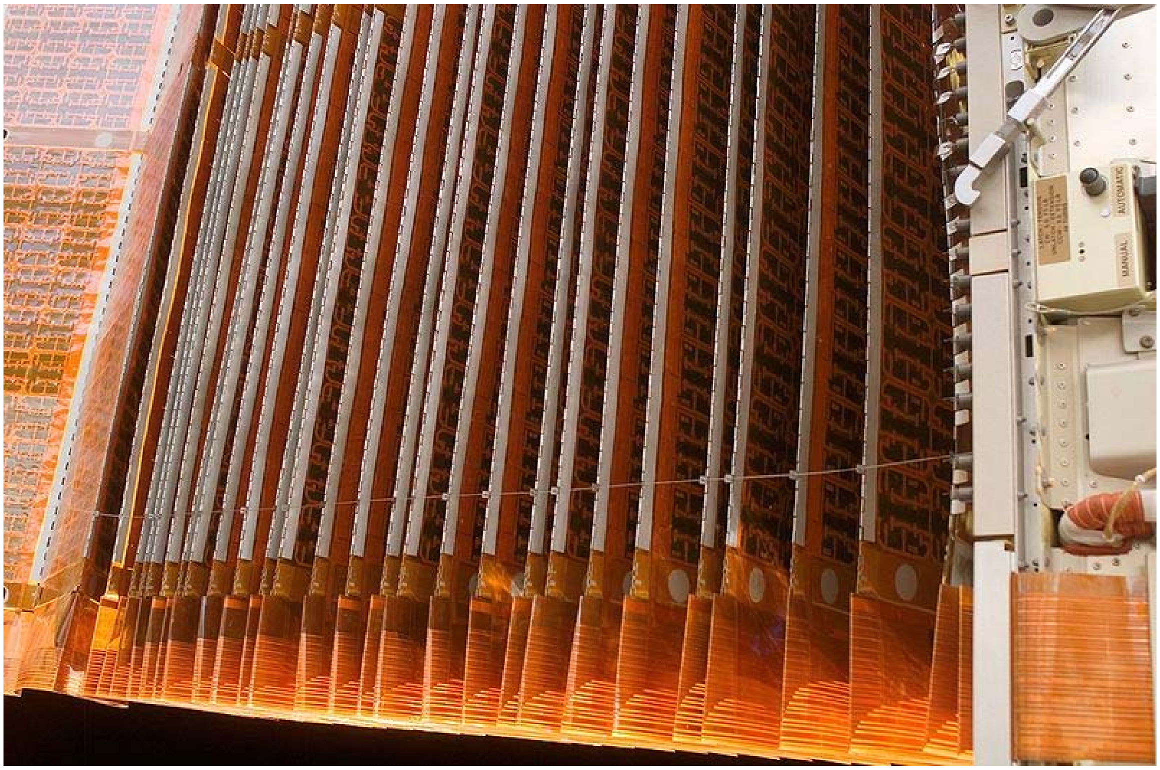


Computer model of the planned completed station (as of June 2006)

## Solar arrays

The International Space Station's main source of energy is from three of the four large U.S.-made photovoltaic arrays currently on the station, sometimes referred to as the *Solar Array Wings* (SAW). The first pair of arrays are attached to the P6 truss segment, which was launched and installed on top of Z1 in late 2000 during STS-97. The P6 segment was relocated to its final position, bolted to the P5 truss segment, in November 2007 during STS-120. The second pair of arrays was launched and installed in September 2006 during STS-115, but they didn't provide electricity until STS-116 in December 2006 when the station got an electrical rewiring. A third pair of arrays was installed during STS-117 in June 2007. A final pair arrived mid March 2009 on STS-119. More solar power was to have been available via the Russian-built Science Power Platform, but it was cancelled.

Each of the Solar Array Wings are 34 m (112 ft) long by 12 m (39 ft) wide, and are capable of generating nearly 32.8 kW of DC power. They are split into two photovoltaic blankets, with the deployment mast in between. Each blanket has 16,400 silicon photovoltaic cells, each cell 8 cm by 8 cm, grouped into 82 active panels, each consisting of 200 cells, with 4,100 diodes.



close-up view of solar array folded like an accordion.

Each pair of blankets is folded like an accordion for compact delivery to space. Once in orbit, the deployment mast between each pair of blankets unfolds the array to its full length. Gimbals, known as the *Beta Gimbal Assembly* (BGA) are used to rotate the arrays so that they face the Sun to provide maximum power to the International Space Station.

## Solar Alpha Rotary Joint

The **Alpha** joint is the main rotary joint allowing the solar arrays to track the sun; in nominal operation the alpha joint rotates by 360° each orbit. One Solar Alpha Rotary Joint (SARJ) is located between the P3 and P4 truss segments and the other is located between the S3 and S4 truss segments. When in operation, these joints continuously rotate to keep the solar array wings on the outboard truss segments oriented towards the Sun. Each SARJ is 10 feet in diameter, weighs approximately 2,500 pounds and can be rotated continuously using bearing assemblies and a servo control system. On both the port and starboard sides, all of the power flows through the Utility Transfer Assembly (UTA) in the SARJ. Roll ring assemblies allow transmission of data and power across the rotating interface so it never has to unwind. The SARJ was designed, built and tested by Lockheed Martin and its subcontractors.

In 2007, a problem was detected in the starboard SARJ. Damage had occurred due to excessive and premature wear of a track in the joint mechanism. The SARJ was frozen during problem diagnosis, and in 2008 lubrication was applied to the track to address the issue.

## Power Conditioning and Storage

The Sequential Shunt Unit (SSU) is designed to coarsely regulate the solar power collected during periods of insolation – when the arrays collect power during sun-pointing periods. A sequence of 82 separate strings, or power lines, leads from the solar array to the SSU. Shunting, or controlling, the output of each string regulates the amount of power transferred. The regulated voltage setpoint is controlled by a computer located on the IEA and is normally set to around 140 volts. The SSU has an overvoltage protection feature to maintain the output voltage below 200 V DC maximum for all operating conditions. This power is then passed through the BMRRM to the DCSU located in the IEA. The SSU measures 32” by 20” by 12” and weighs 185 pounds.

The power storage system consists of a Battery Charge/Discharge Unit (BCDU) and two nickel hydrogen battery assemblies.

The BCDU serves a dual function of charging the batteries during solar collection periods, and providing conditioned battery power to the primary power busses (via the DCSU) during eclipse periods. The BCDU has a battery charging capability of 8.4 kW and a discharge capability of 6.6 kW. The BCDU also includes provisions for battery status monitoring and protection from power circuit faults. Commanding of the BCDU is from the IEA computer.

Each battery assembly consist of 38 lightweight Nickel Hydrogen cells and associated electrical and mechanical equipment. Each battery assembly has a nameplate capacity of 81 A·hr and 4 kW·hr. This power is fed to the ISS via the BCDU and DCSU respectively. The batteries have a design life of 6.5 years and can exceed 38,000 charge/discharge cycles at 35% depth of discharge. Each battery measures 40” by 36” by 18” and weighs 375 pounds.

# Truss and solar array assembly sequence

- All truss segments are in orbit (S2 and P2 were cancelled).

| Element | Flight | Launch date | Length (m) | Diameter (m) | Mass (kg) |
|---|---|---|---|---|---|
| Z1 truss | 3A – STS-92 | October 11, 2000 | 4.9 | 4.2 | 8,755 |
| P6 truss – solar array | 4A – STS-97 | November 30, 2000 | 73.2 | 10.7 | 15,824 |
| S0 truss | 8A – STS-110 | April 8, 2002 | 13.4 | 4.6 | 13,971 |
| S1 truss | 9A – STS-112 | October 7, 2002 | 13.7 | 4.6 | 14,124 |
| P1 truss | 11A – STS-113 | November 23, 2002 | 13.7 | 4.6 | 14,003 |
| P3/P4 truss – solar array | 12A – STS-115 | September 9, 2006 | 13.8 | 4.8 | 15,824 |

| | | | | | |
|---|---|---|---|---|---|
| P5 truss - spacer | 12A.1 – STS-116 | December 9, 2006 | 3.37 | 4.55 | 1,864 |
| S3/S4 truss – solar array | 13A – STS-117 | June 8, 2007 | 73.2 | 10.7 | 15,824 |
| S5 truss - spacer | 13A.1 – STS-118 | August 8, 2007 | 3.37 | 4.55 | 1,818 |
| P6 truss – solar array (relocation) | 10A – STS-120 | October 23, 2007 | 73.2 | 10.7 | 15,824 |
| S6 truss – solar array | 15A – STS-119 | March 15, 2009 | 73.2 | 10.7 | 15,824 |

**Chapter- 11**

# Other Components of the International Space Station

## Zarya

Zarya module as seen from STS-88 (NASA)

**Zarya** (Russian: Заря́; lit. *dawn*), also known as the **Functional Cargo Block** or **FGB** (from the Russian "Функционально-грузовой блок", *Funktsionalno-gruzovoy blok* or *ФГБ*), was the first module of the International Space Station to be launched. The FGB provided electrical power, storage, propulsion, and guidance to the ISS during the initial stage of assembly. With the launch and assembly in orbit of other modules with more specialized functionality, Zarya is now primarily used for storage, both inside the pressurized section and in the externally mounted fuel tanks. The Zarya is a descendant of the TKS spacecraft designed for the Russian Salyut program. The name *Zarya* was given to the FGB because it signified the dawn of a new era of international cooperation in space.

## Construction

The FGB design was originally intended as a module for the Russian Mir space station, but was not flown as of the end of the Mir program. A FGB cargo block was incorporated as an upper stage engine into the Polyus spacecraft, flown (unsuccessfully) on the first Energia launch. With the end of the Mir program, the design was adapted to use for the International Space Station.

Zarya is owned and paid for by the United States space agency NASA and was built from December 1994 to January 1998 in Russia at the Khrunichev State Research and Production Space Center (KhSC) in Moscow. Its control system was developed by the Khartron Corp. (Kharkiv, Ukraine). The module was included as part of NASA's plan for the International Space Station (ISS) instead of Lockheed's "Bus-1" option because it was significantly cheaper (US$220 million vs. $450 million). As part of the contract Khrunichev constructed much of an identical module (referred to as "FGB-2") for contingency purposes. FGB-2 has been proposed for a variety of projects; it is now slated to be used to construct the Russian Multipurpose Laboratory Module.

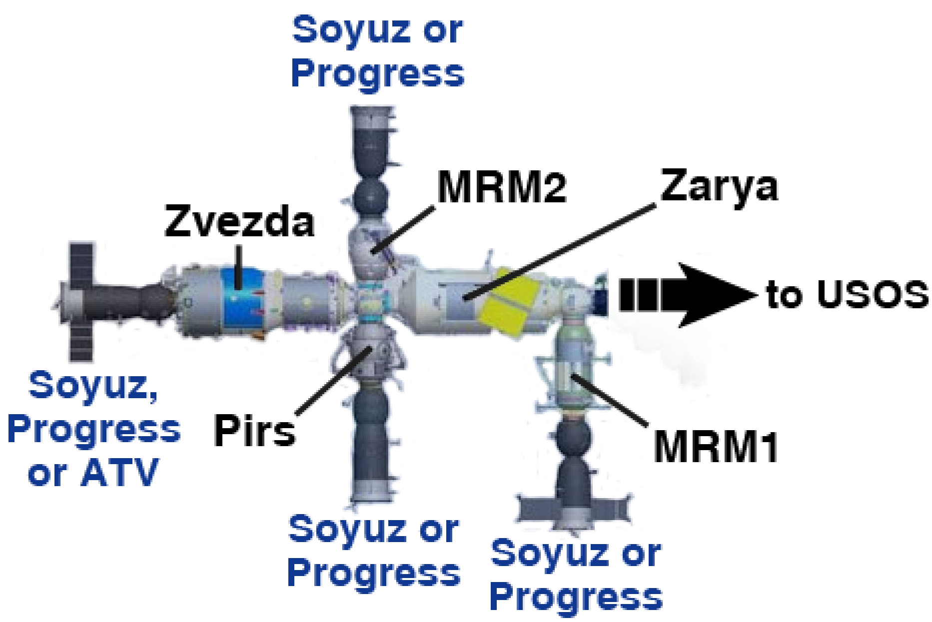
Launch of Zarya module

## Design

Zarya weighs 19,300 kilograms (43,000 lb), is 12.55 meters (41.2 ft) long and 4.1 meters (13 ft) wide at its widest point.

The module has three docking ports, one on each end, and one on the side. The Zvezda Service Module is attached to the aft port, the Pressurized Mating Adapter *PMA-1* attached to the forward port connects to the *Unity* Module, and the side (*axial* or *nadir*) port was used to dock with either of Russian Soyuz or Progress spacecraft until the *Rassvet* module was docked there permanently. Zarya has two solar arrays measuring 10.67 by 3.35 meters (35.0 by 11.0 ft) and six nickel-cadmium batteries that can provide an average of 3 kilowatts of power. These have been retracted so the P1/S1 radiators could deploy. Zarya has 16 external fuel tanks that can hold over 6 metric tons of propellant. Zarya also has 24 large steering jets, 12 small steering jets, and two large engines that were used for reboost and major orbital changes; with the docking of Zvezda these are now permanently disabled. Since they are no longer needed for Zarya's engines, Zarya's propellant tanks are now used to store additional fuel for Zvezda.

## Launch and flight




The location of *Zarya* on the Russian Orbital Segment.

Zarya was launched on November 20, 1998 on a Russian Proton rocket from Baikonur Cosmodrome Site 81 in Kazakhstan to a 400 km (250 mi) high orbit with a designed lifetime of at least 15 years. After Zarya reached orbit, STS-88 launched on December 4, 1998 to attach the Unity Module.

Although only designed to fly autonomously for six to eight months, Zarya was required to do so for almost two years due to delays to the Russian Service Module, Zvezda. Zvezda was finally launched on July 12, 2000, docking with Zarya on July 26 using the Russian Kurs docking system.

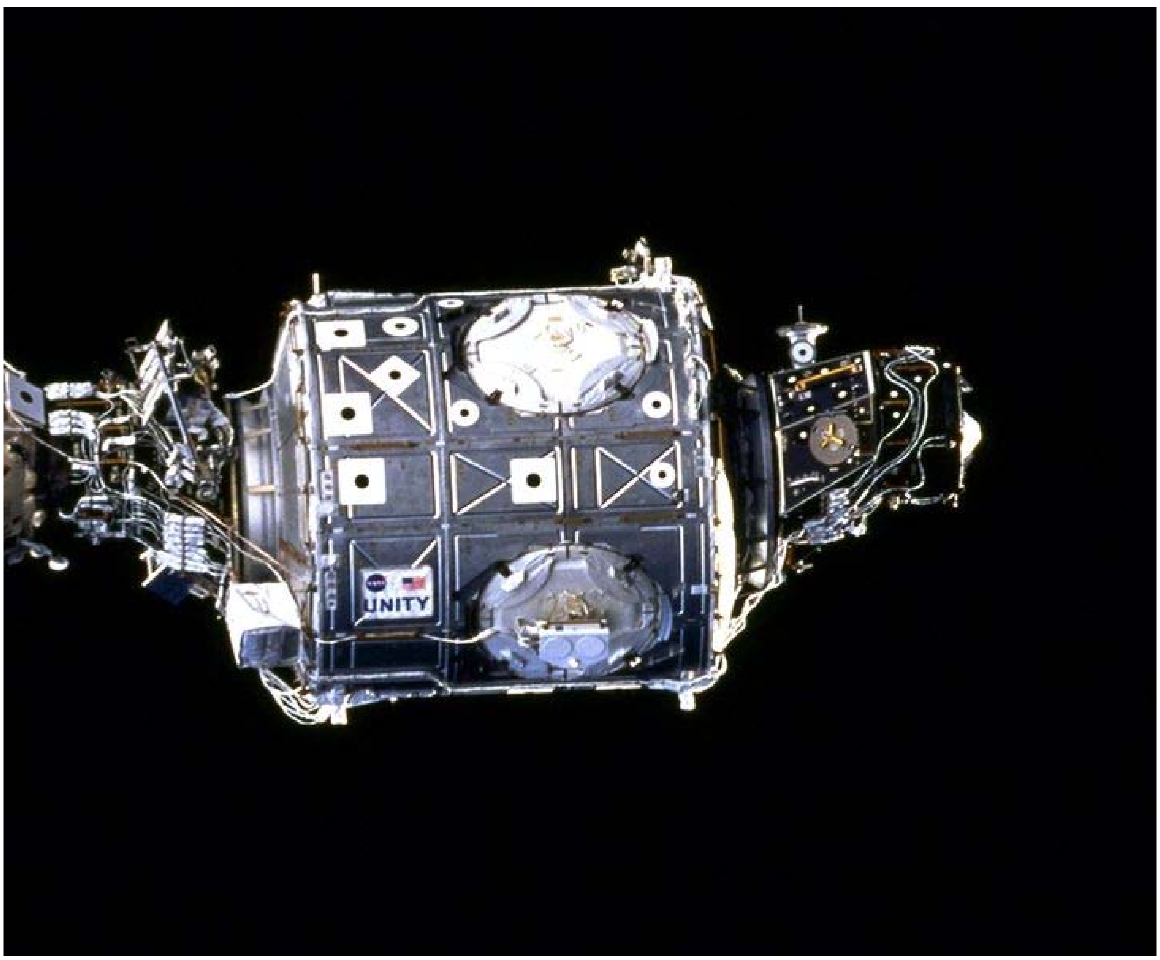
Zarya initially had problems with battery charging circuits, but these were resolved. It will eventually require supplemental micro meteor shielding, as it was given an exemption to the ISS rules when it launched.

Zarya passed the 50,000-orbit mark at 15:17 UTC on August 14, 2007 during the STS-118 mission to the International Space Station.

## Specifications

- Length: 12.56 m (41.2 ft)
- Diameter: 4.11 m (13.5 ft)
- Solar array length: 10.67 m (35.0 ft)
- Solar array width: 3.35 m (11.0 ft)
- Mass: 19,323 kg (42,600 lb)

# *Unity* (ISS module)




ISS *Unity* connecting module (NASA)

The ***Unity*** connecting module was the first U.S.-built component of the International Space Station. It is cylindrical in shape, with six berthing locations (forward, aft, port, starboard, zenith, and nadir) facilitating connections to other modules. *Unity* measures 4.57 metres (15.0 ft) in diameter, is 5.47 metres (17.9 ft) long, and was built for NASA by The Boeing Company in a manufacturing facility at the Marshall Space Flight Center in Huntsville, Alabama. Sometimes referred to as **Node 1**, *Unity* was the first of the three connecting modules; the other two are *Harmony* and *Tranquility*.

## Launch and initial berthing

Unity was carried into orbit as the primary cargo of the Space Shuttle *Endeavour* on STS-88, the first Space Shuttle mission dedicated to assembly of the station. On December 6, 1998, the STS-88 crew mated the aft berthing port of *Unity* with the forward hatch of the already orbiting Zarya module. (Zarya was a mixed Russian-US funded and Russian-built component launched earlier aboard a Russian Proton rocket from Baikonur, Kazakhstan.) This was the first connection made between two station modules.

## Connections to other station components

Unity has 2 axial, and 4 radial Common Berthing Mechanism (CBM) ports. In addition to connecting to the Zarya module, Unity currently connects to the U.S. Destiny Laboratory Module (added on STS-98), the Z1 truss (an early exterior framework for the station added on STS-92), the PMA-3 (also added on STS-92), and the Quest Joint Airlock (added on STS-104). In addition, the *Leonardo* and *Raffaello* Multi-Purpose Logistics Modules have each been berthed to *Unity* on multiple missions. During STS-120 the *Harmony* connecting module was temporarily berthed to the port-side hatch of *Unity*. Tranquility, with its multi-windowed cupola, was attached to *Unity*'s port side during the STS-130 mission. However, recently NASA decided to leave the MPLM Leonardo permanently attached to the ISS, which would be located at the nadir side of Node 1.

## Details

Essential space station resources such as fluids, environmental control and life support systems, electrical and data systems are routed through *Unity* to supply work and living areas of the station. More than 50,000 mechanical items, 216 lines to carry fluids and gases, and 121 internal and external electrical cables using six miles of wire were installed in the *Unity* node. *Unity* is made of aluminum.

Prior to its launch aboard *Endeavour*, conical Pressurized Mating Adapters (PMAs) were attached to the aft and forward berthing mechanisms of Unity. *Unity* and the two mating adapters together weighed about 25,600 pounds (11,600 kg). The adapters allow the docking systems used by the Space Shuttle and by Russian modules to attach to the node's hatches and berthing mechanisms. PMA-1 now permanently attaches *Unity* to Zarya, while PMA-2 provides a Shuttle docking port. Attached to the exterior of PMA-1 are computers, or multiplexer-demultiplexers (MDMs), which provided early command and control of *Unity*. *Unity* also is outfitted with an early communications system that allows data, voice and low data rate video with Mission Control, Houston, to supplement Russian communications systems during the early station assembly activities. PMA-3 was attached to Unity's nadir berthing mechanism by the crew of STS-92.

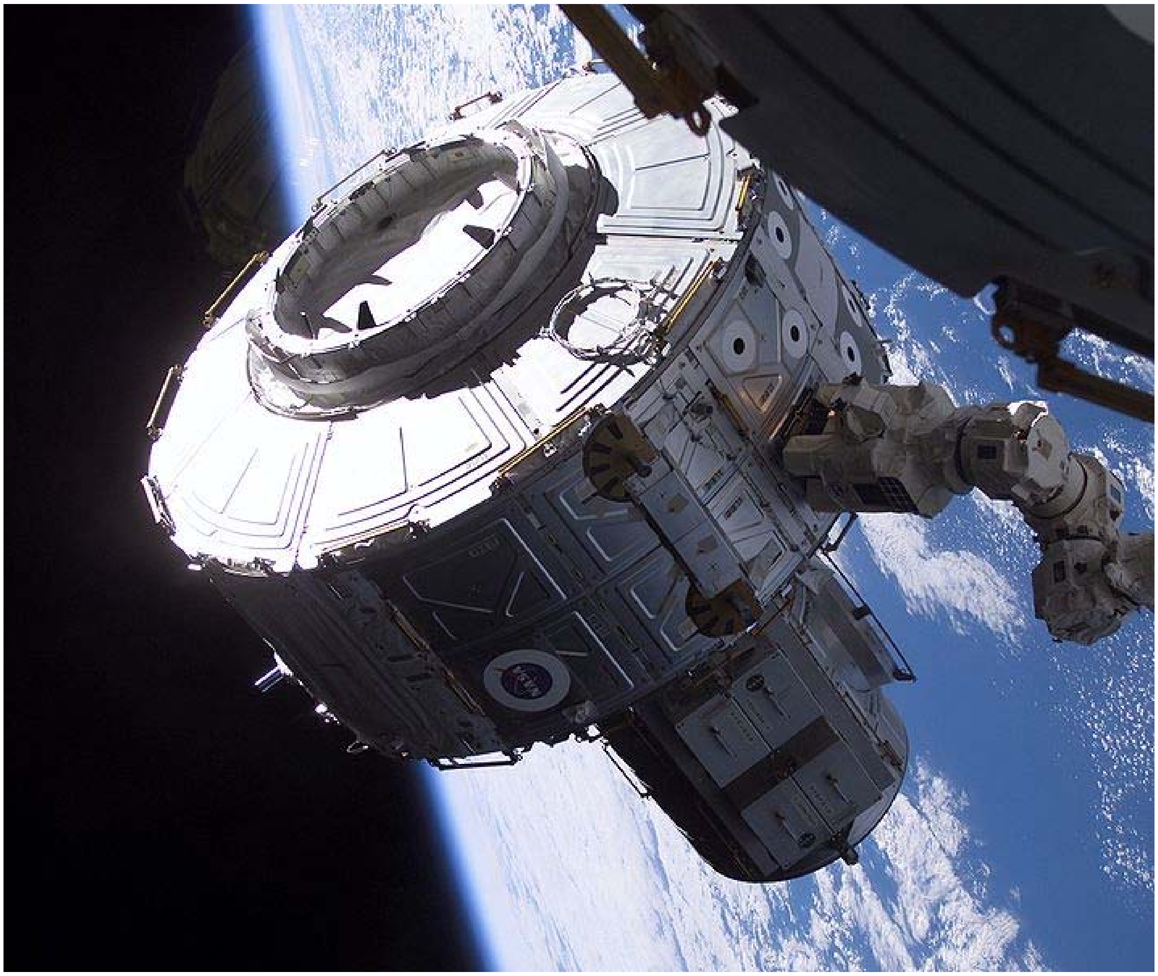
## Other nodes

The two remaining station connecting modules, or nodes, were built in Italy by Alenia Aerospazio, as part of an agreement between NASA and the European Space Agency (ESA). Harmony (formerly known as Node 2) and Tranquility (formerly known as Node 3) are slightly longer than Unity, measuring almost 6.4 meters (21 ft) long. In addition to their six berthing ports, each can hold eight International Standard Payload Racks (ISPRs). Unity, in comparison, holds just four ISPRs. ESA built Nodes 2 and 3 as partial payment for the launch aboard the Shuttle of the *Columbus* laboratory module, and other ESA equipment.

## Specifications

- Length: 5.49 m (18.0 ft)
- Diameter: 4.57 m (15.0 ft)
- Mass: 11,612 kg (25,600 lb)

# *Quest* Joint Airlock



Quest Joint Airlock Module (NASA)

The ***Quest* Joint Airlock**, previously known as the **Joint Airlock Module**, is the primary airlock for the International Space Station. *Quest* was designed to host spacewalks with both Extravehicular Mobility Unit (EMU) spacesuits and Orlan space suits. The airlock was launched on STS-104 on July 14, 2001. Before *Quest* was attached, Russian spacewalks using Orlan suits could only be done from the *Zvezda* service module and American spacewalks using EMUs were only possible when a Space Shuttle was docked. The arrival of *Pirs* docking compartment on September 16, 2001 provided another airlock from which Orlan spacewalks can be conducted.

## Design

The *Quest* airlock consists of two segments, the "Equipment lock" that stores spacesuits and equipment, and the "Crew Lock" from which astronauts can exit into space. It was derived from the Space Shuttle airlock, although it was significantly modified to waste less atmospheric gas when used. It was attached to the starboard CBM of the *Unity* during STS-104. It has mountings for four high-pressure gas tanks, two containing oxygen and two containing nitrogen, which provides for atmospheric replenishment to the American side of the space station, most specifically for the gas lost after a hatch opening during a space walk.

*Quest* was necessary because American suits will not fit through a Russian airlock hatch and have different components, fittings, and connections. The airlock is designed to contain equipment that can work with both types of spacesuits, however, it is currently only able to host American spacewalks because the equipment necessary to work with Russian space suits has not been launched yet, which required the Expedition 9 crew to take a circuitous route to a worksite because of problems with the American space suits.

## Camp out procedure

*Quest* provides an environment where astronauts can "camp out" before a spacewalk in a reduced-nitrogen atmosphere to purge nitrogen from their bloodstream and avoid decompression sickness in the low pressure, 5 psi (34 kPa), pure-oxygen atmosphere of the spacesuit. The previous method of preparing for spacewalks involved breathing pure oxygen for several hours prior to an EVA to purge the body of nitrogen. In April 2006, Expedition 12 Commander Bill McArthur and Expedition 13 flight engineer Jeffrey Williams tested a new method of preparing for spacewalks by "camping out" or spending the night in the *Quest* airlock. In the chamber, the pressure was reduced from the normal 14.7 to 10.2 psi (101 to 70 kPa). Four hours into the Expedition 13 crew's sleep period, an error tone prompted mission controllers to cut short the activity, but the test was still deemed a success. American spacewalk activities thereafter have employed the "camp out" pre-breathing technique.

## High-Pressure Gas Tanks

Two oxygen and two nitrogen High-Pressure Gas Tanks are attached externally to the airlock. These tanks provide a replenishable source of gas to the Atmosphere Control and Supply System and 900 psi (6.2 MPa) oxygen for recharging the space suits (EMUs). Recharging the high pressure tanks is accomplished by the orbiter when it is docked to the station's Pressurized Mating Adapter 2 or Pressurized Mating Adapter 3, using lines that are routed through the pressurized elements. The Oxygen Recharge Compressor Assembly (ORCA) is used to pump oxygen from the shuttle tanks into the high-pressure oxygen tanks on the space station.

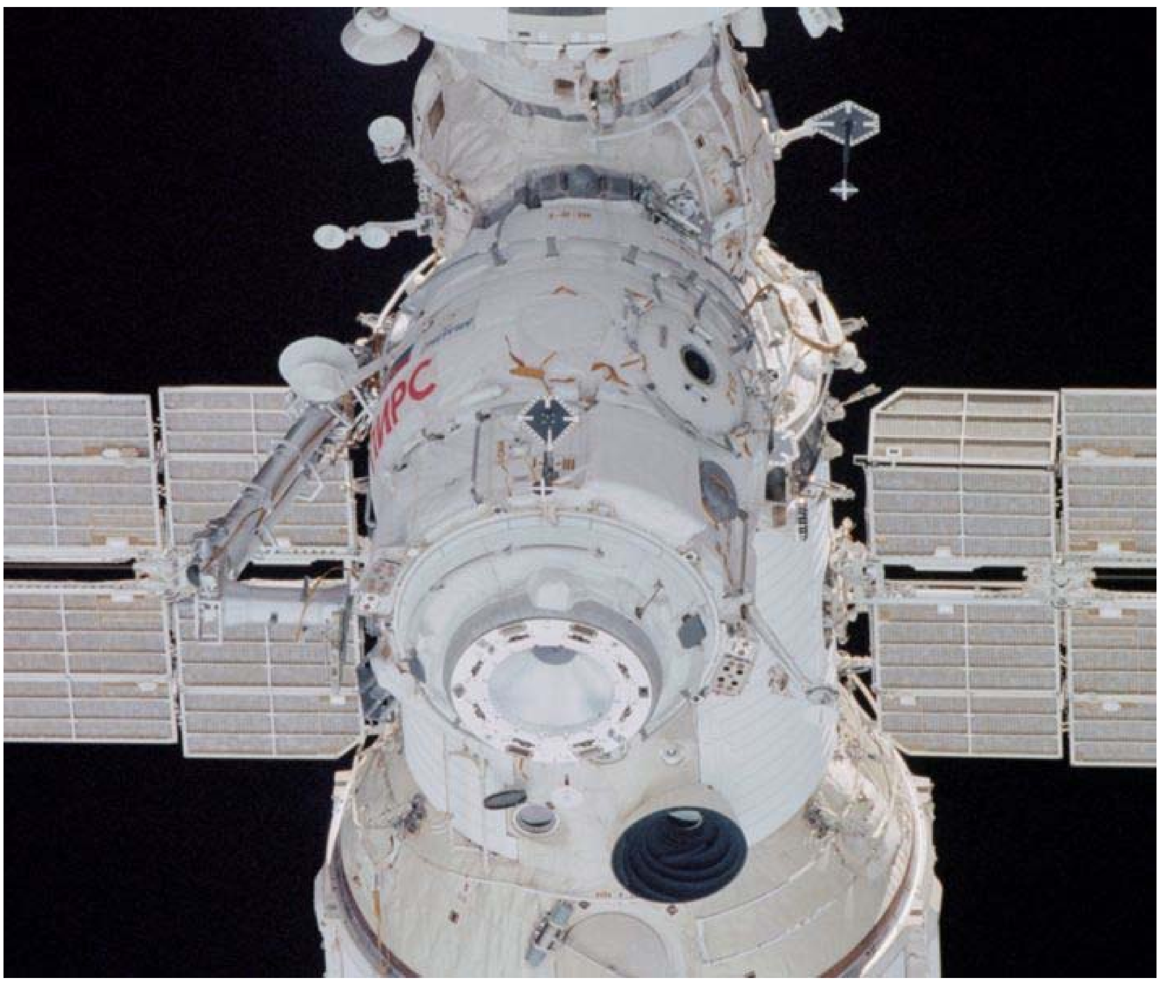
## Construction

The airlock and tank systems were built out of aluminium and tested at NASA's Marshall Space Flight Center in Huntsville, Alabama by the Boeing Company.

## Airlock specifications

- Material: aluminium
- Length: 5.5 meters (18 ft)
- Diameter: 4 meters (13 ft)
- Weight: 6,064 kilograms (13,370 lb)
- Volume: 34 cubic meters (1,200 cu ft)
- Cost: $164 million, including tanks

# *Pirs* (ISS module)



SO1 "Pirs" Docking compartment

The ***Pirs*** docking compartment is a Russian module of the International Space Station (ISS). *Pirs* (Russian: Пирс, meaning "pier") -- also called "Stikovochny Otsek 1" or "SO-1" (Russian: Стыковочный отсек, "docking module") -- is one of the two Russian docking compartments originally planned for the ISS. *Pirs* was launched in August 2001. It provides the ISS with additional docking ports, and allows egress and ingress for spacewalks by cosmonauts using Russian Orlan space suits. When the Russian segment of the ISS was redesigned in 2001, the new design did not include the SO-2, and its construction was canceled. The SO-2 module now forms the basis for the *Poisk* module. Although *Pirs* is the only airlock currently in use on the Russian segment of the station, spacewalks can also be conducted from the *Quest* airlock in the U.S. segment.

## Construction and design

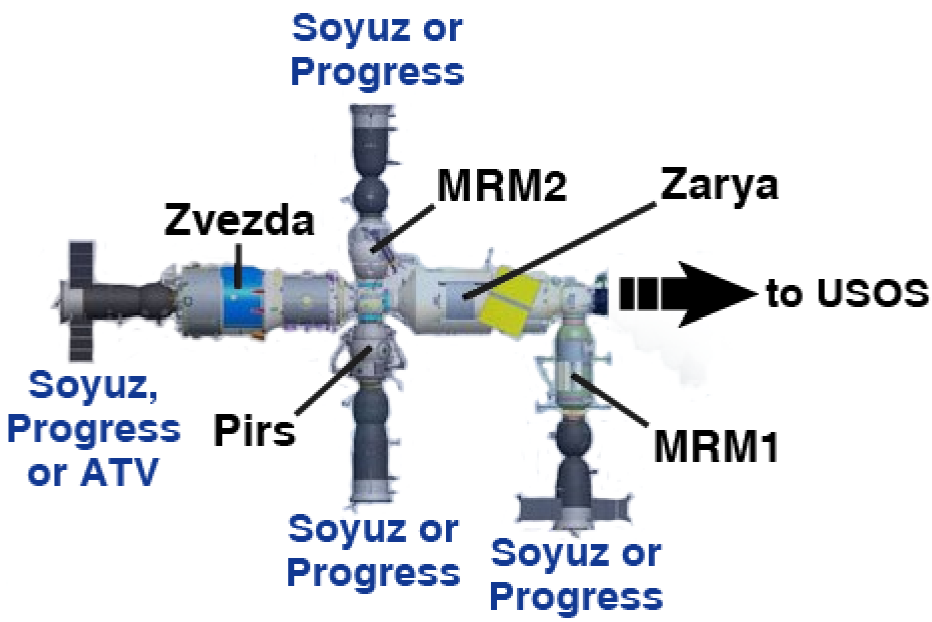
The Russian docking compartment was manufactured by RKK Energia. The Docking Compartment is similar to the Mir Docking Module used on the Mir space station. It provides docking ports for the Soyuz-TMA and Progress-M spacecraft. It also has two airlocks to accommodate spacewalks by cosmonauts wearing Russian Orlan-M spacesuits.

## Launch in 2001

Pirs arrives at the ISS in 2001

The 3,580-kilogram Pirs Docking Compartment is attached to the nadir (bottom, Earth-facing) port of the Zvezda service module. It docked to the International Space Station on September 16, 2001, and was configured during three spacewalks by the Expedition 3 crew. A second *Strela* cargo crane for the ISS was mounted to the module for launch.

Expedition 9 inside Pirs




The location of *Pirs* on the Russian Orbital Segment.

*Pirs* with a docked Progress spacecraft.

*Pirs* was launched on September 14, 2001, as ISS Assembly Mission 4R, on a Russian Soyuz-U rocket, using a modified Progress spacecraft, Progress M-SO1, as an upper stage. The Docking Compartment has two primary functions. It serves as a docking port for the docking of transport and cargo vehicles to the space station, and as an airlock for the performance of spacewalks by two station crewmembers using Russian Orlan spacesuits.

In addition, the Docking Compartment can transport fuel from the fuel tanks of a docked Progress resupply vehicle to either the Zvezda Service Module Integrated Propulsion System or the Zarya Functional Cargo Block. It can also transfer propellant from *Zvezda* and *Zarya* to the propulsion system of docked vehicles—Soyuz and Progress. The docking compartment's planned lifetime as part of the station was five years.

## Future

*Pirs* is scheduled to be detached from the nadir (bottom) port of the Zvezda module to make room for the Russian Multipurpose Laboratory Module which is scheduled for launch in December 2011. It would then be destroyed during atmospheric re-entry and become the first ISS module to be decommissioned.

## Airlock specifications

- Length: 4.91 meters
- Diameter: 2.55 meters
- Weight: 3,580 kilograms
- Volume: 13 cubic meters