# Mission Summary

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Mission Summary

On-Orbit Activities
Node 3 and Cupola, the final European-built habitable modules for the International Space Station (ISS), are scheduled to be launched to the ISS on board STS-130 Space Shuttle Endeavour on 7 February 2010 bringing a challenging and successful undertaking to its conclusion. These two modules, which have been undergoing final processing at the Kennedy Space Center will complete the assembly of the non-Russian side of the Station once they are attached. Node 3 and Cupola follow in the footsteps of the European-built Node 2, which was launched to the ISS in October 2007 and ESA’s Columbus laboratory, which has been the central focus of European research activities on the ISS following its launch and installation in February 2008.

The Nodes are the interconnecting elements between the various pressurised modules on the International Space Station, allowing the passage of astronauts and equipment, and providing important resources to the other modules attached such as distribution of electrical power and thermal and environmental control.

The Cupola observation module will provide an unprecedented capability for external ISS operations as a command tower for robotic operations as well as a stunning view of Earth for the ISS Expedition crews on board the orbiting Space Station. Both Node 3 and the Cupola will help in the efficient exploitation of ISS operations and provide the accommodation for facilities intended to improve the well-being of the crew.

The major parts of the STS-130 mission are as follows:

Node 3/Cupola Installation
After Shuttle Endeavour docks to the Station with its six-member crew the Node 3/Cupola composite will be removed from the Shuttle’s cargo bay and installed on the port-side hatch of Node 1 by robotic arm.
Node 2 in STS-120 Space Shuttle Discovery's cargo bay on 26 October 2007 prior to its installation on the ISS. Photo was taken the day after Discovery docked to the ISS. (Image: NASA)

Node 3 Activation and Outfitting
After installation, Node 3 will undergo activation and outfitting including attaching relevant power and data cabling, thermal control and ventilation lines, and installation of internal racks and facilities. This includes the Regenerative Environmental Control and Life Support Systems racks i.e. two Water Recovery System racks and the Oxygen Generation System rack, as well as installation of the Air Revitalization System, a Waste and Hygiene Compartment, a treadmill and the advanced Resistive Exercise Device. The three Regenerative Environmental Control and Life Support Systems racks and the Waste and Hygiene Compartment may be relocated after Shuttle undocking.

The Cupola being moved by crane to a work stand at the Space Station Processing Facility of NASA’s Kennedy Space Center in Florida on 19 November 2008. (Image: NASA/Cory Huston)

Cupola Relocation and Outfitting
The Cupola will be moved by robotic arm from the docking port on the end cone of Node 3 to the Earth-facing port of Node 3. Once attached, the Cupola will also undergo relevant outfitting and activation. After the Cupola is relocated, Pressurised Mating Adaptor 3 (PMA-3) will be relocated from the zenith port of the European-built node 2 to the Node 3 port where Cupola was located for launch.

Interior view of Node 2 on 27 October 2007, following its attachment to the International Space Station during the STS-120 mission. (Image: NASA)

ESA astronaut Frank De Winne, exercises using the advanced Resistive Exercise Device (aRED) in Node 1 of the ISS on 3 June 2009. (Image: NASA)
Three Mission Spacewalks
Three spacewalks are scheduled to take place during the STS-130 mission in support of installation and activation of Node 3 and the Cupola. This includes: preparations for removing Node 3 from the Shuttle’s cargo bay; connecting relevant avionics and power cabling, and ammonia lines following Node 3/Cupola berthing to the ISS; installing handrails, footplate interfaces and gap spanners on the outside of Node 3; removing thermal covers from the Cupola; and removing bolts that secure the shutters over the Cupolas windows. PMA-3 cabling will also be installed during the third mission EVA.

ISS Reboost
As part of the mission the Space Shuttle may be used to reboost the ISS to a higher orbit to account for atmospheric drag. If so this is likely to happen towards the end of the mission.

STS-130 Crew
STS-130 Space Shuttle Endeavour will have a six-member crew, which consists of NASA astronauts George Zamka (commander) Terry Virts Jr. (pilot) and Mission Specialists Nicholas Patrick, Robert Behnken, Stephen Robinson and Kathryn Hire.

Pre-Launch Activities
After almost 12 years of design, development and storage, Node 3 was shipped to NASA’s Kennedy Space Center in Florida in May 2009 and had been undergoing final preparations prior to its launch. This included mating the Cupola to Node 3 on 1 September 2009; loading of ammonia in the heat

To bring important supplies to the ISS
The Shuttle will bring some important supplies and equipment to the ISS for the Expedition crew on board including items of food and clothing and additional equipment for undertaking the routine work on the ISS.
exchanger loops; the Crew Equipment Interface Test, which allowed the STS-130 astronauts to work closely with the hardware they'll be using on orbit; installation of stowage platforms for transporting cargo to the ISS inside Node 3; outfitting and leak testing of the docking port where Node 3 will be berthed to Node 1; installation of a special centre cover on the forward docking port for thermal protection and protection against orbital debris; and additional inspection and close out activities.

Once ESA transferred ownership of Node 3 to NASA on 20 November 2009 the combined European-built modules underwent launch processing including microbial sampling to make sure that no adverse biological organisms are transported to the Station; cargo was installed on the stowage platforms in Node 3; the modules were filled with the correct atmosphere; the Node 3 hatch was closed and sealed and a thermal cover installed. With this complete the Node 3/Cupola was integrated into the Shuttle’s cargo bay.

Transfer of Node 3, or ‘Tranquility’ as it has now been named, in November completed the final major element of the barter agreement between the European Space Agency (ESA) and NASA under which ESA supplied two of the Station’s interconnecting Nodes (Nodes 2 and 3) and additional high-technology laboratory equipment and services to NASA in return for launching the European Columbus laboratory to the ISS in February 2008.
# Key Mission Data

**SHUTTLE CREW:**

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Agency</th>
</tr>
</thead>
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<tr>
<td>Shuttle Commander</td>
<td>George Zamka</td>
<td>NASA</td>
</tr>
<tr>
<td>Shuttle Pilot</td>
<td>Terry Virts Jr.</td>
<td>NASA</td>
</tr>
<tr>
<td>Mission Specialist 1</td>
<td>Nicholas Patrick</td>
<td>NASA</td>
</tr>
<tr>
<td>Mission Specialist 2</td>
<td>Robert Behnken</td>
<td>NASA</td>
</tr>
<tr>
<td>Mission Specialist 3</td>
<td>Stephen Robinson</td>
<td>NASA</td>
</tr>
<tr>
<td>Mission Specialist 4</td>
<td>Kathryn Hire</td>
<td>NASA</td>
</tr>
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**SPACECRAFT:**

- Shuttle Orbiter: **Endeavour**

**MISSION:**

- Shuttle Mission Designation: **STS-130**
- ISS Assembly Flight Designation: **20A**
- Primary Payload: **Node 3 and Cupola**

**LAUNCH and LANDING SITES:**

- Launch Site: **Launch Pad 39A, Kennedy Space Center, Florida, USA**
- Primary Landing Site: **Kennedy Space Center, Florida, USA**
- Secondary Landing Sites: **Edwards Air Force Base, California, USA**; **White Sands Space Harbor, New Mexico, USA**

**MISSION PARAMETERS:**

<table>
<thead>
<tr>
<th>Parameter</th>
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<tr>
<td>Scheduled Launch Date</td>
<td>7 February 2010</td>
</tr>
<tr>
<td>Launch Window</td>
<td>10 minutes</td>
</tr>
<tr>
<td>Altitude (in orbit)</td>
<td>226 kilometres</td>
</tr>
<tr>
<td>ISS Altitude</td>
<td>~340 kilometres</td>
</tr>
<tr>
<td>Inclination</td>
<td>51.6°</td>
</tr>
<tr>
<td>Mission Duration</td>
<td>13 days (Flight Day 1 and Flight Day 14 are partial days)</td>
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</tbody>
</table>
The crew for the STS-130 mission to install the European-built Node 3 and Cupola on the International Space Station consists the following NASA astronauts:

George Zamka: STS-130 Commander
Zamka is a veteran of the STS-120 mission (23 October – 7 November 2007), which installed the European-built Node 2 on the Station and included ESA astronaut Paolo Nespoli as a mission Specialist. The mission also relocated the P6 truss section from the Z1 truss to the end of the port-side main truss. Born in 1962 in Jersey City, New Jersey, USA, Zamka is married, has two children and enjoys weight lifting, running, cycling, scuba diving and boating. With a Bachelor of Science degree in Mathematics and Masters of Science degree in Engineering Management, Zamka had a distinguished Naval pilot’s career when he was selected as a pilot by NASA in June 1998.

Terry Virts: STS-130 Pilot
STS-130 is the first space mission for Terry Virts. Born in 1967 in Baltimore, Maryland Virts is married, has two children and enjoys running, baseball, astronomy, photography, and church activities. Following graduation from the US Air Force Academy in 1989 Virts had a distinguished Air Force pilot’s career when he was selected by NASA in 2000. Virts has carried out various tasks for NASA including lead astronaut for the T-38 program and ISS and Shuttle CAPCOM. Virts is a Masters graduate in Aeronautics.

Nicholas Patrick: STS-130 Mission Specialist
Patrick is a veteran of the 13-day STS-116 mission in December 2006, during which the P5 truss segment was installed on one of the four mission spacewalks, with ESA astronaut Christer Fuglesang as one of the principal EVA astronauts. The mission also freed a solar array which had trouble retracting, and delivered about two tonnes of equipment and
supplies to the station. Born in 1964 in Saltburn-by-the-Sea, North Yorkshire in the United Kingdom, Patrick is married, has three children and enjoys flying, fixing and building things, scuba diving, Tae Kwon Do, and reading to his children. He has a Ph.D in Mechanical Engineering and is a qualified pilot and Flight Instructor. Dr. Patrick had a distinguished career in engineering before being selected by NASA in 1998.

Robert Behnken: STS-130 Mission Specialist
Behnken is a veteran of the STS-123 mission (11-26 March 2008), which delivered the first section of JAXA’s Kibo laboratory to the ISS, and the final element of the station’s Mobile Servicing System, the Canadian-built Special Purpose Dextrous Manipulator known as Dextre. Behnken performed three spacewalks during the mission and was an operator of the Station’s robotic arm and Dextre. Born in Creve Coeur, Missouri, Behnken is married and enjoys mountain biking, skiing, and backpacking. He has a Ph.D. in Mechanical Engineering, and had a distinguished US Air Force career when selected by NASA in July 2000.

Stephen Robinson: STS-130 Mission Specialist
Robinson is a veteran of three Space Shuttle missions: STS-85 (7-19 August 1997) during which he was a robotic arm operator; STS-95 science mission (29 October – 7 November 1998) during which he was Payload Commander as well as robotic arm operator for deployment/retrieval of the Spartan satellite; and the STS-114 Return-to-Flight mission (26 July – 9 August 2005) during which he conducted three spacewalks to evaluate new procedures for flight safety and Shuttle inspection and repair techniques. This included an unplanned and unprecedented repair of Discovery’s heat-shield. Born in 1955 in Sacramento, California he enjoys flying, antique aircraft, canoeing, hiking, playing music, drawing, painting, and stereo photography. With a doctorate in mechanical engineering, Robinson fulfilled numerous research roles for NASA from 1979 before being selected as an astronaut in December 1994.

Kathryn Hire: STS-130 Mission Specialist
Hire is a veteran of the STS-90 Neurolab mission (17 April -3 May 1998), which covered 26 life science experiments focusing on the effects of microgravity on the brain and nervous system. Born in Mobile, Alabama, Hire enjoys competitive sailing, snow skiing, scuba diving, and fishing. With a Bachelor of Science degree in engineering resources and a Master of Science degree in space technology, Hire had a distinguished full time Naval Officer career from 1981 – 1989 before becoming a Naval reserve and thereafter being recalled to active duty for a period. She fulfilled a number of roles at NASA from 1989 before being selected as an astronaut by NASA in 1994.
The STS-130 patch was designed by the crew to reflect both the objectives of the mission and its place in the history of human spaceflight. The main goal of the mission is to deliver Node 3 and the Cupola to the International Space Station (ISS). Node 3, named "Tranquility," will contain life support systems enabling continued human presence in orbit aboard the ISS. The shape of the patch represents the Cupola: the windowed robotics viewing station, from which astronauts will have the opportunity not only to monitor a variety of ISS operations, but also to study our home planet.

The image of Earth depicted in the patch is the first photograph of the Earth taken from the moon by Lunar Orbiter I on 23 August 1966. As both a past and a future destination for explorers from the planet Earth, the moon is thus represented symbolically in the STS-130 patch. The Space Shuttle Endeavour is pictured approaching the ISS, symbolizing the Space Shuttle's role as the prime construction vehicle for the ISS.
The European-built Node 3 is the final one of the three International Space Station Nodes, which will be launched into orbit. The Nodes are the interconnecting elements between the various pressurised modules on the ISS. They provide a shirtsleeve environment to allow the passage of astronauts and equipment through to other Station elements and provide vital functions and resources for the astronauts and equipment.

Node 3 has systems, which provide many different functions and resources to the attached modules, and to itself, for maintaining a safe and ideal working and living environment onboard the ISS. Today’s Node 3 is significantly different to the Node 3 that Europe initially agreed to develop back in 1997. It has evolved over the years from a connecting module into a very complex element, able to accommodate sophisticated crew and life support equipment currently disseminated in other modules of the Station and in particular the laboratory elements. The relocation of this equipment to Node 3 will improve the potential of the ISS laboratories for scientific utilisation.

Node 3 consists of a pressurised cylindrical hull 4.5 m in diameter with a shallow conical section enclosing each end. It is almost 7 m long and will weigh together with the Cupola over 13.5 tonnes at launch. The pressurised shell of Node 3 is constructed from aluminium alloys. This is covered with a multi-layer insulation blanket for thermal
stability and around 75 sections of panelling to act as a protective shield against bombardment from space debris. This panelling is also constructed of an aluminium alloy together with a layer of Kevlar and Nextel.  Internal and external secondary structures are used to support the installation of equipment, piping and electrical harnesses. Two water loops (respectively low-temperature and moderate-temperature loops) allow the rejection of the heat generated inside the element to the ISS ammonia lines by means of two heat exchangers mounted on the external side of one end cone.

Node 3 can be considered in two halves. One half, with a single docking port on one of the end cones where Node 3 will be docked to the ISS. This half also accommodates eight standard-sized racks, which will house relevant systems and equipment.

The other half consists of an additional five docking ports one located on the other end cone and four arranged around the circumference of the cylindrical main body of Node 3. Originally, the Habitation module and the Crew Return Vehicle would also be attached to Node 3 along with the Cupola and Pressurised Mating Adaptor 3 (PMA-3). However the first two elements were removed from the ISS configuration.

In its launch configuration in the Shuttle cargo bay, Node 3 will have the Cupola attached to the end cone that will eventually face out from the Station. Inside Node 3 the eight rack locations will be taken up with two avionics racks, three pallets loaded with cargo for the ISS, with the three remaining rack bays remaining empty.

In its final on-orbit configuration Node 3 will look slightly different. The Cupola will be relocated to the Earth-facing port of Node 3 during the STS-130 mission and PMA-3 will be relocated from the zenith port of the European-built Node 2 to the end cone docking port of Node 3, where the Cupola was attached during launch. The three cargo pallet racks will be removed and returned on Shuttle flight STS-131 in March 2010. In the place of these three rack locations and the three empty
rack locations will come six new racks which are already on the Station. This includes the second Air Revitalisation System rack for on-orbit air composition monitoring, including carbon dioxide removal; an Oxygen Generation System rack for producing oxygen from water; Water Recovery System Racks 1 and 2 for urine and water processing; a Waste and Hygiene Compartment Rack for crew waste and hygiene processing and a second treadmill. Node 3 will also be outfitted with the Advanced Resistive Exercise Device for crew on-orbit physical exercise. All these racks and equipment are necessary since the ISS crew number was increased from three to six in the spring of 2009.

Node-1 and Node 3 and within Node 3. It also provides the line for the transfer of pre-treated urine from Waste and Hygiene Compartment to Water Recovery System racks inside Node 3. Special lines and sectioning devices are adopted to distribute oxygen and nitrogen.

Fire detection is supported by two cabin smoke sensors and monitoring of electrical equipment. Other smoke sensors are used in particular racks. Fire suppression within predefined internal enclosures is by portable fire extinguisher.

Two avionics racks accommodate almost all the electronic units for the command and data handling, audio and video functions, and for the conversion and distribution of the electrical power from the ISS solar arrays to the internal and attached elements. Command and control functions, as well as fault detection isolation and recovery algorithms, are supported by processing capabilities implemented in Node 3 computers.

Two of the three ISS Nodes (Node 2 and Node 3) were made under a contract in Europe, while Node 1 was made under a NASA contract in the USA. Node 1 has been in orbit since December 1998 while Node 2 has been on orbit since October 2007.

Nodes 2 and 3 are an evolution of Node 1. Thales Alenia Space put forward a design for Nodes 2 and 3, deriving from the experience with the MPLMs, that took into account new habitability requirements with the capability to treat and recycle water, cater for personal hygiene and waste, jettison carbon dioxide and generate oxygen.
The Cupola ISS Observation Module

The Cupola will become a panoramic control tower for the International Space Station (ISS), a dome-shaped module with windows through which operations on the outside of the Station can be observed and guided. It is a pressurised observation and work area that will accommodate command and control workstations and other hardware.

Through the Robotics Work Station, astronauts will be able to control the Space Station’s robotic arm, which helps with the attachment and assembly of the various Station elements, very much like the operator of a building crane perched in a control cabin. At any time, crewmembers in the Cupola can communicate with other crewmembers, either in another part of the Station or outside during spacewalk activities.

Spacewalking activities can be observed from the Cupola along with visiting spacecraft and external areas of the ISS with the Cupola offering a viewing spectrum of 360 degrees. Thus, the Cupola will have an important role in external Space Station activities.

However, the Cupola will operate as more than a workstation. With a clear view of Earth and celestial bodies, the Cupola will have scientific applications in the areas of Earth Observation and Space Science as well as holding psychological benefits for the crew.

The Cupola is a 1.6 tonne aluminium structure of about 2 metres in diameter and 1.5 metres high. Its dome is a single forged unit with no welding. This gives it superior structural characteristics,
which helped shorten the production schedule and lower overall costs.

The Cupola is a ‘shirt sleeve’ module with six trapezoidal side windows and a circular top window of 80 cm in diameter, making it the largest window ever flown in space. Each window is built using very advanced technologies to defend the sensitive fused silica glass panes from years of exposure to solar radiation and debris impacts.

Produced from a single forging, Cupola’s dome requires no welds. Shown is the actual flight unit dome just after machining in October 2002 at the Ratier-Figeac facility in Figeac, France (Image: Thales Alenia Space)

The windows are protected by special external shutters, which can be opened by the crew inside the Cupola with the simple turn of a wrist. At the end of their tasks, the window shutters are closed to protect the glass from micrometeoroids and orbital debris, and to prevent solar radiation from heating up the Cupola or to avoid losing heat to space.

Each window has three subsections: an inner scratch pane to protect the so-called pressure panes from accidental damage from inside the Cupola; two 25 mm-thick pressure panes to help maintain the cabin pressure and environment (the outer pane is a back-up for the inner pane); and a debris pane on the outside to protect the pressure panes from space debris when the Cupola shutters are open.

The 10-year on-orbit lifetime calls for user-friendly replacement of the windows while in orbit. The entire window, an astronaut would first fit an external pressure cover over the window during a spacewalk.

NASA astronaut Terry Virts conducts a fit check of the robotic workstation of the Cupola observation module at the Space Station Processing Facility of NASA's Kennedy Space Center on 31 July 2008. (Image: NASA/Cory Huston)

Internally, the Cupola must provide functions to support the presence of two astronauts operating the instruments. Cupola’s internal layout is dominated by upper and lower handrails around the inside of its cabin supporting most of the equipment and by ‘close-out’ panels, which cover the harness and water lines attached to the Cupola. These internal panels form a pressurized air distribution system with the outer structure. These panels are removable to allow inspection and connection of different utilities.

Limited space for the crew and equipment means that the man-machine interfaces have to be optimised for entry and exit from the Cupola and carrying out workstation tasks and maintenance.
Node 3 Internal Racks and Equipment: Environmental Control

Two Water Recovery System Racks delivered to the ISS in November 2008 and the Oxygen Generation System rack which was delivered in July 2006 will be relocated to Node 3 after its arrival. These racks make up the core of the Regenerative Environmental Control and Life Support System.

Water Recovery System Racks
The Water Recovery System racks use a series of chemical processes and filters to treat the astronauts’ urine, perspiration and hygiene water, recycling about 93 percent of the fluid it receives to provide water clean enough to drink.

Recovering water from urine is achieved in the Urine Processor Assembly by spinning up a keg-sized distiller to create artificial gravity. Contaminants press against the side of the distiller while steam in the middle is pumped out. Water from the urine processor is combined with all other wastewaters and delivered to the Water Processor Assembly for treatment. The water processor removes free gas and solid materials such as hair and lint, before the water goes through a series of multifiltration beds for further purification. Any remaining organic contaminants and micro-organisms are removed by a high-temperature catalytic reactor assembly.

This rigorous treatment creates water that meets stringent purity standards for human consumption. The purity of water is checked by sensors, with unacceptable water being reprocessed, and clean water being sent to a storage tank, ready for use by the crew. The Water Recovery System reduces the amount of water that needs to be delivered to the station by about 65 percent, i.e. about 2,850 litres over the course of a year.

Oxygen Generation System Rack
The Oxygen Generation System produces oxygen for breathing air for the crew and laboratory animals, as well as for replacement of oxygen lost due to experiment use, airlock depressurization, module leakage and carbon dioxide venting. The system consists mainly of the Oxygen Generation Assembly and a Power Supply Module.

The Oxygen Generation Assembly electrolyzes, or breaks apart, water provided by the Water Recovery System, yielding oxygen and hydrogen as by-products. The oxygen is delivered to the cabin atmosphere, and the hydrogen is vented overboard. The Power Supply Module provides the power needed by the Oxygen Generation Assembly to electrolyze the water.

The Oxygen Generation System is designed to generate oxygen at a selectable rate and is capable of operating both continuously and cyclically. It provides up to 9 kg of oxygen per day during continuous operation and a normal rate of about 5.5 kg of oxygen per day during cyclic operation.
The Air Revitalization System is one of the Environmental Control and Life Support Systems that will be relocated to the European-built Node 3 when it arrives at the ISS in February 2010. It provides carbon dioxide removal, trace contaminant control, and monitors the major constituents in the cabin atmosphere.

Crew-generated carbon dioxide is removed from the cabin atmosphere by sorbent beds that are designed to absorb carbon dioxide. The beds are regenerated upon exposure to heat and space vacuum. A Trace Contaminant Control System ensures that over 200 various trace chemical contaminants generated from material off-gassing and crew metabolic functions in the habitable volume remain within allowable and safe concentration limits. The cabin atmosphere is analysed by a mass spectrometer, measuring oxygen, nitrogen, hydrogen, carbon dioxide, methane and water vapour present in the cabin.

The Waste and Hygiene Compartment currently in the US Destiny laboratory of the ISS was the second toilet facility to arrive on the Station in November 2008 as part of the STS-126 mission. The first toilet facility is in the Russian Service Module on the ISS.

This Russian-built toilet system is contained in a booth-like compartment and separately channels liquid and solid waste. While the solid waste goes to a holding tank, the Urine Processor Assembly, which forms a major part of the Water Recovery System racks (see above) delivered in November 2008 reclaims drinking water from crew members’ urine.
Node 3 Internal Racks and Equipment: Conditioning/Exercise Equipment

T2 COLBERT Treadmill

The T2 Combined Operational Load Bearing External Resistance Treadmill or COLBERT was temporarily installed in the European-built Node 2 in September 2009 as an important exercise device to keep the ISS Crew healthy while in orbit, and prepare them for return to Earth. It will be relocated to its permanent place in Node 3 after its attachment in February 2010. The T2 treadmill is adapted from a regular treadmill but designed so as not to shake the rest of the Station. This vibration damping system does not use power and hence makes it more reliable.

The astronauts use elastic straps over the shoulders and round the waist to keep them in contact with the running belt and generate the foot force necessary to give the astronaut's bones and muscles a workout in the absence of gravity. The treadmill is also wider than the TVIS treadmill in the Zvezda Service Module of the Station. Although it is built to handle 240,000 km of running, it will likely see about 60,000 km during its time in orbit.

Advanced Resistive Exercise Device

The advanced Resistive Exercise Device (aRED) will not take up a rack location in Node 3 but will still be located in the new European-built ISS module. It was developed to improve existing International Space Station exercise capabilities. It mimics the characteristics of traditional resistive exercises (weighted bars or dumbbells) by providing a more constant force throughout the range of motion. It offers traditional upper and lower-body exercises, such as squats, dead lift, heel raises, bicep curls, bench press, and many others.

The aRED uses vacuum cylinders to provide concentric workloads up to 270 kg, with an eccentric load up to 90 percent of the concentric force. The aRED also provides feedback to the astronaut during use and data to the NASA exercise physiologists. Flight surgeons, trainers and physiologists expect that the greater loads provided by aRED will result in more efficient and effective exercise, thereby preventing the muscle and bone loss that astronauts sometimes experience during long space missions.
Node 3 and Cupola on-orbit activation *

Node 3 and Cupola on-orbit activation *

Launch and Docking
Following launch and opening of STS-130 Space Shuttle Endeavour’s cargo bay doors, the Node 3 heaters will be powered up to provide temperature control of the shell. Node 3/Cupola will be carried in the back or aft section of the Shuttle cargo bay fixed in place by its trunnions and keel fittings. During launch, the Cupola is protected by a multi-layer insulation shroud covering the whole structure. After its two-day journey the Shuttle will dock to Pressurised Mating Adaptor 2 (PMA-2) on the front of the European-built Node 2. During the journey a detailed heatshield inspection will take place using the Shuttle’s robotic arm to confirm the integrity of the Shuttle’s thermal protection.

Node 3/Cupola Installation
After the first full day of activities on the ISS, the first mission spacewalk will take place. This is on flight day 5. Before the first spacewalk begins Node 3 is grappled by the Station’s robotic arm in the Shuttle’s cargo bay. At the start of the 6.5 hour spacewalk the EVA astronauts (Nicholas Patrick and Robert Behnken) will make their way to the Shuttle’s cargo bay to carry out preparations for unberthing Node 3 and Cupola.

The astronauts will remove the cover from Node 3’s Passive Common Berthing Mechanism, i.e. the port where Node 3 will be attached to the Station. They will also disconnect the cables that provide power to the Node 3 heaters which are used to counter the extremely low temperatures reached on the Shuttle’s journey to the ISS.

With the astronauts coming towards the end of the Node 3 unberthing procedures, a signal is sent from inside the Shuttle to release the special latches that hold Node 3 in place. Once released the robotic arm manoeuvres Node 3 from the cargo bay to its attachment point on the left-hand or port side of Node 1. It takes about three hours to unberth Node 3, move it by robotic arm to Node 1, install it, and for the Node 1/Node 3 berthing mechanisms to be completely locked into each other.

Once Node 3 is berthed, the EVA astronauts will reconnect cables to provide initial power to Node 3 heaters, which were active during transport to
the ISS, and will connect avionics cables to Node 3 before finishing the spacewalk. Inside the ISS, following Node 3 berthing, the area between the hatches of Node 1 and Node 3, known as the vestibule is pressurised. After pressurising the vestibule a leak check is undertaken and the Node 1 hatch is opened.

**Entering Node 3**

Flight Day 6 is an important day from a European perspective as astronauts will enter the new European-built ISS module for the first time. Prior to this outfitting of the vestibule between Node 1 and 3 is undertaken i.e. utility cables (air, data etc.) are installed.

With this completed the hatch to Node 3 is opened, intermodule ventilation and temporary lighting is established, and the new Space Station module is entered to prepare for Cupola relocation.

The first racks are installed in Node 3 on flight Day 6. This includes the advanced Resistive Exercise Device and the Air Revitalization System.

**Cupola Relocation and Node 3 Activation**

On Flight Day 7 the cargo in the Node 3 stowage racks is removed and the stowage racks broken down to make way for the racks that will be permanently installed in these locations. It is also the day of the second mission spacewalk.

During EVA 2 Node 3 is connected up to the Station’s ammonia lines which are an integral part of the ISS thermal control systems and will allow for a full activation of Node 3. Associated thermal
Cupola water lines and the relocation of internal closeout panels, are performed on Flight Day 10.

**Cupola Thermal Shroud/Launch Bolt Removal**

The main activities during the third mission EVA on Flight Day 10 are the removal of the insulating blankets covering the Cupola, needed during transfer to the ISS, and removal of the launch bolts that secure the Cupola’s window shutters in place (three bolts per shutter). The thermal shroud is jettisoned on removal. Additional Node 3 related tasks during the EVA include connecting up utility cables to PMA-3, the installation of Worksite Interface Fixtures, to which elements such as EVA footplates can be connected, and disconnecting the temporary heaters power line to Node 3.

The robotic workstation can now be installed inside the Cupola and used by the crew to drive the robotic arm, monitor ATV and HTV berthing, make observations, or just relax and enjoy the view of Earth and the stars.

**Undocking/Landing**

Following a more relaxed day on Flight Day 11 where the crew get some off duty time, the Shuttle undocks from the ISS on Flight Day 12 and is scheduled to land on Flight Day 13 back at the Kennedy Space Center.

The four additional racks to be installed in Node 3 i.e. the two Water Recovery System racks, the Oxygen Generation System rack and the Waste and Hygiene Compartment may be installed on the final day of the mission if an additional mission day is added. Otherwise they will be installed in Node 3 following Shuttle undocking.

(*) All timeline details listed are subject to change prior to launch.
Countdown starts: 43 hours and counting

At 43 hours to launch the countdown clock is activated. This occurs when the Shuttle Test Director verifies that the launch team is in place and ready to proceed. Over the course of the next 16 hours a number of activities take place including activation and testing of the navigational systems; and preliminary inspections of the flight deck. At 27 hours to launch the countdown is put on hold. This hold normally lasts four hours. During this time all non essential personnel are cleared from the launch site.

When the countdown resumes preparations begin to load liquid oxygen and liquid hydrogen into the storage tanks for the orbiter's fuel cells, which provide power for the orbiter during the mission. Upon completion, the launch pad area is reopened. A second hold in the countdown occurs at 19 hours until launch. This again lasts about four hours.

When the next countdown period begins, the orbiter's three main engines are prepared for propellant tanking and flight, the launch pad sound suppression system is filled with water and various close-out activities take place. With 11 hours to launch the longest hold period begins lasting 12-13 hours. Checks take place on guidance, navigation and communication systems, and the Rotating Service Structure is rolled back to its park position.

The clock begins again at 11 hours to launch. The orbiter's fuel cells are activated and all non-essential personnel are cleared from the blast danger area. The payload bay and other orbiter cavities are filled with gaseous nitrogen in preparation for filling the external tank with its super-cold propellants. Another hold period occurs at 6 hours to launch, lasting about two hours. If the launch team verify that the launch criteria are met, during this period, the launch pad is cleared of all personnel and the countdown begins again.

The propellant transfer lines are chilled and loading of the External Tank with almost 2 million litres of propellant (liquid oxygen and liquid hydrogen) begins. Hereafter the Final Inspection Team proceeds to the launch pad to conduct a detailed analysis of the vehicle. During the following hold period at 3 hours to launch tracking antennas at the nearby Merritt Island Tracking Station are aligned for lift-off.
From 3 Hours and Counting to T minus 10

Just after the clock begins with 3 hours to launch the crew departs for the launch pad. After arriving they are assisted into the orbiter via the so-called White Room at the end of the orbiter access arm. The astronauts now carry out voice checks with the Launch and Mission Control Centres at the Kennedy and Johnson Space Centers. The hatch is closed and hatch seal and cabin leak checks take place.

The penultimate hold in the countdown is initiated at 20 minutes to launch at which time the Shuttle Test Director conducts final launch team briefings. Once the countdown begins about ten minutes later the orbiter’s onboard computers and backup flight system are changed to launch configuration. The last hold in the countdown is at 9 minutes to launch. If a go for launch is agreed the final countdown starts.

With 7 minutes 30 seconds until launch the Orbiter Access Arm is retracted and the orbiter’s flight recorders are activated. The orbiter’s elevons, speed brakes and rudder are checked and manoeuvred to their launch position. The main engine nozzles are also checked for readiness.

With just under 3 minutes to launch the liquid oxygen tank is brought to flight pressure and the so-called beanie cap is removed, which prevents ice build up on the oxygen vents. At 2 minutes to launch the crew lock their visors. The external tank’s liquid hydrogen is brought to flight pressure by closing the boil off vent. With 50 seconds to launch the orbiter switches from ground to internal power.

With 31 seconds to launch the Shuttle’s onboard computers start their terminal launch sequence. The sound suppression system is turned on and water begins to pour onto the deck of the Mobile Launch Platform and pad areas to protect the Shuttle from acoustic damage at lift-off. At T minus 11 seconds the Solid Rocket Booster range safety destruct system is activated.
Lift Off to Orbit

The "go for main engine start" command is issued at T-10 seconds. Flares are ignited under the main engines to burn away any residual gaseous hydrogen. The flight computers order the opening of valves which allow the liquid hydrogen and oxygen to flow into the engine's turbopumps. At T-6.6 seconds the Space Shuttle main engines start, throttling to 90 percent thrust in 3 seconds. At this point the Solid Rocket Booster ignition sequence starts and we have lift off.

Launch of the STS-120 Mission on 23 October 2007 with ESA astronaut Paolo Nespoli and transporting the European-built Node 2 to the International Space Station. (Image: NASA)

Once the Solid Rocket Boosters ignite the Shuttle is now committed to launch. The Shuttle lifts off the pad and clears the tower at about 7 seconds after launch. After the tower is cleared Mission control is handed over to the Johnson Space Center.

One minute after launch the dynamic pressures on the Shuttle are greatest at an altitude of 10.2 km. At this point the main engines are "throttled down," to about 75 percent, to keep the dynamic pressures on the vehicle's surface within allowable levels. After passing through this phase, the main engines are throttled up to full power.

At 2 minutes after launch the fuel of the Solid Rocket Boosters is expended. These are thereafter jettisoned from the orbiter. The Shuttle is at an altitude of about 48 km and travelling at a speed of 4650 km an hour. The spent Solid Rocket Booster casings continue to gain altitude up to 75 km before they begin falling back to Earth.

Five minutes after launch, when the spent casings have descended to an altitude of about 5 km, their parachute deployment sequence starts, slowing them for a safe splashdown in the Atlantic Ocean. The boosters are retrieved, and returned to a processing facility for refurbishment.

Recovery vessel towing Solid Rocket Booster casing. (Image: NASA)

For the orbiter, at eight minutes after launch at an altitude of around 100 km, main engine cut-off occurs. The Shuttle is now travelling at a speed of almost 27000 km/h. After main engine cut-off, a brief firing of the orbiter's two Orbital Manoeuvring System thrusters changes the trajectory and orbit is achieved. This takes place just after the external tank has been jettisoned and while the orbiter is flying "upside down" in relation to Earth.


The separated external tank continues on a ballistic trajectory and enters the Earth's atmosphere to break up over a remote area of the Indian Ocean. Meanwhile, an additional firing of the Orbital Manoeuvring System thrusters places the orbiter into its planned orbit.
Deorbit and Landing Procedures

Mission Control give the order to perform the deorbit burn about 1 hour prior to landing. Before performing the deorbit burn the orbiter is turned so that the tail is facing the direction of travel. The Orbital Manoeuvring System engines are fired for 3 to 4 minutes to slow the orbiter down enough to reduce the orbiter's altitude. The orbiter is then turned back to travelling nose first using control thrusters and now freefalls for about 30 minutes using control thrusters to control roll, pitch and yaw. The orbiter enters the upper layers of the Earth's atmosphere at an altitude of about 120 km and travelling at a velocity of 7.6 km per second. On re-entry super-heated plasma envelops the orbiter causing a communications blackout until an altitude of about 45 km.

The orbiter now begins manoeuvres, which will enable it to start final landing procedures at the desired altitude and velocity. The orbiter performs a series of four steep banks, rolling over as much as 60 degrees to one side or the other, to slow down. The series of banks gives the Shuttle's track toward landing an appearance similar to an elongated letter “S.”

With 5 minutes until landing the orbiter is now in subsonic flight, at 14900 m and about 35 km from its touchdown point. The commander takes over control of the orbiter for final approach and landing manoeuvres.

At an altitude of 5000 m the orbiter is now about 16 km from touchdown. As it aligns with the runway, the orbiter begins a steep descent with the nose angled as much as 19 degrees down from horizontal. This is six times steeper than the 3-degree glide slope of a typical commercial jet airliner as it approaches landing.

During the final approach, the vehicle drops toward the runway 20 times faster than a commercial airliner as its rate of descent and airspeed increase. At less than 600 metres above the ground, the commander raises the nose and slows the rate of descent to bring it into its final landing glide slope of 1.5 degrees in preparation for touchdown. With 15 seconds until touchdown the landing gear is deployed.

At touchdown the orbiter is travelling at a speed ranging from 340 to 360 km/h. The drag chute is deployed, and the orbiter coasts to a stop. Once the orbiter has rolled to a stop, the post-landing procedures begin.
Post-Landing Operations

Once the orbiter has rolled to a stop on the runway, post-landing activities get underway involving the Orbiter Recovery Convoy. Mission responsibility has shifted from the Johnson Space Center back to the Kennedy Space Center. The Orbiter Recovery Convoy consists of a number of specially-designed vehicles and a team of specialists who safe and service the orbiter and assist in crew egress. Included in the convoy are 11 special vehicles and units, augmented by various conventional command and emergency vehicles. The main job of the recovery convoy is to service the orbiter, prepare it for towing, assist the crew in leaving the orbiter and finally to tow it to servicing facilities.

After landing, the first staging position of the convoy is 60 m up wind from the orbiter. The safety assessment team moves to about 30 m of the port side of the orbiter. A crew dressed in protective clothing moves to the rear of the orbiter to test for possible explosive hazards and toxic gases. If present in high levels and if calm weather conditions the Vapour Dispersal Unit moves in to blows away the potentially dangerous gases using a mobile wind machine.

As soon as it is possible lines are attached to the orbiter to determine the on board hydrogen concentration. If the concentration is less than 4 percent, convoy operations continue. However, if it should be greater than 4 percent, an emergency power down of the orbiter is ordered. The flight crew is evacuated immediately and the convoy personnel clear the area and wait for the hydrogen to disperse. If the hydrogen level is below 4 percent, the flow of coolant and purge air through the umbilical lines begins. Purge air provides cool and humidified air conditioning to the payload bay and other cavities thereby removing any residual explosive or toxic fumes.

When it is determined that the area around and in the orbiter is safe, additional post-landing operations can begin. The first priority is to assist the flight crew off the orbiter. The Crew Hatch Access Vehicle moves to the hatch side of the orbiter and the access to the white room is secured. The hatch is opened and a physician boards the orbiter to make a brief medical examination of the crew. The crew then leaves the orbiter and departs.

The flight crew is replaced on board the orbiter by an exchange crew who make preparations for ground towing operations, installing switch guards and removing data packages from onboard experiments, if required. Meanwhile, after allowing for a 30-minute orbiter tire cool down, the orbiter is prepared for towing. The Tow Vehicle is then positioned in front of the orbiter and the tow bar connection is made. Finally, about two hours after landing the orbiter is towed off the runway.
Space Shuttle System

On April 12, 1981, Space Shuttle operations commenced with the launch of Columbia on the STS-1 mission. NASA’s fleet of orbiters has comprised five ships to date: Challenger, Columbia, Discovery, Atlantis and Endeavour. Endeavour, which is the chosen orbiter for the STS-130 mission was the fifth orbiter constructed, undertaking its first mission in 1992. Highlights of its 22 missions to date include the STS-88 mission, which transported the Unity Node as the second ISS module into orbit in December 1998, the Shuttle Radar Topography Mission (STS-99) in February 2000 with ESA astronaut Gerhard Thiele, the STS-100 mission in 2001, which brought Umberto Guidoni as the first European astronaut on mission to the ISS, the STS-111 ISS assembly mission with ESA astronaut Philippe Perrin in June 2002, and two flights to bring major elements of the Japanese Kibo laboratory to the Station (STS-123/STS-127) in March 2008 and July 2009.

Discovery has undertaken 37 missions since its first flight in August 1984 including delivery of the European-built Node 2 to the ISS in October 2007 (STS-120), which included ESA astronaut Paolo Nespoli as a member of the crew. It was Discovery that was also used in December 2006 and in August/September 2009 for Christer Fuglesang’s two two-week missions (STS-116 and STS-128) during which he undertook EVAs for ISS assembly including running cables in preparation for Node 3 installation, and installation of the ISS P5 truss section. The first of these missions also brought ESA astronaut Thomas Reiter back to Earth after serving almost six months on the ISS as the first European ISS Expedition crew member.

Other missions on Discovery include deployment of the Hubble Space telescope in 1990 (STS-31), the Spacelab IML-1 mission (STS-42) with ESA astronaut Ulf Merbold, in 1992, the third Hubble Space Telescope servicing mission (STS-103) in 1999 with ESA astronauts Claude Nicollier and Jean-Francois Clervoy, and transport to the ISS of the Z1 truss element (STS-92), the European-built Multi-Purpose Logistics Module ‘Leonardo’ (STS-102, STS-105 and STS-121), the Japanese Kibo laboratory (STS-124) in June 2008 and the final truss element, S6 (STS-119) in March 2009.

Discovery approaches the International Space Station carrying the European-built Node 2 in its cargo bay on 25 October 2007 (Image: NASA)

ESA astronaut Christer Fuglesang prepares a meal at the galley on the middeck of Space Shuttle Discovery on 11 December 2006. (Image: NASA)
The Space Shuttle System

Atlantis was first launched in October 1985 and has undertaken 31 missions, which include transportation of ESA’s Columbus laboratory to the Station (STS-122) in February 2008, a mission that included ESA crew members Hans Schlegel and Léopold Eyharts, who became an ISS Flight Engineer.

Other Atlantis missions include the deployment of ESA’s European Retrievable Carrier (EURECA) and operation of the Tethered Satellite System on the STS-46 mission in 1992 with ESA astronaut Claude Nicollier and Italian Space Agency astronaut Franco Malerba, transportation of the US Destiny laboratory, the Quest Airlock and two truss elements to the ISS on four separate ISS missions (STS-98, STS-104, STS-110 and STS-112), the final Hubble Servicing mission (STS-125) in May 2009, and the last current Shuttle mission (STS-129) to the ISS in November 2009.

Challenger was lost on launch in January 1986 on its tenth mission and Columbia was lost prior to landing on its 28th mission in February 2003.

The Space Shuttle or Space Transportation system (STS) consists of three major component parts: The orbiter, which most people refer to as the Space Shuttle, the external tank, which holds the orbiter’s propellant and the solid rocket boosters which provide the most lift during the first two minutes of flight. Together they have a length of 56 metres and weigh more than 2,000 tonnes.
at lift-off. The Space Shuttle has a lift-off thrust of over 3,240 tonnes and is capable of carrying a cargo of just over 28 tonnes into orbit. A normal mission lasts between 5 and 16 days. Since 1981 around 800 astronauts have flown on Shuttle and it has put well over 1500 tonnes into orbit. Since the Columbia accident in February 2003 there have been improvements made to all elements of the Shuttle.

The Space Shuttle System

The Orbiter

The 37-metre long orbiter is the element of the Space Shuttle system which contains the crew and returns the crew to earth at the end of their orbital mission. It also contains relevant equipment and supplies, either for use by the Shuttle crew on a non-ISS Shuttle mission, or additionally by the ISS Expedition Crew when on an ISS mission. To protect the orbiter from the up to 1600 °C temperatures during re-entry, all surfaces are covered with thermally protective materials. The main types of thermal materials used are Reinforced Carbon-Carbon (RCC), low- and high-temperature reusable surface insulation tiles, felt reusable surface insulation blankets and fibrous insulation blankets. RCC is used amongst other places on the wing leading edges where improvements have been made to prevent heat flow getting inside the wing structure.

The forward fuselage contains the 65.8 m³ crew station module. This pressurised three-section compartment contains areas for working, living and stowage. It consists of the flight deck, the middeck/equipment bay and an airlock. Four crew members seats are on the flight deck. On the forward flight deck there are more than 2000 displays and controls with the commander’s seat positioned on the left and the pilot’s seat on the right.

The middeck contains the three other crew seats together with provisions and stowage facilities, four crew sleep stations the waste management system, the personal hygiene station and the work/dining table. Outside the aft bulkhead of the crew module in the payload bay, a docking module and a transfer tunnel with an adapter can be fitted to allow crew and equipment transfer for docking, Spacelab and extra-vehicular operations.

The 18-metre long, 5-metre wide mid fuselage is the location of the cargo bay and cargo bay doors. It is in this cargo area that Node 2 was carried to the ISS on the STS-120 mission in October 2007, the European Columbus Laboratory was carried to the ISS on the STS-122 mission in February 2008 and in which the MPLMs are carried as pressurised cargo containers for resupplying the ISS. The cargo bay is the location of the Shuttle’s Remote Manipulator System or robotic arm which
is controlled from the flight deck. This allows payloads to be deployed out of the cargo bay, payloads to be grappled and secured in the cargo bay for return to Earth, and also used for carrying out detailed inspection of the Shuttle’s heat shields following insertion into orbit.

The 5.5 metre long aft fuselage consists of the left and right orbital maneuvering systems, Space Shuttle main engines, body flap, vertical tail and orbiter/external tank rear attachments. The orbiter has a wingspan of 24 metres and, on the runway, a height of 17 metres. It has an in-orbit altitude of between 185 and 643 kilometres, with a velocity of 28,000 km/h. The orbiter’s engines exert a thrust of over 170 tonnes at sea level.

**External Tank**

The External Tank is the fuel tank for the orbiter. It contains the propellants used by the Space Shuttle main engines. It has been redesigned to eliminate the possibility of foam coming off during launch which could potentially damage the Shuttle. When it's empty the External Tank weighs more than 35 tonnes and can carry almost 720 tonnes of propellant, more than 616 tonnes of liquid oxygen and nearly 103 tonnes of liquid hydrogen.

The External Tank is 47 metres long and acts as the "backbone" of the Shuttle during the launch, providing structural support for attachment with the solid rocket boosters and orbiter. The tank is the only component of the Space Shuttle that is not reused. Approximately 8.5 minutes into the flight, with its propellant used, the tank is jettisoned at an altitude of approximately 110 kilometres above the Earth. The now nearly empty tank separates and falls in a preplanned trajectory with the majority of it disintegrating in the atmosphere and the rest falling into the ocean.

The three main components of the External Tank are an oxygen tank holding a volume of more than 540,000 litres of liquid oxygen, located in the forward position, an aft-positioned hydrogen tank holding more than 1,450,000 litres of liquid hydrogen and a collar-like intertank, which connects the two propellant tanks, houses instrumentation and processing equipment, and provides the attachment structure for the forward end of the solid rocket boosters.

The hydrogen tank is 2.5 times larger than the oxygen tank but weighs only one-third as much when filled to capacity. The reason for the difference in weight is that liquid oxygen is 16 times heavier than liquid hydrogen.
The aluminium skin of the External Tank is covered with a thermal protection system that is a 2.5-centimetres thick coating of polyisocyanurate foam. The purpose of the thermal protection system is to maintain the propellants at an acceptable temperature, to protect the skin surface from aerodynamic heat and to minimize ice formation.

The External Tank includes a propellant feed system to duct the propellants to the orbiter engines, a pressurisation and vent system to regulate the tank pressure, an environmental conditioning system to regulate the temperature and render the atmosphere in the intertank area inert, and an electrical system to distribute power and instrumentation signals and provide lightning protection. The tank's propellants are fed to the orbiter through a 43-centimeter diameter connection that branches inside the orbiter to feed each main engine.

**Solid Rocket Boosters**
The two Solid Rocket Boosters (SRBs) operate in parallel with the main engines for the first two minutes of flight to provide the additional thrust needed for the orbiter to escape the gravitational pull of the Earth. Each booster is over 45 metres long and weighs about 590 tonnes at lift-off. At an altitude of approximately 45 km, the boosters separate from the orbiter/external tank, descend on parachutes, and land in the Atlantic Ocean where they are recovered and thereafter refurbished for reuse. The boosters also assist in guiding the entire vehicle during initial ascent. Thrust of both boosters is equal to 2,400 tonnes.

In addition to the solid rocket motor, the booster contains the structural, thrust vector control, separation, recovery, and electrical and instrumentation subsystems.

The solid rocket motor is composed of a segmented motor case loaded with solid propellants, an ignition system, a movable nozzle and the necessary instrumentation and integration hardware. Each solid rocket motor contains more than 450 tonnes of propellant, which requires an extensive mixing and casting operation. The solid fuel is actually powdered aluminium, mixed with oxygen provided by a chemical called ammonium perchlorate.

Following the Columbia accident in 2003 there have been redesigns of the bolt catchers which catch part of the bolts that hold the boosters to the external tank during booster separation and the booster separation motors which push the boosters away from the external tank during separation.
Launch and Landing Site

Aerial view of Space Shuttle Endeavour on Launch Pad 39B, one of the two Shuttle launch pads at the Kennedy Space Center in Florida. 19 September 2008 (Image: NASA/Troy Cryder)

Space Shuttle Endeavour will be launched from Launch Complex 39A of NASA’s Kennedy Space Center, Merritt Island in Florida, just north of Cape Canaveral. Launch pads 39A and B were originally constructed in the 1960’s for launching the Apollo missions and have been used to launch the Apollo, Skylab, Apollo-Soyuz and Space Shuttle missions.

The Space Shuttle is transported to the octagonal-shaped launch pad by a large tracked crawler. Each launch pad has a 106-metre tall Fixed Service Structure with three retractable swing arms and a Rotating Service Structure, which rotates around the orbiter. New coatings were put on the service structures to deal with the critical debris issue.

The retractable swing arms of the Fixed Service Structure provide access to the Shuttle on the pad. The lowest arm provides access to the orbiter crew compartment and acts as an emergency escape route for the crew up to seven minutes, 24 seconds before launch. The middle arm is used amongst other things for attachment of umbilicals to the external tank to support tanking and launch. The highest arm contains a vent hood, which is used to prevent ice formation at the liquid oxygen vent system at the top of the external tank.

The 40-metre high Rotating Service Structure provides protected access to the Shuttle orbiter for installation and servicing of payloads at the launch pad, as well as servicing access to certain systems on the orbiter. It is retracted before launch.

Shuttle Discovery on launch pad on 16 December 1999 prior to launch of STS-103 Hubble Space Telescope servicing mission with ESA astronauts Claude Nicollier and Jean-Francois Clervoy. Rotating Service Structure (left) shown rolled back. (Image: NASA)
Launch and Landing Site

A Recovery Convoy Staging Area, located just east of the runway about midway along its length, houses trailers, mobile units and specially designed vehicles that are used to “safe” the orbiter immediately after landing for crew egress and transfer of the orbiter to the Orbiter Processing Facility.

If for some reason it is not possible to land at the Kennedy Space Center, due to weather for example, back up Shuttle landing sites are located at Edwards Air Force Base in California or at the White Sands Space Harbor in New Mexico.

There is a 3400 m$^3$ tank for storing liquid oxygen at -183 °C and a 3200 m$^3$ tank for storing liquid hydrogen at -253 °C. There is also an 1100 m$^3$ tank for storing water for sound suppression purposes. The launch pad contains a flame trench, which is 150 metres long, 13 metres deep and 18 metres wide.

As a majority of Shuttle orbiters, the STS-130 Endeavour return flight with ESA is scheduled to land at the Kennedy Space Center on one of the largest runways in the world. The runway is located 3.2 km northwest of the Vehicle Assembly Building and is 4,572 meters long and 91.4 meters wide.

The facility includes a 150 x 168 meter parking apron and a 3.2 km tow-way connecting it with the Orbiter Processing Facility. Located adjacent to the parking apron is a Landing Aids Control Building (LACB) which supports landing operations and houses operations personnel. The Shuttle Landing Facility is equipped with a number of navigation and landing aids to assist Shuttle pilots in landing.

Orbiter Atlantis landing at the Kennedy Space Center bringing the STS-122 Columbus ISS assembly mission to a conclusion and ESA astronaut Hans Schlegel back to earth on 20 February 2008. (Image: NASA)

Water tank on launch pad 39A prior to launch of the STS-128 mission, which included ESA astronaut Christer Fuglesang as one of the crew members. 24 August 2009 (Image: NASA)
Control and monitoring of the Shuttle during the countdown and first seven seconds after launch takes place in one of the four firing rooms of the Launch Control Center at the Kennedy Space Center in Florida.

The Firing Room contains consoles associated with many different functions. The Launch Director heads the Firing Room having overall responsibility for management of launch activities and making the final determination to launch or stop.

The consoles are used to monitor the Shuttle systems during countdown and the first few seconds of launch including: navigation, guidance and flight control systems; main engine parameters to verify acceptance for main engine start; control system thrusters; Environmental Control and Life Support Systems; and electrical power systems.

Launch pad systems are also controlled from the Firing Room consoles. This includes functions such as loading the external tank with propellant around eight hours before liftoff and retraction of the Orbital Access Arm through which the crew enter the Shuttle prior to launch.

During the last nine minutes, most of the final configurations and systems checks are carried out by the computers, but the firing room engineers are still carefully checking everything to make sure that the Shuttle is still ready for launch.

At T-31 seconds, an automatic command is sent to the Shuttle on-board launch sequencer that allows the Shuttle to start its engines and launch. Once the Shuttle boosters are ignited the Shuttle is launched. After seven seconds when the Shuttle has cleared the service tower on the launch pad, the control is handed over to the Mission Control Center in Houston.

In addition to space shuttle processing and launching, Kennedy is also the preferred end-of-mission landing. On landing day a team of engineers monitor the orbiter in the firing room. Once the orbiter lands and rolls to a stop, Kennedy Space Center once again take over responsibility from the Mission Control Center in Houston.
Mission Control Center – Houston, Texas
(Overall Control of ISS activities and Space Shuttle Flight Control)

The NASA Mission Control Center, located at the Lyndon B. Johnson Space Center in Houston, Texas has been operational in the control of NASA Human Spaceflight launches since 1965. There are different Flight Control Rooms at the control centre covering ISS Operations and Shuttle flights.

The ISS Flight Control Room began operations on 20 November 1998. It acts as the command and coordination centre for all ISS activities, including ISS flight control. The Shuttle Flight Control Room takes control of Shuttle flight operations from the Kennedy Space Center seven seconds after a Shuttle launch, when the Shuttle has cleared the service tower until the shuttle rolls to a stop following landing.

The equipment and supporting structures in each control room are basically identical, though the ISS Flight Control Room is smaller with fewer consoles and requires fewer flight controllers. The ISS Flight Control Room normally operates with 12 or less flight controllers compared to about 20 in the Shuttle Flight Control Room. The consoles in each control room are associated with specific functions. A flight controller occupies each console with secondary support supplied by other engineers and flight controllers in different locations.

Work is undertaken in shift teams, monitoring systems and activities 24 hours a day with the use of sophisticated communications, computers, and data handling equipment. Each control room has large display screens at the front, two in the ISS Flight Control Room and three in the Shuttle Flight Control Room, and cameras for provision of live broadcasts.

The individual functions in the Flight Control Room start with the Flight Director. The Flight Director is the primary decision maker and responsible for the overall ISS or Shuttle mission operations. Next to him sits the capsule communicator or CAPCOM who is the primary communicator between the control room and the crew.

Other functions relate to guidance, navigation and control, and flight dynamics; monitoring ISS or Shuttle thermal control, power availability and life support systems; mission control and ISS or Shuttle infrastructure and communications systems; robotic arm operations; EVA and robotics operations; crew operations planning; crew health and Public Affairs. The Shuttle Control Room has additional functions such as for monitoring the performance of the main engine, solid rocket boosters, external tank and propulsion systems.
ESA’s Columbus Control Centre (Col-CC) will be supporting the European Columbus Laboratory on orbit during the STS-130/Node 3/Cupola mission. It is situated at the German Aerospace Center (DLR) facility in Oberpfaffenhofen, near Munich, Germany.

The Control Centre is the direct link to the Columbus Laboratory in orbit. Its main functions are to command and control the Columbus laboratory systems, to coordinate operations of the European payloads on board the ISS and to operate the European ground communications network.

In its main function of commanding and controlling the systems of the Columbus Laboratory, the Columbus Control Centre will be making sure that astronauts working within Columbus have a safe and comfortable environment in which to work and that the payload facilities have the necessary system support in order to function properly. This will include monitoring and configuring, by remote command, the life support systems to maintain air quality, the power supply to experiment facilities, and systems for removal of heat from experiment facilities.

European and non-European astronaut activities inside Columbus will be monitored and coordinated from the Columbus Control Centre. The Control Centre also holds overall responsibility for such issues as safety in the Columbus Laboratory under the overall authority of the ISS Mission Control Center in Houston, Texas. The Columbus Control Centre will react to any changes during the mission, coordinating decisions and establishing priorities should any change interfere with the European experiments inside Columbus.

The Columbus Laboratory has experimental facilities both internally and externally covering a multitude of experiments over the course of its lifetime. The involvement of the astronauts with...
these experiments could range from a high
degree of interaction to only some activity limited
to the integration and removal of the experiment
from its processing location.

Any autonomous activities of the Columbus
Laboratory systems and experiment facilities are
monitored and coordinated through the Columbus
Control Centre. The Columbus systems are
configured as and when necessary to account for
alterations in procedures or a change within the
payload facilities. All data coming from the
Columbus Laboratory is routed by the Columbus
Control Centre, exercising its role as network
operations centre. The engineering data is
archived at CoI-CC whereas the scientific and
relevant experiment and facility data is distributed
to de-centralised User Support and Operations
Centres or USOCs, where these are processed
and archived.

The Columbus Control Centre is responsible for
distributing data to the USOCs and receiving
information from them such as requests for
resources and reconfiguration of Columbus
systems in support of experiments and payload
facility operations. Such information, is fed into the
mission planning process that generates timelines
for flight controllers and astronauts.

The USOCs are based in national centres
distributed throughout Europe and are responsible
for the specific operations of the ESA payload and
experiment facilities within the Columbus
Laboratory. At these centres scientific investigators
can monitor, or be linked to, their experiments.

The Columbus Control Centre is also linked to the
European Astronaut Centre in Cologne, which is
responsible for medical support, monitoring, and
safety of ESA astronauts during missions.

Since the Columbus laboratory itself hosts non-
European experiments such as US payload
facilities, decisions taken such as changes in
scheduling are coordinated with the ISS
international partners. For this reason the
Columbus Control Centre is connected to the ISS
Mission Control Center at the Johnson Space Center in Houston, the Huntsville Operations Support Center in Huntsville, Alabama, and to the ISS Mission Control Centre in Moscow.

Further to its functions of command and control of Columbus Laboratory systems as well as the coordination of the Columbus payload operations, the Columbus Control Centre is responsible for operating the ground communications network that provides communication services (voice, video and data) to a large number of sites: ESA Operations Management at ESA/ESTEC; the USOCs; the European Astronaut Centre; industrial engineering support sites; and to the Automated Transfer Vehicle (ATV) Control Centre in Toulouse, France. The ATV is the European-built ISS re-supply ship, the first of which (Jules Verne) was launched on 9 March 2008 by an Ariane 5 rocket from Kourou, French Guiana. The ATV Control Centre coordinates and supports all ATV operations for ESA.

The Integrated Columbus Control Centre Flight Control Team is a joint DLR and EADS Astrium team. This mission control service is provided as part of the overall end-to-end operations service delivered by EADS Astrium as the ISS Industrial Operator. The Flight Control Team is led by DLR flight directors and is under the overall supervision of an ESA Mission Director based at DLR Oberpfaffenhofen.

The Columbus Control Centre has two control rooms: one for real-time operation control and one for preparation activities, such as the training of controllers, simulations, etc. The second control room also acts as a backup for the first control room. A back-up control centre, which can take over operations in case of a major disaster such as fire in the control facility, is provided on site of DLR but not located in the same building.
Organisations and Industry

Nodes Development
The construction of the two European supplied ISS Nodes (Node 2 and Node 3) forms part of the Columbus launch agreement, a barter agreement signed between ESA and NASA on 8 October 1997 in Turin, Italy. Originally the European Columbus laboratory would have been launched on an Ariane 5 though downscaling of the laboratory and the cost saving influence of using the MPLM principal structure for Columbus led to the switch to a Shuttle launch.

Under this agreement, in exchange for NASA launching Columbus and its initial payload aboard the Space Shuttle, ESA would provide two of the Station’s three Nodes, spares and sustaining engineering for laboratory support equipment and additional hardware and services.

On 12 December 1997 ESA signed an agreement with the Italian Space Agency (ASI), which placed responsibility for developing Node 2 and Node 3 with ASI. Under this agreement, ESA entrusted ASI with the management until 2004 when the decision was made to transfer back the management to ESA until programme completion. Alenia Aerospazio (now part of Thales Alenia Space) in Turin was selected as the prime contractor, leading a consortium of European industrial companies.

This agreement enabled Europe to take full advantage of the experience gained by Italian industry through the development of the Multi-
Purpose Logistics Modules (MPLMs) and synergies between the MPLMs, Nodes 2 and 3, and the European Columbus laboratory module, which all use the same structural concept. The ESA/ASI agreement also fostered an increasing use of common subcontractors for the Node and Columbus electrical harnesses and Mechanical Ground Support Equipment (OHB in Germany) and thermal control subsystems (Microtecnica, Italy, part of Hamilton Sundstrand).

The advantage of the barter agreements is that European industry has developed hardware for the Station using ESA funds, rather than ESA paying NASA in dollars for the Columbus launch. This helps to avoid the risk of price uncertainties and helps in the creation of additional industrial work for Europe in high-technology domains.

**Cupola Development**
The Cupola programme is the result of a bilateral barter agreement between ESA and NASA under which the European Space Agency provides the Cupola for the International Space Station in exchange for Shuttle transportation of European equipment and experiments for the Station.
The requirements for Cupola’s contract demanded innovative concepts that met not only stringent technical specifications but also produced a high-quality product on schedule and at minimum cost. The subsequent contract to develop the Cupola for the European Space Agency was signed on 8 February 1999 with Italian company Alenia Spazio (Now part of Thales Alenia Space). Under this contract, Alenia Spazio would act as prime contractor for the 20 million euro project. In addition to the Cupola contract, Thales Alenia Space was also responsible for integration and development of other key elements needed for the ISS. These include the European Columbus Laboratory (launched to the ISS in February 2008 on the STS-122 mission), Node 2 (launched to the ISS in October 2007 on the STS-120 mission) and Node 3.

As prime contractor, Thales Alenia Space coordinated an industrial team of 6 other European companies. The Cupola shutters were built by CASA (Spain) and the meteorite and debris protection system and mechanical ground support equipment came from APCO (Switzerland). SAAB Ericsson (Sweden) produced the harness, Lindholmen Development (Sweden) was in charge of the Cupola mock-up and associated ergonomics analysis, while EADS Space Transportation was in charge of life support analysis. Verhaert (Belgium) was responsible for producing the support structure for the Cupola’s grapple fixtures used for manoeuvring the Cupola in Space, and so-called change-out covers. Verhaert further participated in development of the Cupola’s secondary structure, which was developed primarily by Thales Alenia Space.

In addition to developing the Cupola, Thales Alenia Space was responsible to ESA for the
design, verification and delivery of the Cupola and associated ground support equipment, and for providing on behalf of ESA, support to NASA for tests, pre-launch activities and in-orbit commissioning. After integration and testing at Thales Alenia Space’s Turin facility, the Cupola was transported to the Kennedy Space Center in 2004 for final verification tests before going into storage for a few years, and thereafter being prepared for launch.

During pre-launch procedures in Space Station Processing Facility at the Kennedy Space Center in Florida, the Cupola is being aligned with Node 3 prior to the two modules being mated together in their launch configuration. 31 August 2009. (Image: NASA/Jim Grossmann)

**Barter Agreements**

The element common to all of the barter agreements is that goods and/or services are exchanged by the parties involved without a corresponding financial transaction. For ESA, this approach is especially interesting in those cases where it avoided the need to make cash payments to non-Member States, and instead permit money to be invested with European industry. In addition, the barter agreements made it possible for ESA to fix the costs associated with early utilisation of the ISS by European users prior to the start of the operations of ESA’s Columbus Laboratory, as well as the costs for launch and transportation services provided by NASA, thereby avoiding any risk of later price escalations.

Launch of the Columbus Laboratory on 7 February 2008. This formed part of the barter agreement whereby ESA developed two ISS Nodes in return for launch of the European laboratory. (Image: NASA)

The implementation of the barter agreements made it possible to allocate additional, technologically challenging work to European industry worth more than 300 million euros. The introduction of the barter arrangements has helped a lot in reducing costs for the ISS partners, has helped to streamline the development efforts and to increase the spirit of partnership in the ISS programme and, above all, is a very practical means of implementing cooperation on the basis of no exchange of funds.
The International Space Station is a co-operative programme between United States, Russia, Canada, Japan and ten Member States of the European Space Agency (Belgium, Denmark, France, Germany, Italy, The Netherlands, Norway, Spain, Sweden and Switzerland).

It is governed by an international treaty, signed by these Member States on 29 January 1998, called the ISS Intergovernmental Agreement, which provides the framework for design, development, operation, and utilisation of a permanently inhabited civil Space Station for peaceful purposes.

Furthermore, bilateral Memoranda of Understanding exist between NASA and each of the four associated space agencies: The European Space Agency (ESA), the Russian Federal Space Agency (Roscosmos), the Canadian Space Agency (CSA) and the Japanese Aerospace Exploration Agency (JAXA), outlining relevant ISS responsibilities, obligations and rights between the agencies.

National jurisdiction of the International Partner States extends to the ISS elements in orbit. This applies to areas such as criminal matters, liability issues, and protection of intellectual property rights.

Utilisation rights are outlined in the Memoranda of Understanding. The European Space Agency allocation rights comprise 8.3% of the Space Station utilisation resources including, in particular, 8.3% of crew time, which represent approximately 13 hours per week. In compensation for the provision of the resources (energy, robotics, cooling, telecommunications, etc.) to the Columbus Laboratory by NASA and CSA, Europe provides 49% of the laboratory’s utilisation resources to NASA and 2% to the CSA.

One important point is that ESA and the other Space Station International Partners can barter or sell their unused utilisation rights among themselves and to other non-participants to the Station’s programme.
ISS and Europe’s Major Contributions

Columbus Laboratory
Columbus, which was launched in February 2008 is ESA’s Research laboratory on the International Space Station. It provides space for research facilities in the fields of material science, fluid physics and life science. In addition, an external payload area can accommodate experiments and applications in the fields of space science, Earth observation, technology and innovative sciences from space. Columbus is permanently stationed at the International Space Station, attached to another European-built module, Node 2.

Node 2 and Node 3
Nodes are pressurised modules that interconnect the research, habitation, control and docking modules of the ISS. The Nodes are used to control and distribute resources between the connected elements. The ISS will have three Nodes. Node 1, called Unity, was developed by NASA. It became the second module of the ISS in orbit after its launch in December 1998. Node 2 and 3 are developed under an ESA contract with European industry with Thales Alenia Space as the prime contractor.
Node 2 became the first European Node to be launched on 23 October 2007. It acts as a connection point for the European Columbus laboratory, the US Laboratory Destiny and the Japanese Laboratory Kibo. It is also the attachment point for the Japanese H-II Transfer Vehicle, carries a docking adapter for the US Space Shuttle, and acts as an attachment point for the Multi-Purpose Logistics Modules (MPLMs). The MPLM is a pressurised cargo container, which travels in a space shuttle cargo bay. Node 2 also provides a working base point for the Space Station Remote Manipulator System, a Canadian robotic arm on the ISS called Canadarm 2.

Node 3 will become the second European node and final European-built pressurised module to arrive at the ISS on the STS-130 mission in February 2010 and will be attached to the American-built Node 1, which was launched to the ISS in December 1998. The Earth-facing port of Node 3 will act as the connecting point for the European-built Cupola.

Ownership for Node 2 and Node 3 were transferred to NASA within the framework of a barter agreement between ESA and NASA.

Automated Transfer Vehicle (ATV)
The Automated Transfer Vehicle is Europe’s unmanned supply vehicle for the ISS. It was first launched from the European Spaceport in Kourou, French Guiana, on 9 March 2008. It can take up to 7.5 tonnes of cargo to the ISS, boost the station to a higher orbiting altitude and remove up to 5.5 tonnes of waste from the station. It measures 10.3 metres long by 4.5 metres in diameter, with solar arrays spanning more than 22 metres for generating its electrical power. Cargo transported includes pressurised cargo, water, air, nitrogen, oxygen and attitude control propellant.

European Robotic Arm (ERA)
The European Robotic arm or ERA is a robotic arm, which serves to install solar arrays on the Russian section of the ISS. It further acts as an inspection tool on the Russian segment of the ISS and can carry out additional assembly and replacement tasks on the external surface of the station such as on the Russian Research Module and Multipurpose Laboratory Module. The 11-metre long ERA also serves to support or transfer astronauts carrying out tasks on spacewalks. It has an extensive range, as it is able to walk around...
The European Robotic Arm (ERA). (Image: ESA/D. Ducros)

the Russian segment of the station and while in orbit is able to manipulate up to 8000 kg of mass. ERA is scheduled to arrive at the ISS in 2012.

Data Management System (DMS-R)

Europe’s DMS-R Data Management System was the first piece of European hardware on the ISS in July 2000. It includes three fault-tolerant computers and two control posts. It is the ‘brain’ or control centre of the Russian Segment of the ISS and carries out a great degree of the vital and fundamental functions on the station including: guidance, navigation and control of the entire ISS; failure management and recovery; and control of additional ISS systems and subsystems.

Cupola Observation Module

The Cupola will become a panoramic control post for the ISS, a dome-shaped module with windows through which operations on the outside of the Station can be observed and guided. It is a pressurised observation and work area that will accommodate command and control workstations and other hardware.

Through the Robotics Work Station, astronauts will be able to control the Space Station’s robotic arm, which helps with the attachment and assembly of the various Station elements. However, the Cupola will operate as more than a workstation. With a clear view of Earth and celestial bodies, the Cupola will have scientific applications in the areas of Earth Observation and Space Science as well as holding psychological benefits for the crew. It is scheduled for launch to the ISS on the STS-130 mission along with Node 3 in February 2010.
Credits and Contacts

Credits

This document has been compiled, produced and written by the Coordination Office of the European Space Agency’s Directorate of Human Spaceflight in Noordwijk, The Netherlands. It has been compiled from internal ESA sources with additional images and information kindly supplied by the following organisations:

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