Columbus Mission

Information Kit

Updated: January 2008
Mission Overview

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ESA Astronauts: Hans Schlegel (STS-122 Mission Specialist)
NASA Astronauts: Stephen Frick (STS-122 Commander)
NASA Astronauts: Alan Poindexter (STS-122 Pilot)
NASA Astronauts: Rex Walheim (STS-122 Mission Specialist)
NASA Astronauts: Stanley Love (STS-122 Mission Specialist)
NASA Astronauts: Leland Melvin (STS-122 Mission Specialist)
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European Experiment Programme
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Mission Overview

In February 2008, the European Columbus laboratory will be launched and become an integral part of the International Space Station (ISS), bringing years of organisation and hard work to fruition. With a projected 10 years in orbit, it will create space history as the first European laboratory dedicated to long-term experimentation in weightlessness.

ESA astronauts Léopold Eyharts from France and Hans Schlegel from Germany will be crewmembers on the Columbus assembly and commissioning mission. They are scheduled to be launched on Space Shuttle Atlantis in February 2008 on Shuttle flight STS-122 from the Kennedy Space Center in Florida, USA, as part of a 7-man crew together with five NASA colleagues.

The Columbus mission consists of different parts. The first part during the 11-day STS-122 flight (also known to the ISS partners as the 1E assembly mission) will attach the European laboratory to the ISS, and thereafter, activate, and begin commissioning of the laboratory. This includes the attachment of European external experiment facilities during the third mission spacewalk and additional assembly/maintenance tasks. The Columbus mission will continue after undocking of the Shuttle with Léopold Eyharts remaining on the Station for 7-8 weeks as an ISS Expedition Crewmember. He will continue with Columbus commissioning activities, completing the activation of the internal experiment facilities as well as undertaking European scientific, public relations and educational activities and additional activities in his role as ISS Flight Engineer 2. Schlegel will also be undertaking European science and public relations activities as part of the Columbus mission.

The major activities of the Columbus mission are as follows:

Columbus laboratory installation
The Columbus Laboratory will provide a shirt-sleeve environment in which astronauts can undertake experiment procedures using a variety
of experiment facilities covering a wide range of scientific disciplines. It will be attached to the European-built Node 2, which was docked to the ISS during the STS-120 mission in October 2007.

Columbus will be transported to the Station in the Shuttle’s cargo bay. It will be installed on Flight day 4 during the first mission EVA or spacewalk with ESA astronaut Hans Schlegel as one of the two spacewalking astronauts along with NASA astronaut Rex Walheim. Much of the time of the first spacewalk will be spent preparing Columbus in the Shuttle’s cargo bay and thereafter unberthing it. The Station’s robotic arm will then move the laboratory to its permanent location on the ISS on the starboard or right-hand side of Node 2.

Columbus activation and commissioning of experiment facilities and systems

Once Columbus is attached, Schlegel and Eyharts will both be principal astronauts involved with activation and commissioning of the laboratory along with different NASA colleagues. First the laboratory needs to be connected to the ISS systems for power data and thermal control. Once this is achieved and the pressurised laboratory entered for the first time, on-orbit activities will involve reconfiguring the internal facilities from the launch configuration to their on-orbit configuration. This includes removing launch brackets relocating experiment facilities, and connecting cables between the facilities and the relevant Columbus and ISS systems.

Commissioning the laboratory is a very complex task, not all of which will be carried out during the 11-day Shuttle mission. Léopold Eyharts, who will remain on the Station for three months, will continue commissioning activities in Columbus with members of the Expedition 16 crew. During these commissioning activities all the experiment facilities will become ready for use and the first run of experiments will take place in the Columbus laboratory. The experiment facilities inside Columbus are Biolab for biological experiments, the Fluid Science Laboratory for fluid science experiments, the European Physiology Modules facility for human physiology experiments and the European Drawer Rack, which is a multi-discipline facility for a range of smaller experiments.
Install European external payloads (EuTEF and SOLAR) on Columbus
Two European external experiment facilities, EuTEF and SOLAR will be installed on the outside of the Columbus laboratory during the third EVA of the mission. ESA astronaut Léopold Eyharts will be operating the Station’s robotic arm, transporting one of the spacewalking astronauts between the Shuttle cargo bay (where EuTEF and SOLAR are stowed) and the Columbus laboratory’s External Payload Facility (where they will be installed). The spacewalking astronauts are Rex Walheim and Stanley Love, both representing NASA. EuTEF houses many different experiments including a variety of exobiology experiments. SOLAR will carry out an in-depth study of the Sun currently scheduled to last two years.

Exchange NASA astronaut for an ESA astronaut as a member of the ISS Expedition crew: ESA astronaut Léopold Eyharts will become the second ESA astronaut to become a member of an ISS long-term Expedition Crew when he arrives at the ISS on the STS-122 flight. In addition to his specific robotics and commissioning tasks in relation to the Columbus mission, he will be undertaking many vital tasks on the ISS that could cover the use of systems and procedures for: ISS guidance and control, environmental control and life support systems, crew health and safety, and EVA operations to name a few. He will remain on the ISS for approximately two months, flying back on the STS-123 flight in 2008.

Eyharts will replace NASA astronaut Dan Tani as ISS Expedition 16 Flight Engineer 2. Tani arrived at the ISS on board the STS-120 Shuttle Discovery mission, which was launched on 23 October and landed on 7 November. The STS-120 mission brought the European-built Node 2 to the Station and included ESA astronaut Paolo Nespoli as a crewmember. Tani will come back with the STS-122 crew on the return flight.

Undertake a European experiment programme During their missions, Léopold Eyharts and Hans Schlegel will be undertaking a number of experiments for the European scientific community. This includes runs of the first experiments to be carried out in the experiment facilities in Columbus. Additional European experiments will be carried out by Russian cosmonaut Yuri Malenchenko. These experiments cover a wide range of areas. Those requiring the weightless environment inside the ISS will be in the areas of human physiology and biology, fluid science and radiation dosimetry. Those needing the exposure to the open space environment outside the ISS using the new external experiment payloads on Columbus will also be in a number of different scientific areas including exobiology, solar science and material science, in addition to various monitoring and sensor technologies.
The Fluid Cell Assembly of GeoFlow, the core of the first experiment to take place in the Fluid Science Laboratory in Columbus. See experiment programme (Image: EADS Astrium)

ESA astronaut Léopold Eyharts will also carry out a number of educational activities during his mission.

Remove and return Control Moment Gyroscope
During the third EVA or spacewalk a failed Control Moment Gyroscope temporarily situated on an External Stowage Platform will be removed and placed in the Shuttle’s cargo bay for return to Earth. The Control Moment Gyroscopes are used to control the orbital orientation of the Space Station.

Remove and Replace Nitrogen Tank Assembly
During the second EVA or spacewalk of the mission, ESA astronaut Hans Schlegel and NASA astronaut Rex Walheim will remove and replace a Nitrogen Tank Assembly on the P1 truss section. This is an important piece of equipment that forms part of the external thermal control system of the ISS. The old Nitrogen tank Assembly will be placed in the Shuttle’s cargo bay for return to earth.

Delivery of Supplies/Equipment
As well as bringing some standard logistics supplies for the Shuttle and ISS Expedition Crews, the mission will also bring equipment to the ISS, which will be used, for example, to outfit Columbus (inside and outside) as well as additional equipment that will be installed during spacewalks. One additional piece of equipment that will be brought to the ISS will be the European Flywheel Exercise Device. This is a resistance exercise device that acts to countermeasure muscle atrophy, bone loss, and impairment of muscle function in astronauts.

Canadian Space Agency astronaut Dave Williams installs failed Control Moment Gyroscope on External Stowage Platform 2 in August 2007 (Image: NASA)

Former ESA astronaut Philippe Perrin testing the Flywheel Exercise device the 35th parabolic flight campaign in October 2003 (Image: ESA)
The STS-122 Atlantis crew. Front row: ESA astronaut Léopold Eyharts (centre) and NASA astronauts Stephen Frick, commander (left), and Alan Poindexter, pilot (right). Back row from left NASA astronauts Leland Melvin, Rex Walheim, Stanley Love and ESA astronaut Hans Schlegel (Image: NASA)

The Crew
ESA astronauts Léopold Eyharts and Hans Schlegel form part of a seven-member Shuttle crew along with NASA astronauts Stephen Frick (Shuttle commander), Alan Poindexter (pilot) and mission specialists Rex Walheim, Stanley Love and Leland Melvin. On the ISS when they arrive will be the Expedition 16 Crew: ISS Commander Peggy Whitson (NASA), and ISS Flight Engineers Yuri Malenchenko (Roscosmos) and Daniel Tani (NASA) who Léopold Eyharts will be replacing.

The Columbus mission is borne out of the ISS Intergovernmental Agreement in which Columbus formed a major contribution by ESA and an agreement between ESA and NASA whereby one ESA astronaut will be involved in the Columbus assembly mission and further that ESA can provide astronauts to be members of the ISS Expedition crews following attachment of Columbus to the Station.
Key Mission Data

SHUTTLE CREW:
Shuttle Commander: Stephen Frick (NASA)
Shuttle Pilot: Alan Poirn Dexter (NASA)
Mission Specialist: Hans Schlegel (ESA)
Mission Specialist: Rex Walheim (NASA)
Mission Specialist: Stanley Love (NASA)
Mission Specialist: Leland Melvin (NASA)
ISS Flight Engineer (Ascent): Léopold Eyharts (ESA)
ISS Flight Engineer (Descent): Dan Tani (NASA)

SPACECRAFT:
Shuttle Orbiter: Atlantis

MISSION:
European Mission Name: Columbus
Shuttle Mission Designation: STS-122
ISS Assembly Flight Designation: 1E
Primary Payload: Columbus
Secondary Payloads: EuTEF, SOLAR, Nitrogen Tank Assembly

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:
Scheduled Launch Date: 7 February 2008
Launch Window: 10 minutes
Altitude (In orbit): 226 kilometres
ISS Altitude: ~400 kilometres
Inclination: 51.6°
Mission Duration: 11 days
Columbus Laboratory Logo

Columbus takes its name from the famous Genoan navigator Christopher Columbus who made the notable voyages to the Americas from 1492 to 1504. The lower half of the Columbus logo consists of a lighter blue circle symbolising the Earth surrounded by a darker blue ellipse signifying the initial orbit of the Shuttle transporting Columbus after launch. Above these the International Space Station is symbolised at its higher orbiting altitude.

The white strip across the Earth symbolises two different things. Firstly it symbolises the path from east to west, which Christopher Columbus took on his way to the Americas. Secondly it symbolises the path of the Columbus laboratory from west to east from the launch pad in Florida into orbit and to the International Space Station, following an orbital path symbolised by the stars. These stars (10 gold and one blue) symbolise the eleven ESA Member States that contribute to the human spaceflight programme within ESA. With last star being the central part of the ISS the stars also symbolise the fact that following its orbital journey, the Columbus laboratory, will become an integral part of the International Space Station.

This final star, not only symbolises the Columbus laboratory, it also symbolises the spark of genius inherent in the groundbreaking science that will take place in the laboratory once it is commissioned.
The STS-122 patch depicts the continuation of the voyages of the early explorers to today's frontier, space. The ship denotes the travels of the early expeditions from the east to the west. The space shuttle shows the continuation of that journey along the orbital path from west to east. A little more than 500 years after Columbus sailed to the new world, the STS-122 crew will bring the European laboratory module "Columbus" to the International Space Station to usher in a new era of scientific discovery.
The Columbus laboratory is the cornerstone of ESA’s contribution to the International Space Station (ISS) and is the first European laboratory dedicated to long-term research in space. Named after the famous explorer from Genoa, the Columbus laboratory will give an enormous boost to current European experiment facilities in weightlessness and to the research capabilities of the ISS once it becomes an integral part of the Space Station. This is currently scheduled in February 2008 following its launch on Space Shuttle Atlantis on ISS assembly flight 1E.

During its projected lifespan of 10 years, Columbus will support sophisticated research in weightlessness, having internal and external accommodation for numerous experiments in life sciences, fluid physics and a whole host of other disciplines. The laboratory marks a significant enhancement in European space experimentation and hardware development when compared to the missions of the European-developed Spacelab in the 1980s and 1990s.

The 7 m long Columbus laboratory consists of a pressurised cylindrical hull 4.5 m in diameter, closed with welded end cones. To reduce costs...
and maintain high reliability, the laboratory shares its basic structure and life-support systems with the European-built Multi-Purpose Logistics Modules (MPLMs): pressurised cargo containers, which travel in the Space Shuttle's cargo bay.

Ten of the sixteen are International Standard Payload Racks fully outfitted with resources (such as power, cooling, video and data lines), to be able to accommodate an experiment facility with a mass of up to 700 kg. This extensive experiment capability of the Columbus laboratory has been achieved through a careful and strict optimisation

The primary and internal secondary structures of Columbus are constructed from aluminium alloys. These layers are covered with a multi-layer insulation blanket for thermal stability and a further two tonnes of panelling constructed of an aluminium alloy together with a layer of Kevlar and Nextel to act as protection against bombardment from space debris.

The Columbus laboratory has a mass of 10.3 tonnes and an internal volume of 75 m³, which can accommodate 16 racks arranged around the circumference of the cylindrical section in four sets of four racks. These racks have standard dimensions with standard interfaces, used in all non-Russian modules, and can hold for example experimental facilities or subsystems.
of the system configuration, making use of the end cones for housing subsystem equipment. The central area of the starboard cone carries system equipment such as video monitors and cameras, switching panels, audio terminals and fire extinguishers.

Although it is the Station’s smallest laboratory module, the Columbus Laboratory offers the same payload volume, power, and data retrieval, for example, as the Station’s other laboratories, but on a smaller and cheaper scale. A significant benefit of this cost-saving design is that Columbus will be launched already outfitted with 2500 kg of experiment facilities and additional hardware. This includes the ESA-developed experiment facilities:

- **Biolab**, which supports experiments on micro-organisms, cell and tissue culture, and even small plants and animals;
- **Fluid Science Laboratory**, looking into the complex behaviour of fluids, which could lead to improvements in energy production, propulsion efficiency and environmental issues;
- **European Physiology Modules** facility, which supports human physiology experiments concerning body functions such as bone loss, circulation, respiration, organ and immune system behaviour in weightlessness;
- and the **European Drawer Rack**, which provides a flexible experiment carrier for a large variety of scientific disciplines.

These multi-user facilities will have a high degree of autonomy in order to maximise the use of astronauts’ time in orbit.

Outside its pressurised hull, Columbus has four mounting points for external payloads related to applications in the field of space science, Earth observation, technology and innovative sciences from space. Two external payloads will be installed after the Columbus Laboratory is attached to the ISS: the **European Technology Exposure Facility (EuTEF)** will carry a range of experiments, which need exposure to space, and the **SOLAR observatory**, which will carry out a spectral study of the Sun for at least 18 months. These will be followed in the first instance by the **Atomic Clock Ensemble in Space (ACES)**, which will test a new generation of microgravity cold-atom clock in space and the **Atmosphere Space Interaction Monitor**, which will study the coupling of thunderstorms processes to the upper atmosphere, ionosphere and radiation belts and energetic space particle precipitation effects in the mesosphere and thermosphere.
In addition to the accommodation for experiment facilities, three rack positions contain Columbus laboratory subsystems such as water pumps, heat exchanger and avionics, and three racks are for general storage purposes. When fully outfitted the Columbus laboratory will provide a shirt sleeve environment of 25 m³ in which up to three astronauts can work. The laboratory will receive a supply of up to 20 kW of electricity of which 13.5 kW can be used for experimental facilities.

For the internal environment, Columbus is ventilated by a continuous airflow sucked in from Node 2, the European-built ISS module where the Columbus Laboratory will be permanently attached. The air returns to Node 2 for refreshing and carbon dioxide removal. This air content is monitored by Columbus subsystems for contamination.

The crew can also control the temperature (16-27°C) and humidity in Columbus. A water loop system, connected to the ISS heat removal system, serves all experimental facility and system locations for removal of heat and thus stopping equipment from overheating. In addition, there is an air/water heat exchanger to remove condensation from the cabin air. A system of electrical heaters also helps to combat the extreme cold possible at some Station attitudes.

Once it is attached to the ISS, ESA’s Columbus Control Centre (Col-CC) in Oberpfaffenhofen in Germany on the premises of DLR’s German Space Operations Centre will be responsible for the control and operation of the Columbus laboratory. All the European payloads on Columbus will transfer data, via the ISS data transfer system, directly to the Columbus Control Centre.

Col-CC will coordinate European experiment (payload) operations. Relevant data will be distributed from Col-CC to the different User Support and Operations Centres across Europe, responsible for either complete facilities, subsystems of facilities or individual experiments.

Col-CC will also be in close contact with the Mission Control Centre in Houston, USA, which has overall responsibility for the ISS, together with the Mission Control Centre in Moscow. In addition, Col-CC coordinates operations with the ISS Payload Operations and Integration Center at the Marshall Space Flight Center in Huntsville, Alabama, USA, which has overall responsibility for ISS experiment payloads.
ESA has developed a range of payload racks for the Columbus laboratory, all tailored to acquire the maximum amount of research from the minimum of space and to offer European scientists across a wide range of disciplines full access to a weightless environment that is not possible on Earth. When Space Shuttle assembly flight 1E is launched, Columbus will be outfitted with the five pressurised (internal) payloads: Biolab, the Fluid Science Laboratory, the European Physiology Modules facility, the European Drawer Rack, and the European Transport Carrier. The first three were developed within ESA’s Microgravity Facilities for Columbus Programme, while the last two fall under ESA’s Utilisation Programme.

The above ISS experiment facilities represent a first in European research and hardware development by providing the scientific community with a European platform for running long-term experiments in weightlessness on the ISS rather than the short-term experiments typical of the earlier Spacelab missions.

The multi-user facilities are modular in design to allow for upgrading and easy refurbishment and repair because of the long-term operations foreseen in the Space-Station era, beyond the retirement of the Space Shuttle in 2010. This modularity provides the opportunity and flexibility to be used over again with different experiment containers, to allow for shorter mission preparation times and contributes to a faster scientific development in the specific field.

The research facilities have been designed to be compact enough to fit into the restricted space of an International Standard Payload Rack, durable enough to withstand years of service, able to accommodate multiple users, and largely automatic and fully controllable from ground stations since the station crew have only a limited amount of time to supervise ongoing experiments.

Experiment containers to be processed in the facilities will be transported separately within the Multi-Purpose Logistics Modules (MPLMs), which are pressurised cargo transportation modules that travel inside the Space Shuttle cargo bay. Experiments requiring late access can also be transported within the Space Shuttle Middeck Lockers. Experiment Containers will also be transported using the European Automated Transfer Vehicle (ATV) or the H-II Transfer Vehicle (HTV) or the Russian Progress vehicles. This includes certain biological and medical samples that will need to be thermally conditioned in storage in the Minus Eighty degrees Laboratory Freezer for the ISS (MELFI), which serves as the major permanent ISS refrigerator/freezer.
Internal Facilities: Biolab

Biolab is a facility designed to support biological experiments on micro-organisms, cells, tissue cultures, small plants and small invertebrates. The major objective of performing Life Sciences experiments in space is to identify the role that weightlessness plays at all levels of an organism, from the effects on a single cell up to a complex organism including humans.

The first experiment to take place in Biolab, when Columbus arrives at the ISS, will investigate the effect of weightlessness on the growth of seeds and will aim to better understand the cellular mechanism which impairs the immune functions and aggravates the radiation response under spaceflight conditions. This experiment is important in view of future, long-term human space missions. Further experiments will try to unravel the influence of gravity on cellular mechanisms such as signal transduction and gene expression. These two effects are important steps in the reaction of a cell to changes in its environment, so the results are important for finding causes or treatments for diseases on Earth.

Biolab is divided physically and functionally into two sections: the automatic section in the left side of the rack, and the manual section in the right side of the rack. In the automatic section, known as the Core Unit, all activities are performed automatically by the facility, after manual sample loading by the crew. By implementing such a high level of automation, the demand on crew time is drastically reduced. The manual section, in which all activities are performed by the crew themselves, is mainly devoted to sample storage and specific crew activities of experiment handling.

The main element of the Core Unit is the large Incubator, a thermally controlled volume where the experiments take place. Inside the Incubator are two centrifuges that can each hold up to six Experiment Containers, which contain the biological samples, and can be independently spun to generate artificial gravity in the range from $10^{-3}$ g to 2 g. This allows for the simultaneous performance of 0g experiments with 1g reference experiments in the facility.

During processing of the experiment, the facility handling mechanism will transport the samples to the facility’s diagnostic instrumentation where, through teleoperations, the scientist on the ground can actively participate in the preliminary in-situ analyses of the samples. The Handling Mechanism also provides transport of samples into the ambient and temperature-controlled Automatic Stowage units for preservation or for later analysis. The typical Biolab experiment durations range from 1 day to 3 months.

Biolab's manual section carries a laptop for crew control, two Temperature Control Units for sample storage and a BioGlovebox. The Temperature Control Units are cooler/freezers (+10°C to -20°C) for storing larger items and experiment containers. The BioGlovebox is an enclosed container for handling toxic materials and delicate biological samples that must be protected against contamination by the Space Station environment. An ozone generator ensures sterilisation of the BioGlovebox working volume.

The Biolab facility will be launched inside the European Columbus laboratory.
Internal Facilities: European Drawer Rack

This approach allows a quick turn-around capability, and provides increased flight opportunities for the user community wishing to fly payloads that do not require a complete rack. The overall design of the facility is optimised for the parallel accommodation of three to four payloads, i.e. an average experiment payload accommodating 2 drawers/lockers, but both larger and smaller payloads may be accommodated.

The resource management covers the monitoring of resource allocations to individual payloads, but the operating concept of the European Drawer Rack assumes that payloads are largely autonomous. The facility computer distributes ISS data to payloads and routes payload data to ground and the European Drawer Rack laptop. The European Drawer Rack data management system supports all modes of payload operation, ranging from fully automatic to step-by-step control by an astronaut.

In addition to distributing Columbus resources to the experiment modules, the European Drawer Rack provides services such as an air cooling loop and conversion of the 120 volt Columbus power standard to 28 volts.

The first configuration of the European Drawer Rack will include one experiment module. This is the Protein Crystallisation Diagnostics Facility and is a multi-user material science instrument, which will tackle the problems of protein crystallisation in space. This facility will help to establish the conditions under which good zeolite crystals can be grown. This can only be determined in weightlessness. The results generated will hold benefits in various industrial applications.

A second module will be launched with a later flight. This is the Facility for Adsorption and Surface Tension (FASTER), which will establish a link between emulsion stability and characteristics of droplet interfaces. This research has a lot of application links in industrial domains and is linked to investigations like foam stability/drainage/rheology.
The European Physiology Modules facility is designed to investigate the effects of long-duration spaceflight on the human body, with typical research areas including neuroscience, cardiovascular and respiratory system, bone and muscle physiology and endocrinology and metabolism. The research into human physiology under weightless conditions will also contribute to an increased understanding of terrestrial problems such as the ageing process, osteoporosis, balance disorders, and muscle wastage.

A selection of the first set of experiments to take place in the European Physiology Modules, when Columbus arrives at the ISS, relate to neuroscience, mechanisms of heart disease, weightless effects on human skeletal muscle function, and sodium retention in weightlessness.

The facility consists of a set of up to eight science Modules mounted in a Carrier infrastructure. The Carrier provides these modules with data handling, thermal control and housing. It interfaces directly with Columbus and provides support for both rack-mounted and external Science Modules. In addition to Science Modules mounted in the Carrier, it is possible for instruments deployed in the Columbus centre aisle to interface to the Carrier via a Utility Distribution Panel.

Three science modules have been selected for the first launch configuration of the European Physiology Modules facility. These are:

**Cardiolab**: This is a facility for investigating the different systems which are involved in the regulation of arterial blood pressure and the heart rate. Data from Cardiolab will also be used to maintain the crew in good health during their stay on board, and to prepare the astronauts for their return to Earth. Cardiolab, developed by CNES and DLR has been added to the European Physiology Modules through cooperative agreements.

**MEEMM (Multi Electrodes Encephalogram Measurement Module)**: MEEMM will be used to study brain activity by measuring electrical signals from electrodes mounted on the experiment subject.

**PORTEEM (Portable Electroencephalogram Module)**: This instrument is a flexible, modular and portable digital recorder for ambulatory and sleep studies. The instrument is outfitted with a 16 channel EEG/polysomnography module for EEG sleep studies, but can be easily reconfigured for a wide variety of other applications.

ESA’s European Physiology Modules facility is closely linked to NASA’s Human Research Facility racks in the US Laboratory where even some of ESA’s physiology science modules like the Pulmonary Function System are accommodated. The Pulmonary Function System is now in orbit and is functioning successfully.

New Science Modules and other necessary items will be transported to the Station on the 1E assembly flight and on future flights for use in conjunction with the European Physiology Modules. This will mainly comprise countermeasures equipment like the FlyWheel Exercise Device, a Portable Pulmonary Function System, Radiation Monitors, etc. This European Physiology Modules equipment can be brought to the ISS by the European Automated Transfer Vehicle (ATV), the Russian Progress and Soyuz vehicles or the Space Shuttle. Samples are returned using the MPLM, the Shuttle's mid-deck lockers and the Soyuz spacecraft.
Internal Facilities: Fluid Science Laboratory

The Fluid Science Laboratory is a multi-user facility designed to study the dynamics of fluids in the absence of gravitational forces. The major objective of performing fluid science experiments in space is to study dynamic phenomena in the absence of gravitational forces. Under weightless conditions, as on the ISS, such forces are almost entirely eliminated, resulting in significant reductions in gravity-driven convection, sedimentation, stratification and fluid static pressure. This allows the study of fluid dynamic effects normally masked by gravity.

The first experiments to take place in the Fluid Science Laboratory, when Columbus arrives at the ISS, include the heat and mass transfer from free surfaces in binary liquids, a study of emulsion stability, an investigation of geophysical flow in weightlessness, which can have importance in areas such as global-scale flow in the atmosphere and oceans, studies of electric fields on the boiling process, and a study to improve the processing of peritectic alloys.

The Fluid Science Laboratory is modular in design and based on the use of drawer elements. This facilitates the removal and transport of components, either to upgrade them or to repair defective parts. It can be operated in fully-automatic or semi-automatic mode and can be controlled on board by the ISS astronauts, or from the ground in telescience mode.

The right side of the Fluid Science Laboratory contains functional subsystems for power distribution, environmental conditioning and data processing and management. The Core element on the left side of the Fluid Science Laboratory consists of the Optical Diagnostics Module and Central Experiment Module, into which the Experiment Containers are inserted for operation.

The Optical Diagnostics Module houses the equipment for visual, velocimetric and interferometric observation, the related control electronics, and the attachment points and interfaces for special Front Mounted Cameras.

The Central Experiment Module is divided into two parts. The first contains the suspension structure for the Experiment Containers, including all the functional interfaces and optical equipment. This structure is designed to be pulled out from the rack to allow insertion and removal of the standard dimension experiment containers into which the experiments are integrated. The second part contains all of the diagnostic and illumination equipment, together with the control electronics to command and monitor the electromechanical and opto-mechanical components.

Cooperative agreements have added to the facility the Microgravity Vibration Isolation System developed by the Canadian Space Agency. This system will provide good isolation for experiments from disturbances in the weightless environment from the Station.

An Experiment Container may also be equipped with dedicated experiment diagnostics to complement the standard diagnostics provided by the Fluid Science Laboratory itself.

A facility like Fluid Science Lab, which can be used over and over again with different Experiment Containers, allows shorter individual mission preparation times and contributes to a faster scientific development in the specific field.
Internal Facilities: European Transport Carrier

The European Transport Carrier accommodates items for transport and stowage based on standardised Cargo Transfer Bags that are compatible for transportation with the European-built Multi-Purpose Logistics Module (MPLM) and ATV, and for use on board ISS modules such as Columbus. The modular European Transport Carrier design, based on rigid stowage containers, offers maximum flexibility for handling different Cargo Transfer Bag sizes. All European payload items will be transported and stored in ISS Cargo Transfer Bags. These are Nomex bags in four standard sizes with removable, reconfigurable dividers.

The European Transport Carrier’s rigid stowage containers are optimized in size for accommodation of the different sized Cargo Transfer Bags. There are two smaller containers for accommodating full- and half-size Cargo Transfer Bags, each one equivalent in volume to 1.5 Shuttle middeck lockers. There are four containers, which offer about 3 times the volume of a Shuttle middeck locker. They can be filled with any combination of Cargo Transfer Bags, up to the triple-size. All stowage containers are designed to withstand the launch and landing loads while carrying their stowage contents.

The European Transport Carrier will carry payload items that cannot be launched within the ESA facilities because of stowage or transport limitations. In orbit, it will serve as a workbench and stowage facility to support experiments with Biolab, Fluid Science Lab, European Physiology Modules and European Drawer Rack. One piece of equipment that will be brought to the ISS inside the European Transport Carrier will be the European Flywheel Exercise Device. This is a resistance exercise device that acts to countermeasure muscle atrophy, bone loss, and impairment of muscle function in astronauts. It will be transported within two of the triple-sized Cargo Transfer Bags.

The European Transport Carrier’s secondary use is within the MPLM after it is eventually replaced in Columbus by an active experiment rack. (ESA currently ‘owns’ five rack positions, all are active/powered positions). The European Transport Carrier may then act as a logistics carrier between Earth and the ISS for the Columbus ESA payload racks. It is designed for 15 launches, and can be reconfigured on the ground to the specific stowage needs of each flight.

In general, the European Transport Carrier will stow and transport commissioning items, complementary instruments, consumables, flight and orbital support equipment, orbital replaceable units, resupply items and science items like experiment containers and consumables.

In addition, European Transport Carrier’s Zero-g Stowage Pockets (two upper, one lower) allow on-orbit use of the remaining internal volume. They can only be filled in orbit and cannot be used for launch and descent transportation.

The European Transport Carrier can carry more than 400 kg of payload and experiment items, totalling up to about 800 litres. On-board the ISS, Zero-g Stowage Pockets extend capacity to about 1000 litres.
Columbus External Facilities

We usually think of astronauts aboard the International Space Station performing experiments inside the pressurised laboratory modules, but external payloads offer the choice of experimentation in the open space environment with the major advantages of long duration exposure and return to Earth thereafter for examination and analysis. One noticeable example of this is the ESA Matroshka radiation dosimetry facility, which was located on the external surface of the ISS for 1.5 years following installation in March 2004.

ESA has equipped the Columbus module with the External Payload Facility, which provides four locations (platforms) to accommodate research payloads. It is a framework mounted on the module’s end-cone and provides power, data and command links.

The Columbus External Payload Facility offers the opportunity for classical space science and technology experiments in a diverse array of disciplines. The External Payload Facility will enhance the Station’s return without significantly increasing the infrastructure cost by exploiting automated operations, with almost no crew intervention.

The External Payload programme consists of two elements: early utilisation (before Station assembly is complete) and routine exploitation (after assembly completion). Each payload is mounted on an adaptable to accommodate small instruments and experiments totalling up to 227 kg. Following an Announcement of Opportunity and peer review, five payloads were selected, of which four entered development. They were originally planned to use the NASA external sites but will now be located on Columbus.

Two of the payloads: The European Technology Exposure Facility (EuTEF) and SOLAR are flying on the 1E assembly flight with Columbus and will be attached to the outside of Columbus during the last mission spacewalk. The Atomic Clock Ensemble in Space (ACES) and the Atmosphere Space Interaction Monitor (ASIM) will be flown to the ISS on a later flight.

This first batch of external Columbus payloads will be replaced by new payloads in the future. One such payload is ASIM, (Atmosphere/Space Interactions Monitor), payload composed of optical instruments for the observation of high altitude emission from the stratosphere and mesosphere related to thunderstorms.

In the future the in-orbit transfer of the unpressurised payloads from the Shuttle to the External Payload Facility, and vice-versa, will be performed by the Space Station Robotic Manipulator System. For SOLAR and EuTEF, however the transfer will be carried out by astronauts with robotic arm assistance, as part of EVA tasks. Future Payloads like ASIM and ACES could be uploaded with the HTV; smaller/modular ones with the ATV or Progress as well.
External Facilities: European Technology Exposure Facility (EuTEF)

The European Technology Exposure Facility (EuTEF) will be mounted outside the Columbus module and carry experiments requiring exposure to the space environment. It is a programmable, fully automated, multi-user facility with modular and flexible accommodation for a variety of technology payloads. EuTEF is specifically designed to facilitate the rapid turnaround of experiments and for its first configuration on orbit will accommodate nine different instruments.

The experiments and facility infrastructure are accommodated on the Columbus External Payload Adaptor, consisting of an adapter plate, the Active Flight Releasable Attachment Mechanism and the connectors and harness. The experiments are mounted either directly on the Adapter plate or a support structure that elevates them for optimum exposure to the direction of flight or pointing away from the Earth.

In total, the payload mass is under 350 kg, and requires less than 450 W of power. The suite of experiments consists of:

- **MEDET**, the Material Exposure and Degradation Experiment (CNES, ONERA, University of Southampton, ESA);
- **DOSTEL**, radiation measurements (DLR Institute of Flight Medicine);
- **TRIBOLAB**, a testbed for the tribology properties of materials in space (INTA, INASMET);
- **EXPOSE**, photobiology and exobiology (Kayser-Threde, under ESA contract);
- **DEBIE-2**, a micrometeoroid and orbital debris detector (Patria Finavitec, under ESA contract). Shares a standard berth with FIPEX. DEBIE-1 flew on the Proba satellite;
- **FIPEX**, an atomic oxygen detector (University of Dresden). Shares a standard berth with DEBIE-2;
- **PLEGPAY**, plasma electron gun payload for plasma discharge in orbit (Thales Alenia Space, under ASI contract);
- **EuTEMP**, an experiment candidate to measure EuTEF’s thermal environment during unpowered transport from the Shuttle to the Columbus External Payload Facility. (EFACEC, under ESA contract);
- **EVC:** an Earth Viewing Camera, developed by ESA/Carlo Gavazzi Space for outreach activities.
Apart from contributing to solar and stellar physics, knowledge of the interaction between the solar energy flux and Earth's atmosphere is of great importance for atmospheric modelling, atmospheric chemistry and climatology. SOLAR, will study the Sun with unprecedented accuracy across most of its spectral range. This is currently scheduled to last two years. It will be located on the Columbus External Payload Facility zenith position (i.e. pointing away from the Earth).

The SOLAR payload consists of 3 instruments complementing each other to allow measurements of the solar spectral irradiance throughout virtually the whole electromagnetic spectrum - from 17 nm to 100 µm - in which 99% of the solar energy is emitted. The three complementary solar science instruments are:

**SOVIM (SOlar Variable & Irradiance Monitor)**, which covers near-UV, visible and thermal regions of the spectrum (200 nm – 100 µm) is developed by PMOD/WRC (Davos, Switzerland) with one of the instrument’s radiometers provided by IRM (Brussels, Belgium).

**SOLSPEC (SOlar SPECtral Irradiance measurements)** covers the 180 nm - 3,000 nm range. SOLSPEC is developed by CNRS (Verrières-le-Buisson, France) in partnership with IASB/BIRA (Belgium) and LSW (Germany).

**SOL-ACES (SOlar Auto-Calibrating Extreme UV/UV Spectrophotometers)** measures the EUV/UV spectral regime. SOL-ACES is developed by IPM (Freiburg, Germany).

SOVIM and SOLSPEC are upgraded versions of instruments that have already accomplished several space missions. SOL-ACES is a newly developed instrument.
Future External Facilities

Atomic Clock Ensemble in Space (ACES)

ACES will test a new generation of atomic clock in space. PHARAO (Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbite) developed by CNES in France and the Space Hydrogen Maser developed in Switzerland will be characterised and their output signals compared with each other and with national frequency standards worldwide using a dedicated microwave link. The ultimate performance of PHARAO in microgravity will be explored and a number of fundamental physics experiments will be performed.

ACES is a complex payload involving state-of-the-art instruments and subsystems. The atomic clocks are extremely sensitive to their operating environment, so the particularly harsh environment of space provides new challenges to the clock and payload designs. Thermal and electromagnetic sensitivity places particularly severe constraints on the payload.

PHARAO uses six orthogonal laser beams to cool caesium atoms to a few µK. The combination of these slow atoms and their low acceleration in microgravity allows observation times significantly longer than on Earth, providing better stability and accuracy of the frequency.

Atmosphere Space Interactions Monitor (ASIM)

The mesosphere and lower thermosphere are the regions of the atmosphere about which the least is known. They are too low for in situ spacecraft observations, and remote sensing is hampered by low densities and a high degree of variability over a range of time and spatial scales.

ASIM (Atmosphere Space Interactions Monitor) will study the interaction of thunderstorms with the upper regions of the atmosphere, reaching into the ionosphere and magnetosphere and energetic space particle radiation effects on the mesosphere and thermosphere. The scientific objectives of this payload are complementary to the ones of the Taranis satellite mission developed by CNES.

The ASIM payload consists of two instrument units, the Miniature Multispectral Imaging Array (MMIA) and the Miniature X- and Gamma-Ray Sensor (MXGS) and subsystems. The MMIA incorporates two CCD cameras and a photometer. Two MMIA are dedicated to limb observation with a field of view of 20°. A third MMIA in conjunction with the Miniature X- and Gamma-Ray Sensor will be nadir pointing with a field of view of 80°. The nadir-pointing instruments will keep track of X-ray and gamma-ray bursts.
Additional Payloads

Protein Crystallisation Diagnostics Facility

The Protein Crystallisation Diagnostics Facility (PCDF) is a multi-user instrument for the fundamental study of the processes of nucleation and crystallisation of biological macro-molecules, and specifically, how these processes are influenced by gravity. This instrument may be utilised to conduct detailed measurements of physical phenomena in individual reactors, and to control these phenomena through changes in temperature and concentration of solution. The PCDF will be accommodated in the European Drawer Rack during launch and on the ISS.

It consists of: a processing unit with diagnostics equipment and a process chamber into which the experiment boxes are placed; and an electronics unit accommodating all of the controls necessary for performing the experiments.

Data and digital video images from the PCDF are either stored on-board the International Space Station, or transmitted to the ground control station, depending on the transmission capabilities at the time of the experiment.

Flywheel Exercise Device

The Flywheel Exercise Device is a non-gravity dependent resistance exercise device developed by Yo-Yo Technology that acts to countermeasure muscle atrophy, bone loss, and impairment of muscle function in human beings, which develop in response to long duration space flights. It is a strength training system that uses a rotating flywheel that replaces weight plates and other means of resistance training devices that rely on gravity.

The resistance is provided by a spinning flywheel. It is rotated by a drive belt that links the flywheel axle to a cord reel axle, which in turn has a cord being wound and unwound by the subject. A concentric muscle action overcomes the inertia of the flywheel, accelerating it. A subsequent eccentric muscle action is required to decelerate it. The more force used when accelerating the flywheel the more force will be required to decelerate it. Its variable resistance offers unlimited training potential to any user with virtually no limit to the amount of force or power that can be produced.

While performing the exercises continuous measurements of the force and flywheel speed are recorded using a laptop-based program. Calculations of work and power are performed. Other auxiliary measurements like joint angle and EMG (Electromyography) can also be simultaneously recorded. The Flywheel Exercise Device will be transported to the ISS in the European Transport Carrier, integrated in the Columbus Module.
ESA Astronauts: Léopold Eyharts (Expedition 16 Flight Engineer)  
(Ascent only)

Personal Data
Born 28 April 1957, in Biarritz, France. He is married and has one child. His hobbies are jogging, mountain biking, tennis, reading and computers.

Education

Special Honours
Léopold has been decorated as Officer of the French Légion d'Honneur and Chevalier de l'Ordre National du Mérite. He has been awarded the Médaille d'Outre-Mer, the Silver Medal of the Défense Nationale and the Russian medals for Friendship and Courage.

Experience
He joined the French Air Force Academy of Salon-de-Provence and graduated as an aeronautical engineer in 1979. In 1980 he became a fighter pilot assigned to an operational Jaguar A squadron in Istres Air Force Base (France). In 1985, he was assigned as a flight commander at Saint-Dizier Air Force base.

In 1988 he graduated as a test pilot in the French test pilot school (EPNER) and was assigned to the Brétigny-sur-Orge Flight Test Centre near Paris, becoming Chief Test Pilot in 1990.

Eyharts has logged 3800 hours flying time on over 50 types of aircraft and 21 parachute jumps including one ejection. He holds a commission as general in the French Air Force.

In 1990, Léopold Eyharts was selected as an astronaut by the French National Space Agency (CNES) and assigned to support the Hermes space plane programme managed by the Hermes Crew Office in Toulouse. He became also one of the test pilots and engineer in charge of the CNES parabolic flight programme (with Caravelle aircraft) and also carried out Airbus A300 Zero-G qualification flights.

In 1992, he participated in the European Space Agency (ESA) astronaut selection.

In July 1994, he was assigned as a back-up crewmember for the Franco-Russian Cassiopée spaceflight, which took place in August 1996.

In December 1996, he was selected as cosmonaut for the CNES follow-on scientific space mission called Pegase, which took place from 29 January to 19 February 1998.

In August 1998, Léopold Eyharts joined ESA’s European Astronaut Corps whose homebase is the European Astronaut Centre (EAC) located in Cologne, Germany. He was assigned to train at
NASA’s Johnson Space Center in Houston, Texas and entered the 1998 Mission Specialist Class.

Léopold Eyharts received technical assignments within NASA Astronaut Office at the Johnson Space Center, Houston. He is currently working in the ISS Operations Branch as a section chief for ISS systems, software and on board information technology.

Russian mission called Pegase, he performed various French experiments in the area of medical research, neuroscience, biology, fluid physics and technology.

Current assignment

Léopold Eyharts is currently scheduled for a 7-8 week assignment to the International Space Station to deliver and commission the European Columbus laboratory. During this mission Eyharts will also fulfil the role and carry out the tasks of ISS Flight Engineer 2 for the Expedition 16 crew. This includes robotic arm activities relating to installation of the Columbus laboratory and the two European external payloads (EuTEF and SOLAR) to be installed on Columbus during the mission as well as activation and commissioning of the Columbus laboratory.

He will fly to the ISS with Space Shuttle Atlantis on flight STS-122, currently scheduled for launch in February 2008. Eyharts is due to return to Earth with Space Shuttle flight STS-123.
ESA Astronauts: Hans Schlegel (STS-122 Mission Specialist)

Special Honours and Awards

Experience
From 1970-72, he served as a paratrooper with the Federal Armed Forces. He left with the rank of second lieutenant, and after several reserve trainings, he was appointed reserve lieutenant in 1980. From 1979-86 he worked as an experimental Solid State Physicist at the Rheinisch Westfälische Technische Hochschule (RWTH) Aachen (University of Aachen) and performed research in the field of electronic transport properties and optical properties of semiconductors. From 1986-88 he was a Specialist in non-destructive testing methodology in the research and development department of the company “Institut Dr. Förster GmbH & Co. KG” in Reutlingen, Germany.

Personal Data
Born 3 August 1951 in Überlingen, Germany, but considers Aachen to be his hometown. Married to Heike Walpot. He has seven children. Recreational interests include skiing, scuba diving and flying. He also enjoys reading, and being a handyman.

Education
He spent 1968/69 in the US as an American Field Service (AFS) exchange student and graduated from Lewis Central High School, Council Bluffs, Iowa. In 1970 he graduated from Hansa Gymnasium, a secondary school emphasizing mathematics and science at Cologne, Germany. In 1979 he received a Diploma in Physics (Master of Physics) from the University of Aachen, Germany.

Organisations
Member of the Deutsche Physikalische Gesellschaft (German Physical Society) and of the AFS - Interkulturelle Begegnungen (American Field Service Germany).
The Crew

Establishment (DLR). This training included academic education and microgravity experience on approximately 1300 parabolas on KC-135. He became a certified research diver and holds a Private Pilot's license, including instrument rating and aerobatics.

In 1990 he was assigned payload specialist for the D-2 Mission and started Payload Training in Cologne, Germany and at the Johnson Space Center in Houston, Texas. This second German Spacelab mission successfully took place from 26 April to 6 May 1993 (STS-55 Columbia).

In 1995 he went to the Yuri A. Gagarin Training Center (Moscow) to train for the German-Russian Mir 97 Mission as a backup. During the mission (10 February to 2 March 1997) he served as Crew Interface Coordinator responsible for ground-to-air communications. Between June 1997 and January 1998, he received additional training and certification as 2nd board engineer for the Russian Space Station Mir.

In 1998 he joined the European Astronaut Corps of the European Space Agency.

In August 1998, ESA sent him to the Johnson Space Center for training as a mission specialist with the NASA Astronaut Class of 98. In addition to his training he is also assigned to the CAPCOM Branch of the Astronaut Office, conducting voice communication to the International Space Station.

Spaceflight Experience

From 26 April to 6 May 1993, Schlegel served as Payload Specialist on STS-55 aboard Space Shuttle Columbia. Nearly 90 experiments were conducted during the German Spacelab D-2 mission to investigate life sciences, material sciences, physics, robotics, astronomy, and the Earth and its atmosphere.

Current Assignment

Hans Schlegel is assigned as a mission specialist on the STS-122 mission that will deliver and attach the European Space Agency’s Columbus Laboratory to the International Space Station. As part of this mission Hans Schlegel will be a member of the first two EVA’s or spacewalks, the first of which includes the unberthing and attachment of the Columbus laboratory. Schlegel’s mission also includes activities to activate and commission the Columbus laboratory.
The Crew

NASA Astronauts: Stephen Frick (STS-122 Commander)

**Personal Data**
Hometown: Gibsonia, Pennsylvania, USA. Married and enjoys skiing, hiking, camping.

**Education**
Graduated from Richland High School, Gibsonia, Pennsylvania in 1982; received a Bachelor of Science degree in Aerospace Engineering from the US Naval Academy in 1986; Master of Science degree in Aeronautical Engineering from the U.S. Naval Postgraduate School in 1994.

**Organizations**

**Special Honours and Awards**
Numerous U.S. service medals and awards.

**Experience**
Frick was commissioned upon graduation from the U.S. Naval Academy in May 1986. After being designated as a U.S. Naval Aviator in February 1988, he reported to U.S. Strike Fighter Squadron 106 at Naval Air Station Cecil Field, Florida, USA for transition to the F/A-18 Hornet. Upon completion of training, he reported to Strike Fighter Squadron 83 also at Cecil Field, and deployed to the Mediterranean Sea and Red Sea onboard the USS Saratoga. He was also designated an airwing qualified landing signals officer.

After leaving U.S. Strike Fighter Squadron 83 in 1991, Frick participated in a programme of 15 months at the Naval Postgraduate School in Monterey, California, USA and 1 year with the U.S. Naval Test Pilot School at Naval Air Station Patuxent River, Maryland USA. Upon graduation in June 1994, he was assigned as a project officer and test pilot to the Carrier Suitability Department of the U.S. Strike Aircraft Test Squadron also located at Patuxent River. While there, he conducted shore-based and shipboard testing of the F/A-18 Hornet. Frick was assigned to U.S. Strike Fighter Squadron 125 in Lemoore, California, USA preparing for return to a deployed F/A-18 squadron when selected for the NASA astronaut programme in April 1996.

Frick has logged over 3,200 flight hours in 35 different aircraft, and has over 370 carrier landings.

**NASA Experience**
Selected by NASA in April 1996, Frick reported to the Johnson Space Center in August 1996. Having completed two years of training and evaluation, he is qualified for flight assignment as a pilot. Initially, Frick was assigned technical duties in the NASA Astronaut Office Spacecraft Systems/Operations Branch. He completed his first space flight as pilot on the STS-110 mission, and has logged over 259 hours in space. Frick is assigned to command the STS-122 mission that will deliver the European Space Agency’s Columbus Laboratory to the International Space Station.

**Space Flight Experience**
STS-110 Atlantis (8-19 April 2002) was the 13th Shuttle mission to visit the International Space Station. Mission milestones included: delivery and installation of the SO (S-Zero) Truss; first manoeuvring of spacewalkers using the ISS robotic arm; and the first mission on which all spacewalks were based from the station’s Quest Airlock. The crew prepared the station for future spacewalks and spent a week in joint operations with the Station’s Expedition-4 crew.
NASA Astronauts: Alan Poindexter (STS-122 Pilot)

Personal Data
Born November 1961 in Pasadena, California, USA. Married and has two children. Recreational interests include motorcycling, running, weight lifting, water skiing, boating, hunting, and fishing.

Education
Graduated from Coronado High School, Coronado, California, USA in 1979. Graduated with highest honors from Georgia Institute of Technology, USA with a Bachelor of Aerospace Engineering degree in 1986 and a Master of Science in Aeronautical Engineering from the U.S. Naval Postgraduate School in 1995.

Organizations
Society of Experimental Test Pilots.

Special Honours and Awards
NASA Aviation Safety Award and various U.S. service medals and awards.

Experience
Poindexter was commissioned following graduation in 1986. After a short tour of duty at the Hypervelocity Wind Tunnel Facility, Naval Surface Weapons Center, White Oak, Maryland, USA, Poindexter reported for flight training in Pensacola, Florida. He was designated a US Naval Aviator in 1988 and reported to Fighter Squadron 124, Naval Air Station Miramar, California, for transition to the F-14 Tomcat. Following his initial training, Poindexter was assigned to Fighter Squadron 211, also at Miramar, and made two deployments to the Arabian Gulf.

During his second deployment in 1993, he was selected to attend the U.S. Naval Postgraduate School/Naval Test Pilot School Cooperative Programme. Following graduation in December 1995, Poindexter was assigned as a Test Pilot and Project Officer at the Naval Strike Aircraft Test Squadron, Naval Air Station Patuxent River, Maryland, USA. While stationed there, Poindexter was assigned as the lead test pilot for the F-14 Digital Flight Control System where he logged the first carrier landing and catapult launch of an F-14 with the upgraded flight controls. He also flew numerous high angle of attack/Departure tests, weapons separation tests and carrier suitability trials. Following his tour at Patuxent River, Poindexter reported to Fighter Squadron 32, Naval Air Station Oceana, Virginia, USA where he was serving as a department head when he was selected for NASA astronaut training.

Poindexter has more than 3,500 hours in over 30 aircraft types and has logged over 450 carrier landings.

NASA Experience
Selected by NASA in June 1998, he reported for training in August 1998. Initially Poindexter served in the NASA Astronaut Office Shuttle Operations Branch performing duties as the lead support astronaut at Kennedy Space Center. Poindexter is assigned as pilot on the STS-122 mission that will deliver the European Space Agency’s Columbus Laboratory to the International Space Station.
NASA Astronauts: Rex Walheim (STS-122 Mission Specialist)

Personal Data
Born 10 October 1962, in Redwood City, California, USA. Married and has two children. He enjoys snow skiing, hiking, softball and football.

Education
Graduated from San Carlos High School, San Carlos, California, USA in 1980; received a Bachelor of Science degree in Mechanical Engineering from the University of California, Berkeley, in 1984, and a master of science degree in industrial engineering from the University of Houston in 1989.

Experience
Walheim was commissioned as a second lieutenant in the U.S. Air Force in May 1984. In April of 1985 he was assigned to Cavalier Air Force Station in Cavalier, North Dakota, USA where he worked as a missile warning operations crew commander. In October 1986, he was reassigned to the Johnson Space Center, Houston, Texas, where he worked as a mechanical systems flight controller and was the lead operations engineer for the Space Shuttle landing gear, brakes, and emergency runway barrier. Walheim was transferred to Headquarters Air Force Space Command in Colorado Springs, Colorado, in August 1989, where he was manager of a programme upgrading missile warning radars. He was selected for the flight test engineer course at the U.S. Air Force Test Pilot School in 1991, and attended the course at Edwards Air Force Base California in 1992. Following his graduation, he was assigned to the F-16 Combined Test Force at Edwards where he was a project manager, and then commander of the avionics and armament flight. In January 1996, Walheim became a U.S. Air Force Test Pilot School instructor, where he served until he commenced astronaut training.

NASA Experience
Walheim served as a flight controller and operations engineer at the Johnson Space Center from October 1986 to January 1989. He was selected by NASA in March 1996 and reported to the Johnson Space Center in August 1996. After completing two years of training and evaluation, he qualified for flight assignment as a mission specialist. Initially, Walheim was assigned technical duties in the Astronaut Office Space Station Operations Branch, where he helped develop the initial procedures and displays used on the space station, and served as a Capcom in the Mission Control Center. He served on the EVA crew of the STS-110 mission. After his first flight, he was assigned to the EVA branch, where he served as the astronaut office representative for the Extra Vehicular Mobility Unit, (the EVA spacesuit). Walheim is assigned as a mission specialist on the STS-122 mission that will deliver the European Space Agency’s Columbus Laboratory to the International Space Station and will undertake all three spacewalks during the mission.

Space Flight Experience
STS-110 Atlantis (8-19 April 2002) was the 13th Shuttle mission to visit the International Space Station. Mission milestones included: the delivery and installation of the SO (S-Zero) Truss; the first time the station’s robotic arm was used to manoeuvre spacewalkers around the Station; and the first time that all of a shuttle crew's spacewalks were based from the Station’s Quest Airlock. Walheim performed 2 EVAs totalling 14 hours and 5 minutes. The crew mechanically attached and powered up the new truss, and spent a week in joint operations with the Station’s Expedition-4 crew.
NASA Astronauts: Stanley Love (STS-122 Mission Specialist)

Personal Data
Born 8 June 1965 in San Diego, California, USA. Married. Two children. Recreational interests include flying, alpine hiking, bicycling, music, and animation.

Education
Graduated from Winston Churchill High School, Eugene, Oregon, USA in 1983; received a Bachelor of Science degree in Physics from Harvey Mudd College, Claremont, California, in 1987; received Master of Science and Doctor of Philosophy degrees in Astronomy from the University of Washington in 1989 and 1993, respectively.

Organizations
American Astronomical Society; American Geophysical Union; American Institute of Aeronautics and Astronautics; Harvey Mudd College Alumni Association; Meteoritical Society.

Awards
Various awards including the NASA Johnson Space Center Performance Award (2003, 2004 and 2006).

Experience
As a graduate teaching assistant at the University of Washington in Seattle beginning in 1987, he taught and led laboratory sections for undergraduate courses in general and planetary astronomy.

He worked as a graduate research assistant at the University of Washington from 1989 to 1993 on a variety of projects including space propulsion and energy storage, stellar photometry and spectroscopy, analysis of space-exposed surfaces, hypervelocity impact and particle capture, atmospheric entry heating of micrometeoroids, infrared imaging of the zodiacal light, and electron microscopy of interplanetary dust particles.

Moved to the University of Hawaii in Honolulu in 1994 for a postdoctoral research appointment modelling the formation of meteoritic chondrules and the collisional evolution of asteroids, and investigating the possibility of meteorites from the planet Mercury. Awarded a prize postdoctoral fellowship at the California Institute of Technology in 1995: work there included computational fluid dynamic simulations of asteroid collisions, calibration of the Cassini spacecraft dust particle impact detector, and experimental shock compression of the mineral calcite. Transferred to the Jet Propulsion Laboratory as a staff engineer in 1997 to work on, for example, computer models of spacecraft optical instrument systems.

NASA Experience
Selected by NASA in June 1998, he reported for training in August 1998. Love served as a CAPCOM (spacecraft communicator) in Mission Control for International Space Station Expeditions 1 through 7 and for Space Shuttle missions STS-104 (ISS-7A), STS-108 (ISS-UF-1), and STS-112 (ISS-9A). He served in NASA’s Astronaut Office Exploration Branch, helping to develop future space vehicles and missions. Dr. Love is assigned as a mission specialist on the STS-122 mission that will deliver the European Space Agency’s Columbus Laboratory to the International Space Station. Love will be a member of the third and final mission EVA or spacewalk, which will install the external experiment facilities EuTEF and SOLAR on Columbus.
NASA Astronauts: Leland Melvin (STS-122 Mission Specialist)

Personal Data
Born 15 February 1964 in Lynchburg, Virginia, USA. Unmarried. Recreational interests include photography, piano, reading, music, cycling, tennis, and snowboarding. Loves walking his dogs, Jake and Scout.

Education
Graduated from Heritage High School, Lynchburg, Virginia, in 1982; received a Bachelor of Science degree in chemistry from the University of Richmond, Richmond, Virginia, USA in 1986; and a Master of Science degree in Materials Science engineering from the University of Virginia in 1991.

Organizations

Special Honours and Awards
Various honours and awards including NASA Outstanding Performance Awards (8), and NASA Superior Accomplishment Award (2),

NASA Experience
Melvin began working in the Fiber Optic Sensors group of the Nondestructive Evaluation Sciences Branch at NASA Langley Research Center in 1989 where he conducted research in the area of physical measurements for the development of advanced instrumentation for Nondestructive Evaluation. His responsibilities included using optical fibre sensors to measure strain, temperature, and chemical damage in both composite and metallic structures. Additional projects included developing optical interferometric techniques for quantitative determination of damage in aerospace structures and materials.

In 1994, Melvin was selected to lead the Vehicle Health Monitoring team for the cooperative Lockheed/NASA X-33 Reusable Launch Vehicle programme. The team developed a variety of sensors for the reduction of vehicle operational costs and to monitor composite liquid oxygen tank and cryogenic insulation performance. In 1996, Melvin co-designed and monitored construction of an optical Nondestructive Evaluation facility capable of producing in-line fibre optic Bragg grating strain sensors at rates in excess of 1000 per hour. This facility will provide a means for performing advanced sensor and laser research for development of aerospace and civil health monitoring systems.

Selected by NASA in June 1998, Melvin reported for training in August 1998. Since then he has been assigned to NASA’s Astronaut Office Space Station Operations Branch, and the Education Department at NASA Headquarters, Washington, D.C. As co-manager of NASA’s Educator Astronaut Programme, Leland Melvin travelled across the country, engaging thousands of students and teachers in the excitement of space exploration, and inspiring them to pursue careers in science, technology, engineering and mathematics. He next served in the Robotics Branch of the Astronaut Office. Melvin is assigned as a mission specialist on the STS-122 mission that will deliver the European Space Agency’s Columbus Laboratory to the International Space Station.
NASA Astronauts: Daniel Tani (Expedition 16 Flight Engineer)  
(Descent only)

Personal Data
Born 1 February 1961 in Ridley Park, Pennsylvania, USA. Married and has two children. He enjoys golf, flying, running, tennis, music, cooking.

Education
Graduated from Glenbard East High School, Lombard, Illinois, in 1979; received a Bachelor and a Master of Science degree in Mechanical Engineering from Massachusetts Institute of Technology in 1984 and 1988, respectively.

Awards

Experience
After Tani received his bachelor’s degree he worked at Hughes Aircraft Corporation in El Segundo, California USA as a design engineer in the Space and Communications group. On his masters degree he specialised in human factors and group decision making. After graduation, Tani worked for Bolt Beranek and Newman in Cambridge, Massachusetts, USA in the experimental psychology department. In 1988, Tani joined Orbital Sciences Corporation in Dulles, Virginia, USA initially as a senior structures engineer, and then as the mission operations manager for the Transfer Orbit Stage. In that role, he served as the flight operations lead, working with NASA Johnson Space Center mission control in support of the deployment of the ACTS/TOS payload during the STS-51 mission in September 1993. Tani then moved to the Pegasus programme at the Orbital Sciences Corporation as the launch operations manager. In that capacity, he served as lead for the development of procedures and constraints for the launching of the air launched Pegasus unmanned rocket. Tani also was responsible for defining, training, and leading the team of engineers who worked in the launch and control room.

NASA Experience
Selected as an astronaut candidate by NASA in April 1996, Tani reported to the Johnson Space Center in August 1996. Having completed two years of training and evaluation, he qualified for flight assignment as a mission specialist in 1998.

He held technical duties in the Astronaut Office Computer Support Branch, and EVA Branch and has served as a Crew Support Astronaut for Expedition 4. In 2002, he was a crewmember on the Aquarius undersea research habitat for 9 days as part of the NEEMO-2 mission (NASA Extreme Environment Mission Operations). Tani then trained and qualified as the backup flight engineer for Expedition 11, which launched aboard the Soyuz TMA-6 in April 2005.

Space Flight Experience
STS-108 (5-17 December 2001) was the 12th shuttle flight to visit the International Space Station. During the mission, which exchanged the Expedition 3 for the Expedition 4 Crew and delivered almost 3 tonnes of supplies, logistics and science experiments in a Multi-Purpose Logistics Module, Tani performed a 4 hours and 12 minutes space walk to wrap thermal blankets around ISS Solar Array Gimbals.

He took over as flight engineer for Expedition 16 from Clayton Anderson after arriving at the ISS on the STS-120 mission in October 2007. He has performed three spacewalks and numerous robotic operations in support of the installation and checkout of Node 2 during his several months on the ISS, and will return on Shuttle Flight STS-122.
Mission Summary
This is a summary of activities during the Shuttle phase of the mission. An overview of Columbus mission activities on completion of the Shuttle mission is covered under ISS Flight Engineer 2 tasks i.e. the tasks of Léopold Eyharts. ESA astronauts Léopold Eyharts and Hans Schlegel will be undertaking experiments as part of the Columbus mission though these are not shown in the timeline below. The following timeline is also subject to change.

Flight Day 1
• Launch
• Configure Shuttle for on-orbit activities
• Checkout of Shuttle robotic arm
• Switch on Columbus laboratory 'Launch-to-Activation' Heaters

Flight Day 2:
• Shuttle heat shield check using robotic arm and robotic arm extension
• EVA preparations including EVA suit checks
• ISS rendezvous preparations

Flight Day 3:
• Rendezvous and docking including Shuttle backflip manoeuvre
• Preparations for EVA 1
• Unberth robotic arm extension to provide clearance for unberthing Columbus during EVA 1
• EVA astronauts ‘campout’ in Quest Airlock to help remove nitrogen from bloodstreams

Flight Day 4:
• EVA 1 – Attach Power and Data Grapple Fixture to Columbus; Prepare and unberth Columbus from Shuttle cargo bay; Prepare P1 truss Nitrogen Tank Assembly for removal;
• Attach Columbus to Node 2 with Station robotic arm
• Check out Node 2 docking mechanism for Columbus

Flight Day 5:
• Columbus commissioning - Connect utility cabling (power, data etc.) and ventilation ducting between Node 2 and Columbus; Replace launch to attachment pressure valves with on-orbit air distribution valves
• Leak check on Columbus
• Hatch open
• Activate Columbus Systems
• Columbus ingress
• Shuttle heat shield check
• EVA 2 preparations
• EVA astronauts ‘campout’ in Quest Airlock to help remove nitrogen from bloodstreams

Flight Day 6:
• EVA 2 – Remove and replace failed Nitrogen Tank Assembly on P1 truss section with new Nitrogen Tank Assembly in Shuttle cargo bay
• Columbus Commissioning – Additional audio, data connections; Install panelling in vestibule (between Node 2 and Columbus hatches); Install handrails and foot restraints; Install portable workstation and video cameras; Relocate European Physiology Modules facility from launch to on-orbit location and attach cabling

Flight Day 7:
• Columbus Commissioning – Install interfaces for racks; Connect nitrogen lines from Node 2 to Columbus; Relocate European Drawer Rack from launch location to on-orbit location
• EVA 3 preparations
• EVA astronauts ‘campout’ in Quest Airlock to help remove nitrogen from bloodstreams
• Crew off-duty time

Flight Day 8:
• EVA 3 – Install SOLAR and EuTEF on Columbus External Payload facility from Shuttle cargo bay; Install failed Control Moment Gyroscope from External Stowage Platform 2 to Shuttle cargo bay for return to Earth
• Columbus Commissioning - Relocate Biolab from launch to on-orbit location; Install items in Biolab (power switches, DC converter); Remove launch locks from different Biolab assemblies; Install items on European Drawer Rack (smoke detector, partitions and air ducting)

Flight Day 9:
• Columbus Commissioning – Remove launch lock from Biolab Glovebox; Outfit Biolab; Biolab power data and cooling lines mated; Power data and cooling lines connected on European Drawer Rack; Water and data connections from European Drawer Rack to protein Crystallisation Diagnostics Facility; European Physiology Modules checkout procedures
• Transfer operations between ISS and Shuttle
• Crew farewells, Shuttle crew into orbiter and close hatches
• Orbiter Docking System leak check

Flight Day 10:
• Undocking
• Station flyaround
• Shuttle heat shield survey

Flight Day 11:
• Landing preparations

Flight Day 12:
• Landing preparations
• Deorbit
• Landing
Flight Day 1: Shuttle Configuration for On-Orbit Activities

Following launch, the crew will take images of the external tank shortly after separation using photo and video cameras. This imagery will be analysed to see if anything has fallen off the tank during launch and ascent such as insulation foam.

![STS-115 external tank after separation from the Space Shuttle Atlantis on 9 September 2006. A crew member onboard the shuttle recorded the image with a digital still camera.](Image: NASA)

The Space Shuttle will now be converted from a launch vehicle into a cargo transporter, workplace and home for the astronauts during their time in space. The seats are stowed away, containers and boxes that were installed in a launch configuration are moved around, spacesuits are taken off and packed away and normal clothes put on, the galley and the toilets are activated. The Shuttle robotic arm will be activated and checked out, along with various mission-specific computers and related equipment. Columbus heaters will also be activated.

![NASA astronaut Joseph Tanner prepares to remove a launch and entry seat on mid deck of Atlantis soon after the Crew reached Earth orbit on flight day 1 of the STS-115.](Image: NASA)

Approximately six hours after launch the astronauts start the first sleep period. The majority sleep on the middeck, with some perhaps in the Shuttle airlock.

![NASA astronauts David Wolf, Piers Sellers, and Jeffrey Ashby during sleep on the middeck of the Space Shuttle Atlantis on the STS-112 mission in October 2002.](Image: NASA)
Flight Day 2: Shuttle Heat Shield Checks and EVA Preparations

After eight hours sleep the crew are woken up by music transmitted from Ground Control, often chosen by relatives of the crew. On the first full day in space for the crew, one of the major tasks is to test the Space Shuttle’s robotic arm and, thereafter, spend a large part of the day checking the Space Shuttle’s heat shields to make sure that nothing has damaged them during the launch. ESA astronaut Hans Schlegel will be one of the astronauts undertaking robotic arm procedures for the heat shield surveys.

Along the outside of the left-hand side of the cargo bay lies the 15 m long robotic arm, which is controlled from the flight deck. Along the outside of the right-hand side of the cargo bay is an equally long robotic arm extension or boom with camera equipment at one end. The Shuttle’s robotic arm is connected to the robotic arm extension, which is then unberthed from the cargo bay in order to start the heat shield surveys.

The robotic arm controller will grip the non-camera end of the boom with the robotic arm and then slowly sweep the other end of the boom with the camera equipment, along the Shuttle’s wings and nose and around and underside of the Space Shuttle. Once the surveys are complete the robotic arm extension is again berthed back in the shuttle cargo bay.

Other major tasks that will take place on flight day 2 relate to the three spacewalks or extravehicular activities (EVAs) that will take place during the mission. Hans Schlegel and NASA astronaut Rex Walheim, the EVA astronauts for spacewalks 1 and 2 will have the main responsibility for carrying out these tasks, which includes testing the EVA suits known as Extravehicular Mobility Units or EMUs.

In addition the crew will prepare for docking with the ISS on the following day. This includes a checkout of the tools and equipment needed for rendezvous and docking.
Flight Day 3: Rendezvous, Docking and EVA Preparations

On day 3 the Shuttle starts rendezvous and docking procedures. This takes about 6 hours until docking. During rendezvous with the ISS the Shuttle carries out a backflip manoeuvre so that the ISS crew can photograph the underside of the orbiter to check that there is no damage to the heat shields. In the final stages of rendezvous and docking the whole crew is involved carrying out duties from taking photographs to carrying out independent distance and speed measurements.

The Shuttle docking mechanism is located inside the forward section of the Shuttle’s cargo bay. This will mate to the Pressurised Mating Adapter (PMA-2) for the first time on the front of Node 2. Once leak checks on the hatches have been successfully completed on the Shuttle side and the ISS side, the hatches are opened and greetings take place between the Shuttle and ISS crews. The Shuttle crew will, hereafter receive a Space Station safety briefing.

Preparations now start for the following days EVA when the Columbus laboratory will be docked to Node 2. ESA astronaut Hans Schlegel and NASA astronauts Rex Walheim and Alan Poindexter will be involved principally with EVA procedures for the following day: transferring EVA suits and tools etc. to the Quest Airlock (See section: EVA Support Information), carrying out checks on the EVA suits and preparing the Quest Airlock and EVA tools.

ESA astronaut Léopold Eyharts and NASA astronauts Leland Melvin and Dan Tani will be involved with robotic arm procedures. The Station robotic arm will un-grapple the Shuttle robotic arm extension and hand it over to the Shuttle arm, where it will remain till the end of the mission, to support either the focused heat shield inspection on Flight Day 5, if required, or the late heat shield inspection after undocking.

After review about the EVA tasks and procedures by the crews, the EVA astronauts (Schlegel and Walheim) are sealed into the airlock for the night at 70% of normal atmospheric pressure i.e. 0.7 bar with a higher % oxygen level. This is to help flush nitrogen out of the body and reduce the risk of decompression sickness in connection with the EVA they will carry out.
On flight day 4 the first mission spacewalk or EVA takes place and is one of the most important days in European space history. Following pre-spacewalk preparations and depressurisation, the EVA astronauts (Schlegel and Walheim) open the hatch and leave the Quest airlock. The astronauts make their way to the Shuttle’s cargo bay, translating along handrails on the US Destiny laboratory and the newly installed European-built Node 2. Whilst moving along Node 2, one of the astronauts will open a flap in the berthing mechanism where Columbus will dock. This open flap will allow an outside view for a camera system in Node 2 that will be used to keep the berthing mechanisms on Columbus and Node 2 precisely aligned during the Columbus docking procedures.

Once in the Shuttle’s cargo bay the astronauts prepare Columbus for unberthing and permanent attachment to the Station. The first task is to install a Power and Data Grapple Fixture on Columbus. This fixture can act as a base point for the Station’s robotic arm and will be used to grapple and move Columbus to its permanent installation location.
Debris protection panelling is removed from around the grapple fixture attachment point on Columbus and Launch-to-Activation heater cables are disconnected. These cables provide power to the Columbus heaters to counter the extremely low temperatures reached on the Shuttle’s journey to the ISS. Covers are removed from the berthing mechanism on Columbus and the grapple fixture is removed from where it is attached to the cargo bay side wall. The grapple fixture is moved to its attachment point on Columbus, bolted into place and relevant power and data cables are attached. Once this is completed the debris protection panels are reinstallled.

While the grapple fixture installation is taking place Léopold Eyharts is making preparations for
Columbus docking inside Node 2, together with Dan Tani, including carrying out an inspection of the Node 2 berthing mechanism and deactivating locking devices so that docking can take place. Afterwards Eyharts will begin preparations for outfitting the area between the Node 2 and Columbus hatches (known as the vestibule) together with ISS Commander Peggy Whitson.

The Station’s robotic arm is now attached to the grapple fixture on Columbus and a signal is sent from inside the Shuttle to release the special latches that hold Columbus in place. Once released the robotic arm begins moving Columbus from the cargo bay to its permanent attachment point on the right-hand (starboard) side of Node 2. While Columbus is being unberthed, Schlegel and Walheim make their way to the P1 truss section to prepare a Nitrogen Tank Assembly for removal on the second EVA. This assembly forms a part of the external thermal control system of the ISS and is being returned to earth due to a failed heater. Preparations for its removal include demating N₂ and electrical lines.

On completion of this task the astronauts make their way back into the airlock and close the hatch signifying the end of the first mission EVA. The EVA should last about 6.5 hours.

While the EVA is still in progress, Columbus is being installed on the starboard docking port of Node 2. It takes about an hour for the berthing mechanisms to be completely locked into each other. Once this has happened the area between the hatches of Columbus and Node 2 is pressurised and a leak check is undertaken.
Flight Day 5: Columbus Activation, Ingress and Commissioning. Heat Shield Inspection

The commissioning of the European Columbus laboratory, which starts on flight day 5 is mainly carried out by ESA astronauts Léopold Eyharts and Hans Schlegel and ISS Commander Peggy Whitson. Once the hatch on the Node 2 side is opened all relevant utilities need to be connected up before the hatch into Columbus is opened.

Power, data and fluid lines are installed. Pressure valves are removed, which stabilised the pressure in Columbus on the journey to the ISS. These are replaced with valves, which assist with air distribution between Columbus and Node 2. Ventilation ducting is now installed between the two modules.

Equipment used to control the connecting bolts between Node 2 and Columbus is removed and additional cabling is attached. At the same time a leak check is carried out on Columbus. Once complete the hatch is opened, the Columbus laboratory systems are activated, and ESA astronaut Léopold Eyharts becomes the first astronaut to enter the European Columbus laboratory on orbit and begin setup procedures. These include preparations for relocating the Columbus experiment facilities from their launch locations to their on-orbit locations. The crew also transfer equipment to Columbus from the Shuttle’s middeck. This equipment will support the rest of the Columbus module commissioning.

On Flight Day 5 another detailed inspection is carried out of the Shuttle’s heat shields using the Shuttle’s robotic arm and the Shuttle arm extension.

Over the course of the day preparations are made for the following day’s EVA. Schlegel and Walheim who are again the EVA astronauts on Flight Day 6 will be involved in preparing the Equipment Lock of the Quest Airlock and configuring the tools needed for the following days EVA. One of the last activities to take place during Flight Day 5 is an EVA procedures review involving all astronauts on the ISS. Once again the EVA astronauts will ‘campout’ in the Quest Airlock in order to remove nitrogen from their bloodstreams.
Flight Day 6: EVA 2 – Nitrogen Tank Assembly, Columbus Commissioning

On Flight Day 6 EVA 2 takes place. Following pre-spacewalk preparations and depressurisation of the Quest airlock, the hatch is opened and the EVA astronauts (Schlegel and Walheim) exit the Station. The first task is to translate to the payload bay of the Shuttle and remove the replacement Nitrogen Tank Assembly (see graphic impression on flight day 4), which will be installed on the P1 truss section during the EVA. This is manoeuvred to the installation location by one of the EVA astronauts attached to the station’s robotic arm.

Before the new Nitrogen Tank Assembly is put in place the failed unit is removed. All relevant cabling was detached during the first EVA so it just needs physically unbolting from the Station. Once unbolted the old Nitrogen tank Assembly is temporarily attached to a Crew Equipment Translation Aid (CETA) cart on the Station’s truss. This cart can be moved on special rails along the Station’s truss for carrying out EVA work. It is attached to the CETA cart by a device called a Multi-Use Tether.

Schlegel and Walheim install the new Nitrogen Tank Assembly and attach all relevant cabling such as $\text{N}_2$ lines and electrical cabling. The astronauts now move to the Shuttle’s cargo bay, one on the Station’s robotic arm with the old
Nitrogen Tank Assembly, the other manually using handrails and tethers. Once in the cargo bay the Nitrogen Tank Assembly is attached for return to Earth.

If the astronauts have managed to do these tasks with enough time to spare, they will continue with so-called get-ahead tasks. This could include installing covers on the trunnion fittings on Columbus. These fittings are where the Columbus laboratory was fixed in the Shuttle’s cargo bay. Other tasks include: repair/installation of panelling on the US Destiny Laboratory and Node 1, which protects against damage from orbital debris; relocation of EVA aids for subsequent flights; and release of restraints on the port-side berthing mechanism of Node 2 to allow for the Japanese Kibo laboratory to be docked there following its launch, currently scheduled for 24 April 2008. The 6.5 hour EVA concludes when the astronauts reenter the airlock.

Columbus commissioning continues on Flight Day 6. The activities are principally carried out by Léopold Eyharts and Daniel Tani. Additional audio and data connections are made in Columbus and panelling is installed in the vestibule between Columbus and Node 2 to cover up all the cabling and ducting that has been connected between the two modules on the previous day.

Handrails are installed on the front of the Columbus racks and foot restraints are also installed in certain locations to help astronauts secure themselves in place while undertaking different activities in weightlessness. The close-out panels for racks D2/D3 are removed to remove hardware stowed behind them and then they are re-installed. A portable workstation is now taken out of Node 2 and installed in Columbus as are a couple of video cameras. The first experiment facility, the European Physiology Modules, is relocated from its launch location to its final on-orbit location and power, data and cooling lines are connected up to the facility. A portable computer system is also activated in the laboratory.
Flight Day 7: Crew Free Time and Columbus Commissioning

On Flight Day 7 the Shuttle crew have some off-duty time lasting a few hours, having worked solidly for the previous six days. They still have various mission tasks to carry out through the day though it is less intensive than Flight days 1 to 6.

For Columbus commissioning, starting with Eyharts and Whitson, the D1 rack in Columbus is rotated in order to gain access for installation of interfaces for other racks and nitrogen lines are connected between Node 2 and Columbus. Nitrogen is required to support pressure control of the Columbus thermal loops and to provide Nitrogen to experiments requiring it.

Schlegel and NASA astronaut Leland Melvin now continue with the work, relocating the European Drawer Rack from its launch location to its on-orbit location.

Operations relating to the third and final spacewalk of the mission on flight day 8 take place: the Quest Equipment Lock is prepared and the EVA tools are configured for the spacewalk. As before one of the last tasks of the day is that the entire ISS and Shuttle crews run over the EVA procedures for the following day.

The astronauts undertaking the final EVA for the mission, NASA astronauts Rex Walheim and Stanley Love, are sealed into the Airlock to remove nitrogen from their bloodstreams to help avoid decompression sickness.
Flight Day 8: EVA 3 – Attachment of Columbus External Facilities

The third and final EVA of the mission is mainly concerned with the attachment of the first two external experiment facilities for Columbus (EuTEF and SOLAR) and the removal and return of a failed Control Moment Gyroscope. The Station’s Control Moment Gyroscopes are used to control the Station’s orientation in space.

Following standard pre-EVA activities including airlock depressurisation the airlock hatch is opened and the EVA astronauts exit the airlock and again transfer to the Shuttle’s cargo bay where the Columbus external experiment facilities are located.

The first facility they detach is the SOLAR facility, which (like EuTEF) is attached to a Multi-Purpose Experiment Support Structure (MPESS) in the Shuttle’s cargo bay. Both astronauts now translate to the SOLAR installation location called the External Payload Facility on the Columbus laboratory. Walheim is moved to the External Payload Facility by the Station’s robotic arm, together with SOLAR. Stanley Love translates there manually.

Once at the installation location the astronauts bolt SOLAR into place on the topmost External Payload Facility location and attach power and data cabling between SOLAR and Columbus. Whilst on Columbus additional handrails will be installed as well as Worksite Interface Fixtures. These fixtures can be used for attaching different pieces of equipment to help with EVA activities e.g. footplates. Protective covers are also put on the keel pins on Columbus. These are attachment points on Columbus where it was fixed in the Shuttle’s cargo bay.

With this task complete the astronauts make their way to the External Stowage Platform attached to the Quest Airlock. This is where the failed Control Moment Gyroscope is located.
Columbus Installation and Daily Mission Activities

External Stowage Platform 2 (ESP-2) attached to the Quest Airlock. Picture taken from Shuttle Discovery on STS-114 mission on 6 August 2005. (Image: NASA)

After detaching the gyroscope from the stowage platform it is moved by one of the astronauts attached to the robotic arm to the Shuttle cargo bay where the astronauts attach it for return to Earth for refurbishment and relight.

The EuTET facility is now detached from the Multi-Purpose Experiment Support Structure in the cargo bay and moved by Walheim on the robotic arm to the External Payload Facility on Columbus. Love again translate there manually. EuTET is attached to the upper, forward facing location of the External Payload Facility. Whilst on Columbus additional handrails and Worksite Interface Fixtures will again be installed. With the EVA activities complete the astronauts make their way back to the airlock and conclude the 6.5 hour EVA.

Hans Schlegel is very much the astronaut at the forefront of Columbus commissioning activities on Flight day 8 as he is not involved in the third mission spacewalk and Léopold Eyharts is one of the Station robotic arm support astronauts for the spacewalk. Biolab is relocated from its launch location to its on-orbit location. Different items are installed in Biolab including a set of power switches and a direct current converter, and launch fixations are removed from Biolab’s thermal control unit, incubator and handling mechanism. Inspection is also made of the Biolab’s nitrogen valves and oxygen/carbon dioxide bottles.

Biolab facility integrated into Columbus. (Image: ESA)

A smoke detector, partitions and air ducting are installed at the back of the European Drawer Rack and a switch in the Payload Power Switch Box is turned on to power SOLAR.
Flight Day 9: Columbus Commissioning, Farewells and Hatch Closing

Flight Day 9 is the day of farewells for the crews and is principally concerned with transfer operations between the Shuttle and the ISS moving any items due for return to earth into the Shuttle and any items due to stay on the ISS from the Shuttle to the Station.

During much of the transfer procedures on Flight day 9 commissioning once again is principally carried out by Eyharts, Schlegel and Whitson. Items are installed relating to Biolab’s Handling Mechanism, Analysis Instruments and Automatic Control System. The launch fixation is removed from Biolab’s glovebox and power, data and cooling lines are mated.

For the European Drawer Rack power, data and coolant lines are connected and water coolant and data connections are made to the Protein Crystallisation Diagnostics Facility inside. Certain checkout procedures also occur with the European Physiology Modules facility.

The complete crews will also take part in a crew conference in the middle of the day followed by the taking of a complete crew photo.

Once the Shuttle crew finish their final activities on the ISS, the crews say their farewells and the Shuttle crew head into the Orbiter and close the hatch. One of the main tasks that is undertaken before sleeping is a leak check on the Orbiter Docking System.
Flight Days 10/11/12: Undocking and Configuration for Landing

On Flight day 10 the Shuttle undocks. Poindexter as pilot is at the helm for undocking. The Shuttle’s flight path is first straight out from the Space Station in the direction of its orbit around the Earth. After 100 m the Shuttle is manoeuvred up over the ISS, doing a circuit around the Station at a distance of approximately 200 m with the crew taking photographs and video footage. After this circuit the Shuttle fires thrusters and puts distance between itself and the ISS.

There is a final inspection of the Shuttle’s heat shields by the Shuttle’s robotic arm, in which Hans Schlegel is involved with robotic arm operations.

On flight day 11 the crew make preparations for landing the following day. Everything not needed anymore is stowed away and the orange spacesuits worn for the launch and landing are brought out. The seats are again installed.

Tani, who has experienced over three months of weightlessness, has a special seat where he can lie down. The longer the time that astronauts have spent in space, the more susceptible they are to fainting.

The others astronauts on Shuttle who have only been in weightlessness for 11 days, will sit up, wearing G-suits under the spacesuits which, by pressing on the legs and around the waist, help to force the blood up into the upper body. A last press conference is held from space during the day.

The final day, day 12, is solely concerned with the preparations for the actual landing. They are similar to the post-launch procedures but in reverse. Everything is put into place and one by one the crewmembers put on their launch/landing spacesuits, beginning with the commander and the pilot, and get fastened into their seats.

About 1 hour prior to landing, following the order from mission control, deorbit and landing procedures will begin (See Launch to Landing Procedures).
ESA Expedition mission overview: ISS Flight Engineer 2 tasks

ESA astronaut Léopold Eyharts will undertake many tasks in his role as Flight Engineer 2 of the ISS Expedition 16 crew during his 7-8 week stay on the ISS before returning on the STS-123 Shuttle mission. As such he has trained in order to be able to carry out many functions, which utilise ISS systems and scientific hardware.

During the course of his mission, Eyharts responsibilities will involve carrying out any number of these tasks as and when required. These not only involve the utilisation of the relevant systems but can also involve the reconfiguration and repair of them using specially designed tools configured to the relevant equipment in the different sections of the ISS. These include:

**Space Station Robotic Arm Operation**

Léopold Eyharts is qualified in the operation of the Space Station Remote Manipulator System (SSRMS) known as Canadarm 2, the Space Station’s robotic arm used for ISS assembly and maintenance. During the STS-122 docked phase with the ISS he will be undertaking robotic arm procedures as part of the Columbus mission in relation to firstly docking Columbus to the ISS and secondly installation of European payloads on the Columbus laboratory.

For the second part of these activities he will be the operator of the robotic arm during the third EVA, which involves transferring an astronaut from the Shuttle cargo bay to the Columbus External Payload Facility where the European EuTEF and SOLAR payload facilities will be installed by the spacewalking astronauts. He will also be the operator of the robotic arm during the same EVA for transferring an astronaut from External Stowage Platform 2 to the Shuttle cargo bay in order to transfer a failed Control Moment Gyroscope for return to Earth.

Eyharts will also be involved in robotic arm procedures during the 1J/A ISS assembly mission scheduled for launch in mid-March 2008.

**Columbus Commissioning**

Eyharts is qualified in the activation and commissioning of the Columbus laboratory and is one of the principal astronauts undertaking these activities along with fellow ESA astronaut Hans Schlegel and with support from NASA colleagues. Commissioning activities include: connecting utility lines (power, data, fluid etc) between Node 2 and Columbus; relocating experiment facilities from launch locations to on-orbit locations and connecting them to relevant ISS systems (power, data, cooling etc); installing facility equipment; activating the facilities; and carrying out the first runs of experiments in certain facilities (Biolab and Fluid Science Laboratory) to determine that they are functioning according to plan.

**ATV, Soyuz, Progress Docking/Undocking**

Scheduled to be onboard for the arrival of the first European Automated Transfer Vehicle (ATV), early in 2008, Eyharts is trained in the operation of the Russian docking mechanism and ATV docked operations. The Russian docking mechanisms are used on the unmanned ATV and Progress supply spacecraft for bringing regular supplies and scientific equipment to the ISS and removing waste from the ISS, and on the Soyuz TMA spacecraft for bringing crewmembers to and from the ISS. Eyharts is also trained as Flight Engineer for the Soyuz TMA spacecraft, which act as an emergency escape vehicle for the Expedition Crews.

**ISS Guidance and Control**

Operating the onboard computer and equipment control systems in the Russian section of the ISS. At the heart of these systems is the ESA-developed Data Management System (DMS-R).
This is used for control of the entire Russian section of the ISS and can be used for reconfiguring equipment. Eyharts is also trained in the command and data handling systems in the US section of the ISS.

**Environment Control**
Operating the US and Russian Environmental Control and Life Support Systems, and the thermal control systems. Environmental Control and Life Support will cover areas such as water recycling and purification, oxygen generation and purification, air conditioning, atmospheric pressure, and even fire detection and suppression. Thermal control systems not only help to help to maintain a comfortable working environment for astronauts in the ISS, it helps to remove heat from equipment in order to prevent overheating. This includes air filters, water loops and radiators on the external surface of the ISS.

**Electrical Power**
Operating US and Russian electrical power systems. The equipment is used for power generation (via solar arrays attached to the ISS), energy storage, power management, and distribution. These kind of operations can be used for distribution of electrical power between different experiment facilities or ISS systems.

**Crew Health and Safety**
Operating systems in the Russian and American sections of the ISS such as the Crew Health Care
Communication
Operating of the ISS onboard communication and tracking systems and the onboard audio and video equipment. This provides two-way audio and video communications among ISS crew, between crew and Mission Control, and between crew and Earthbound scientists via Ku-band, S-band, and UHF frequencies.

EVA Operations
This includes undertaking generic EVA operations in both sections of the ISS as well as using EVA-related hardware such as airlock systems for depressurisation and repressurisation and Russian and American EVA suits.

Scientific Hardware
Due to the nature of his mission, Eyharts is specialist qualified in all of the Columbus experiment facilities: Biolab, dedicated to biological experiments, the Fluid Science laboratory for experiments in fluid physics, the European Physiology Modules for experiments in Human Physiology and the European Drawer Rack, which can cover a range of different scientific disciplines. Eyharts is also qualified in commissioning of the Protein Crystallisation Diagnostics Facility (a subrack facility of the European Drawer Rack).

In addition to these experiment facilities in Columbus, Eyharts is specialist qualified in a range of European-developed scientific facilities in the US Destiny laboratory. This includes the European Modular Cultivation System dedicated to biological experiments, the Microgravity Science Glovebox (MSG) for materials,
Emergency Operations
Each crewmember needs to be capable of reacting correctly and expeditiously to emergency situations. These situations are trained over and over again during the years of preparation and include crew responses to fire, depressurisation and to toxic atmosphere. In such cases it has to be decided, if the cause of the problem can be located and properly handled, in order to ensure the crew’s survival on-board the ISS. However, if there is either insufficient time to fight the problem or the emergency cannot be confined, the crew might have to abandon the station and perform an emergency reentry using the Soyuz-capsule as a rescue vehicle.
The ISS Joint Airlock ‘Quest’ is attached to the ISS on the starboard or right-hand side of the ISS Node 1. The six-tonne Airlock was attached to the ISS in July 2001 as part of the STS-104 mission on Shuttle Atlantis. It is known as the Joint Airlock since it is possible for EVAs to begin from the Airlock using either the US EVA suits known as Extravehicular Mobility Units (EMUs) or the Russian Orlan-M spacesuits. The Station also has another airlock called Pirs (also pictured above) which is further to the back of the station on the Russian segment of the ISS, but this only supports spacewalks using the Orlan spacesuits.

The 6-metre long Quest Airlock is composed of two connected cylindrical chambers: the larger Equipment Lock and the smaller Crew Lock.

**Quest Equipment Lock**

The Equipment Lock is 4 metres in diameter and has stations to assist astronauts getting into and out of their spacesuits before and after EVAs and to perform periodic maintenance. Most of the EVA equipment is stored here. This includes two full EMUs and one EMU upper torso section (which contains the life support systems), the Simplified Aid for EVA Rescue (SAFER) units that allow an astronaut to return to the ISS if he comes untethered during the EVA, ancillary equipment, batteries, power tools, and other important supplies. Two Orlan spacesuits may also be stored in the Equipment Lock in the event of an Orlan-based EVA.

![NASA astronaut Michael Gernhardt in the Equipment Lock of the Quest Airlock with EMU space suits during the STS-104 mission to the ISS (12-24 July 2001). On the right is the upper torso section, which contains the life support systems.](image:nasa)
units for charging and storing batteries used for powering EVA spacesuit systems and power tools, and pumps for transferring water to the EMUs via the Crew Lock used for thermal stability whilst on EVA.

The Equipment Lock is also used by astronauts for 'camping out' prior to an EVA. This means that the astronauts spend a night in the airlock at a reduced pressure to help purge nitrogen from their blood in order to avoid decompression sickness.

**Quest Crew Lock**
The Quest Crew Lock is that part of the airlock that is depressurised to a vacuum so that the crew can exit the airlock's EVA hatch to start their spacewalk.

Prior to starting the EVA a depress pump is used to reduce the pressure in the Crew Lock to 0.2 bar. This is 20% of normal air pressure. The remaining atmosphere is vented to space through the pressure equalisation valve on the EVA hatch. On completion of the EVA, the high pressure oxygen and nitrogen tanks on the external surface of Quest are used to bring the airlock and EVA suit pressures back up to normal levels. Similar pressure valves on the hatches from the Crew Lock to the Equipment Lock and from the Equipment Lock to Node 1 are also used to equalise pressure prior to opening of the relevant hatches. In between EVAs, EMUs may also be stored in the Crew Lock.
Standard EVA Preparations

Before the airlock hatch is opened and the EVA gets underway there are lots of preparations that have to take place to make sure that the EVA proceeds seamlessly. What follows is an overview of some of the tasks that take place:

- **Airlock Preparation**
  
  With a Shuttle-based ISS assembly mission, after the Shuttle docks with the ISS, relevant equipment is transferred from the Space Shuttle to the Quest airlock in preparation for the EVAs that will take place during the mission. The day before the first EVA starts, the ISS Quest Joint Airlock needs to be configured and activated. The equipment has to be laid out to be easily accessible to the EVA astronauts during the EVA. This includes hardware for installation during the EVA and tools needed to carry out the relevant work, which will also need configuring before the start of the EVA (and during).

- **EVA Suit Checkout**
  
  The EVA suits are known as Extravehicular Mobility Units or EMUs. These procedures are performed at least 1 day before the EVA.

  [Image: ESA astronaut Thomas Reiter (left) and NASA astronaut Steven Lindsey working in the Quest airlock on their first day aboard the ISS on 6 July 2006. (Image: NASA)]

  [Image: View of EVA tethers and tether lines in the Quest Airlock on the International Space Station. (Image: NASA)]

  [Image: ESA astronaut Thomas Reiter (left) looking over a procedure checklist with NASA astronaut Jeffrey Williams in his Extravehicular Mobility Unit in the Quest Airlock of the International Space Station on 28 July 2006. (Image: NASA)]

  [Image: NASA astronaut Ed Lu undertaking periodic maintenance of an EMU in the Quest Airlock. (Image: NASA)]
purpose of EMU checkout is to ensure the integrity of the suits. This can include tasks such as powering up and installing the suits batteries necessary during the EVA, checking the Life Support Systems and Simplified Aid for EVA Rescue (SAFER) units that allow an astronaut to return to the ISS if he comes untethered during the EVA and checking that the suits communication devices are working.

**Camping Out (Nitrogen Purge)**
Astronauts have to be in very good physical condition in order to undertake an extravehicular activity. One of the potential risks relating to EVA work is decompression sickness. For this reason, prior to the EVA the astronauts go through a regime of breathing pure oxygen in order to purge nitrogen out of their blood systems.

The day before the EVA, the relevant astronauts will sleep in the airlock, which will be sealed and the pressure reduced from 1 bar to 0.7 bar. 1 bar is normal ISS (and earth sea-level) pressure. This process is known as camping out.

The following day after the camp out the airlock will be repressurised to 1 bar in order to open the hatch to the airlock so that the EVA astronauts can take breakfast and carry out their morning ablutions. Before the airlock is repressurised the EVA astronauts will don oxygen masks.

On returning to the airlock the hatch will be closed and the airlock depressurised again over 20 minutes to 0.7 bar. The EVA astronauts will then be assisted into their EVA suits during which process the oxygen masks will be removed.

**Donning EVA suits**
The EVA suits known as Extravehicular Mobility Units or EMUs are extremely complex, containing many different layers and systems in order to provide the astronaut with an as safe and comfortable environment during EVAs whilst remaining functional for performing the tasks at hand. The EVA astronauts are usually assisted in donning their suits by one or more astronauts, with relevant checks being carried out during this procedure.
The EMUs are principally the same as the Shuttle EVA suit with a few adjustments. EMU-based EVAs are nominally planned for 7 hours, including 15 minutes to egress the airlock, 6 hours of useful tasks, 15 minutes to ingress the airlock, and 30 minutes of reserved unplanned time. In addition, the EMU is equipped with a 30-minute supply of emergency oxygen located in the Secondary Oxygen Pack at the bottom of the Primary Life Support System. This acts as a backup if the primary oxygen supply fails.

When suiting up the astronaut first puts on the urine collection device and then a Liquid Cooling and Ventilation Garment. This spandex garment has water-cooling tubes running through it and also supports a network of ducting that draws ventilation gas from the suit extremities and routes it back to the primary life support system.

The astronaut now gets into the Lower Torso Assembly of the space suit and then rises into the Hard Upper Torso section, which is attached to the airlock wall by an adaptor. The Lower Torso Assembly can be seen as the waist, trousers and boots of the EMU and has separation joints above the knee and above the ankle. The flexible waist section and waist bearing afford the astronaut a large degree of movement about the waist, e.g. bending and hip rotation.

The Hard Upper Torso is a rigid fibreglass vest onto which the Lower Torso Assembly attaches. It also acts as the attachment point for the helmet and the flexible arm sections, which have an arm bearing to allow for arm rotation. The Life Support System is attached to the back of this assembly with Life Support controls mounted to the front in easy reach of the astronaut. Connections between the two parts must be aligned to enable circulation of water and gas into the Liquid Cooling Ventilation Garment and return. The Life Support System provides the crew member with pure oxygen to breath, removes carbon dioxide exhaled, regulates the temperature in the suit, and keeps the pressure during EVA at 0.3 bar, this is 30% of the air pressure at sea level on Earth and 30% of the normal ISS air pressure. This low
pressure is necessary to maintain suit flexibility. If the pressure level was higher the suit would become too stiff to work.

Once the upper torso section is donned the astronauts put on their communications headset otherwise known as a snoopy cap with headphones and microphones for two-way communications between crew members and to Mission Control. This is followed by the gloves and lastly the extravehicular visor and helmet assembly.

This provides protection from micrometeoroids and from solar ultraviolet and infrared radiation. This is made of a rugged, impact resistant polycarbonate material. A vent assembly, bonded to the inside rear of the polycarbonate shell, serves to diffuse the incoming gas over the astronaut's face.

The Extravehicular Visor Assembly is a light-and-heat-attenuating shell which fits over the Helmet Assembly. It is designed to provide protection against micrometeoroid activity and accidental impact damage, plus protect the crewmember from solar radiation. A special coating gives the sun visor optical characteristics similar to those of a two-way mirror; it reflects solar heat and light, yet permits the astronaut to see. Adjustable eyeshades may be pulled down over the visor to provide further protection against sunlight and glare.
An extra unit that is attached to the EMU once it is donned is the SAFER unit. This is a small, self-contained, propulsive backpack system used to provide a free-flying self-rescue capability for an EVA crewmember if he becomes separated from the ISS during an EVA.

So as to not unnecessarily use up EMU battery power the EMUs will remain plugged into the ISS electrical power supply via an umbilical. The spacesuits will then be ventilated with pure oxygen and the airlock will be repressurised to 1 bar. The EVA crew members will continue the pre-breathe of pure oxygen inside their spacesuits for 50 minutes. The EVA astronauts will go into the Crew Lock of the Quest airlock where the hatch will be closed. The depressurisation of the Crew Lock will now be initiated.

**Depressurisation**

The usual pressure inside the ISS is 1 bar, though in the Quest airlock this is 0.7 bar during depressurisation in connection with nitrogen purging. When the astronauts are in the Crew Lock ready to start their EVA this pressure is reduced first to 0.35 bar when a leak check is performed on the suits. If this is ok the Crew Lock is reduced in pressure down to 0.2 bar. The final depressurisation to vacuum occurs through venting through a valve in the EVA hatch. The hatch can now be opened and the EVA can begin.
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.

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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.

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.

For the orbiter, at eight minutes after launch, 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 at an altitude of 225 km. 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.

As the air pressure increases, the forward control thrusters are turned off. Hereafter the aft control thrusters are turned off as the ailerons on the orbiter's wings begin to operate to help control the orbiter more like an aircraft. The orbiter’s wing elevators then become operational and the pitch thrusters are stopped. When the orbiter's velocity falls below Mach 10 a speed brake on the vertical tail opens. This is about 12 minutes to touchdown. At Mach 3.5, the rudder is activated and the final yaw jets are stopped.

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 80 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 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.
On April 12, 1981, 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. Atlantis, which is the chosen orbiter for the STS-122/Columbus mission was first launched in October 1985 and has undertaken 28 missions, which include 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, and transported the US Destiny laboratory, the Quest Airlock and four truss elements to the ISS on six separate missions (STS-98, STS-104, STS-110, STS-112, STS-115 and STS-117).

Discovery has undertaken 34 missions since its first flight in August 1984 the last flight being the STS-120 mission (23 October – 7 November 2007), which transported the European-built Node 2 to the ISS and included ESA astronaut Paolo Nespoli as a member of the crew. Other Discovery missions include deployment of the Hubble Space telescope in 1990 (STS-31), the STS-42 Spacelab IML-1 mission 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) and the European-built Multi-Purpose Logistics Module ‘Leonardo’ (STS-102, STS-105 and STS-121). In December 2006 Discovery was the orbiter used for the STS-116 mission, which included ESA astronaut Christer Fuglesang who undertook EVAs for ISS assembly including installation of the ISS P5 truss section. The flight 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.

Endeavour was the fifth orbiter constructed, undertaking its first mission in 1992. Highlights of its 19 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, and the STS-111 ISS assembly mission with ESA astronaut Philippe Perrin in June 2002. It was last launched on the STS-118 mission in August 2007.

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 more than 700 astronauts have flown on Shuttle and it has put some 1500 tonnes into orbit. Since the Columbia accident in February 2003 there have been improvements made to all elements of the Shuttle.

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 extravehicular operations.

The 18-metre long, 5-metre wide mid fuselage is the location of the payload bay and payload 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 will be 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 payload 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 payload bay or payloads to be grappled and secured in the payload bay for return to Earth.
The 5.5 metre long aft fuselage consists of the left and right orbital manoeuvring 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 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.
Space Shuttle Atlantis 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 have been 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.

There is a 3400 m³ tank for storing liquid oxygen at -183 °C and a 3200 m³ tank for storing liquid hydrogen at -253 °C. 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-122 Atlantis return flight with ESA astronaut Hans Schlegel, 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.
European Experiment Programme

Columbus will immediately support a full European experiment programme in a host of different scientific areas with many utilising the internal and external experiment facilities of the Columbus laboratory due to arrive on the ISS 1E assembly flight in February 2008. Some will be undertaken by members of the Expedition 16 crew, including ESA astronaut Léopold Eyharts and Russian cosmonaut Yuri Malenchenko. Other experiments will include those carried out by ESA astronaut Hans Schlegel who will be a mission specialist on the STS-122/1E assembly flight.

Internal Experiments: Biology

Biolab Facility: WAICO

This is the first experiment to be carried out in the Biolab facility within the European Columbus Laboratory. WAICO, which is the short name for Waving and Coiling of Arabidopsis Roots at different g-levels, concerns the effect that gravity has on the spiralling motion (circumnutation) that occurs in plant roots.

Either it is the case, as is suspected, that this spiralling mechanism is an internal mechanism in the plant, independent of the influence of gravity. If so as the level of gravity decreases the level of root spiralling should increase. If however the presence of gravity does affect this spiralling mechanism, then as the level of gravity decreases, the spiralling should also decrease and the roots should straighten out.

Two types of seed will be used in the experiment a wild type Arabidopsis seed and a mutant strain of Arabidopsis seed. The mutant strain is defective in gravitropism i.e. it has a very low response to the effect of gravity. The addition of this mutant strain helps to provide additional information of the growth processes at work.

By observing Arabidopsis roots growth in space, one can predict that without the interference of gravity the roots will grow in spirals. Root samples from Arabidopsis seedlings will be grown from seed for 10-15 days in space. High resolution photos will be taken during this time. The seedlings will then be fixed to stop growth and analysed on return to earth. This will include an analysis of the microtubules in the seedling roots to determine root structure and the way in which the seedling roots coil. This will help to determine if the surface cells twist the root. Post-flight analysis will also look into the part that the growth hormone auxin plays in this process.

In addition to the seedling samples held in weightlessness on the ISS, seedlings will be held under Earth gravity conditions (1g) for the same period of time. These will either be ground control experiments or held in a 1g centrifuge on the ISS. The 1g experiments will be held at 45 degrees to the direction of gravity as this is the optimal angle for the roots to grow on a flat surface without spreading. This makes it easier to observe any root spiralling motion that either does or does not occur.

Not only does this kind of research help to increase our knowledge of such growth processes that can help to increase the efficiency of agricultural processes on Earth, it also provides the basis for research into agricultural processes in space for future longer-term missions to the Moon and Mars.

Science Team:
G. Scherer (DE)
European Modular Cultivation System: Multigen-1

The European Modular Cultivation System (EMCS) is an ESA experiment facility dedicated to biological investigations in weightlessness. The main goal of the Multigen-1 experiment, which takes place in the experiment facility will be to test how plants will behave at different stages of development under weightless conditions and ultimately to produce viable seeds from multi-generation plant growth in space. The complete Multigen experiment will consist of growing the plant *Arabidopsis thaliana* (thale cress) over three generations, the first part of which will come to its conclusion during the Expedition 16 tour of duty. *Arabidopsis thaliana* is chosen as a model plant with a known genome, can develop under variable conditions and shows a wide range of morphological variations depending on the environment.

The following part of the experiment, Multigen-2, will again germinate harvested seeds from Multigen-1 for 2-3 months on the ISS. Seeds will again be collected and the plants will be analysed post flight to look for genetic adaptations to gravity. Multigen-3 will repeat the 2-3 month growth process on the ISS using seeds harvested from Multigen-2. In addition to standard plant growth observations, Multigen-3 will study root spiralling (circumnutation) in the plants.

Multigen and similar experiments concerning plant growth processes in space could have a future impact on agricultural processes on Earth as well as forming the basis for development of long-term multi-generation plant growth in space. This will impact upon future longer-term exploration missions by providing additional food sources and the development of plant-based life support systems for helping with carbon dioxide recycling.

**Science Team:**

T.-H. Iversen (NO), A.-I. Kittang (NO), B.G.B. Solheim (NO), A. Johnsson (NO), H. Svare (NO), F. Migliaccio (IT)
Internal Experiments: Fluid Science

Fluid Science Laboratory: Geoflow

The Geoflow experiment is of importance in such areas as flow in the atmosphere, the oceans, and the movement of Earth’s mantle on a global scale as well as other astrophysical and geophysical problems having spherical geometry flows shaped by rotation and convection. It is also the first experiment to take place within the Fluid Science Laboratory inside the European Columbus Laboratory.

The experiment will investigate the flow of an incompressible viscous fluid (silicone oil) held between two concentric spheres. A central force field is introduced by applying a high voltage difference between the two spheres. Maintaining the inner sphere at a higher temperature to the outer sphere also creates a temperature gradient from inside to outside. This geometrical configuration can be seen as a representation of the Earth, where the role of gravity is played by the central electric field. These experiments require a weightless environment in order to “turn off” the unidirectional effect of gravity on Earth.

The thermal convection will be observed between the two spheres, measuring the temperature distribution with the spheres revolving around a common axis at low, medium and high rotation rates and also whilst stationary. In the case of a high rotation rate high centrifugal effects are expected.

Measurement of the temperature distribution will be carried out using Wollaston Shearing Interferometry, though additional optical diagnostics may also be used (Schlieren or shadowgraphy).

Understanding and controlling fluid flow in a spherical geometry under the influence of rotation will also be useful in a variety of engineering applications, such as improving spherical gyroscopes and bearings, and centrifugal pumps. Furthermore, study of effects, which serve to simulate the central gravity field, will find applications in areas such as high-performance heat exchangers and in the study of electro-viscous phenomena. It will also help to understand the motion of liquids in several ground-based industrial applications where injected ions are a source of charge, e.g. in electrostatic precipitators and ion-drag pumps.

The Geoflow experiment will fly to the ISS with STS-122/ISS assembly flight 1E flight and is scheduled to return with the ULF2 flight in October 2008.

Science Team:
Science Team: Ch. Egbers, F. Feudel, Ph. Beltrame (DE), P. Chossat, I. Mutabazi, L. Tuckerman (FR), R. Hollerbach (UK)
Internal Experiments: Human Physiology

Early Detection of Osteoporosis in Space (EDOS)

The mechanisms underlying the reduction in bone mass, which occurs in astronauts in weightlessness, are still unclear. The Early Detection of Osteoporosis in Space (EDOS) experiment will evaluate the structure of weight and non-weight bearing bones of cosmonauts/astronauts pre and post-flight using the method of computed tomography (pQCT) together with an analysis of bone biochemical markers in blood samples.

The objective of the project is to demonstrate the efficiency of this technique as an early detection of impairment in bone remodelling and ultimately to provide information on the mechanics underlying bone loss and to accurately evaluate the efficiency of relevant countermeasures.

EDOS should significantly contribute to the development of a reference technique to perform an early detection of osteoporosis on Earth. The ground experiment with the ISS increment crews will take place at Star City near Moscow and is scheduled to use 10 to 12 short- and long-term subjects.

Science Team:
C. Alexandre (FR), L. Braak (FR), L. Vico (FR), P. Rüegsegger (CH), M. Heer (DE)
Chromosome-2
During space flights crew members are exposed to different types of ionizing radiation. To assess the genetic impact of these radiations, this experiment will study chromosome changes and sensitivity to radiation in lymphocytes (white blood cells) of ISS crew members. The Chromosome-2 experiment is planned to be carried out using eight subjects: four subjects from short-duration flights and four Expedition crew members.

Science Team:
C. Johannes (DE), M. Horstmann (DE)

ETD
The working of our balance system and our eyes are strongly interconnected and understanding their adaptation to weightlessness can help with our understanding of the occurrence of space sickness. Our eyes can rotate around three axes whereas normally only two are used. The name of the coordinate framework which describes the movement of the eyes in the head is called Listing’s plane. This experiment centres on the evaluation of Listing’s plane under different gravity conditions using the Eye Tracking Device (ETD), which is able to record horizontal, vertical and rotational eye movements and measure head movement.

Science Team:
A. Clarke (DE), T. Haslwanter (CH), E. Tomilovskaya (RU), I. Koslovkaya (RU)

Immuno
The aim of this experiment is to determine changes in stress and immune responses, during and after a stay on the ISS. This will include the sampling of saliva, blood and urine to check for hormones associated with stress response and for carrying out white blood cell analysis and a questionnaire to be filled out by the astronaut. There will also be a focus on the adaptation of cellular energy metabolism, which can affect immune response.

Science Team:
A. Chouker (DE), F. Christ (DE), M. Thiel (DE), I. Kaufmann (DE), B. Morukov (RU)

Low Back Pain
The deep muscle corset plays an important role in posture when in the upright position. It is thought that this deep muscle corset atrophies during spaceflight leading to strain and hence pain in certain ligaments, in particular in the iliolumbar region in the back. The objective of this experiment is to assess the back pain in response to exposure to weightlessness.

Science Team:
A. Pool-Goudzwaard (NL), C. Richardson (AU), J. Hides (AU), L. Danneels (BE)

MOP
When entering weightlessness, astronauts suffer from a phenomenon called space motion sickness, which has symptoms comparable to seasickness. This disturbance in the body’s orientation and balance is similar to the disturbances experienced by subjects who have undergone rotation in a human centrifuge having experienced two to three times Earth’s gravity for up to several hours. This experiment aims to obtain an insight into this process and could help in developing countermeasures to space motion sickness.

Science Team:
E. Groen (NL), J. Bos (NL), S. Nooij (NL), W. Bles (NL), R. Simons (NL), T. Meeuwsen (NL)
Neocytolysis
This experiment covers the effects of weightlessness on the hemopoietic system: the system of the body responsible for the formation of blood cells. The experiment will study a process called neocytolysis, the selective destruction of young red blood cells. The experiment will analyse the physical and functional characteristics of young red blood cells taken from astronaut blood samples before and after spaceflight.

Constituents of blood. E is an erythrocyte or red blood cell, L is a lymphocyte or white blood cell and P is a blood platelet. (Image: NASA)

Science Team:
A. Risso (IT), G. Antonutto (IT), M. Cosulich (IT), G. Minetti (IT)

Sample
This experiment will investigate what kind of microbial species are to be found on board of the International Space Station and how these adapt to conditions of spaceflight. The participant will take samples in certain areas of the Space Station and from his own body. The samples will be taken at places by rubbing swab sticks over surfaces, which are susceptible to having bacteria including switches, keyboards and personal hygiene equipment.

Science Team:
H. Harmsen (NL), G. Welling, (NL), J. Krooneman (NL), L. van den Bergh (NL)

Spin
This experiment is a comparison between pre-flight and post-flight testing of astronaut subjects using a centrifuge and a standardized tilt test. Orthostatic tolerance i.e. the ability to maintain an upright posture (without fainting) will be correlated with measures of otolith-ocular function i.e. the body’s mechanism linking the inner ear with the eyes that deals with maintaining balance.

Science Team:
F. Wuyts (BE), S. Moore (US), H. MacDougall (AU), G. Clement (FR), B. Cohen (US), N. Pattyn (BE), A. Diedrich (US)

ZAG
ZAG, which stands for Z-axis Aligned Gravitoinertial force is an investigation into the effect that weightlessness has on an astronaut’s perception of motion and tilt as well as his level of performance during and after spaceflight. Different tests will take place pre and post flight including an analysis of the astronaut’s motion perception and eye movements whilst using a track-and-tilt chair.

Science Team:
G. Clement (FR), S. Wood (US), M. F. Reschke (US), P. Denise (FR).
Internal Experiments: Radiation Dosimetry

**ALTCRISS**
ALTCRISS (Alteino Long Term monitoring of Cosmic Rays on the International Space Station) is an ESA experiment to study the effect of shielding on cosmic rays in two different and complementary ways. The detector of the Alteino device will monitor differences in the flow of cosmic rays with regard to the position and orientation of the Alteino device, with the focus being on radiation monitoring in the Pirs module in the Russian segment of the ISS.

**Science Team:**
- M. Casolino (IT)
- F. Cucinotta (US)
- M. Durante (IT)
- C. Fuglesang (SE)
- C. Lobascio (IT)
- L. Narici (IT)
- P. Picozza (IT)
- L. Sihver (SE)
- R. Scrimaglio (IT)
- P. Spillantini (IT)

**EuCPD**
The European Crew Personal Dosimeters (EuCPDs) will be worn by the ESA astronauts onboard the ISS to measure the radiation exposure during their flights. The dosimeters are worn around the waist and the left ankle for astronauts inside the Station and at the same locations above the liquid cooling garment inside the space suit for astronauts undertaking spacewalks. Each dosimeter is only 8 mm thick and consists of a stack of five different passive radiation sensors. The different sensors will measure different radioactive particles such as a range of neutrons and heavy ions as well as measuring particle impact angles and energy transfer from particles.

**Science Team:**
- U. Straube - ESA
- C. Fuglesang - ESA

**Project Team:**
- J. Dettmann - ESA
- G. Reitz – DLR (DE)

**Matroshka 2B**
The ESA Matroshka facility was initially installed on the external surface of the ISS on 27 February 2004 with the aim of studying radiation levels experienced by astronauts during spacewalk activities. It consists of a human shape (head and torso) called the Phantom equipped with several active and passive radiation dosimeters. This is mounted inside an outer container of carbon fibre and reinforced plastic to simulate a spacesuit. The facility was brought back inside the ISS on 18 August 2005 to continue the experiment for radiation measurements inside the ISS.

For the Matroshka 2B experiment new passive radiation sensors were uploaded on Soyuz 15S on 10 October 2007 for installation inside the Phantom. The active radiation dosimeters inside the facility will be activated in February 2008. The Matroshka facility will be installed inside the ISS to taking similar measurements related to the internal ISS radiation environment.

**Science Team:**
- G. Reitz (DE)
- R. Beaujean (DE)
- W. Heinrich (DE)
- M. Luszik-Bhadra (DE)
- M. Scherkenbach (DE)
- P. Olko (PL)
- P. Bilski (PL)
- S. Derne (HU)
- J. Palvalvi (HU)
- E. Stassinopoulos (US)
- J. Miller (US)
- C. Zeitlin (US)
- F. Cucinotta (US)
- V. Petrov (RU)

**Project Team:**
External Experiments: EuTEF Facility

The European Technology Exposure Facility (EuTEF) is one of the first two external facilities to be attached to the Columbus laboratory and houses the following experiments requiring either exposure to the open space environment or a housing on the external surface of the ISS:

**EXPOSE-E**

EXPOSE-E is a subsection of EuTEF and consists of five individual exobiology experiments:

**LIFE** – The *Lichens and Fungi Experiment (LIFE)* experiment will test the limits of survival of Lichens, Fungi and symbionts under space conditions. Some of the organisms being exposed for approximately 1.5 years include the black Antarctic fungi (*Cryomyces antarcticus* and *Cryomyces minteri*), the fungal element (mycobiont) of the lichen *Xanthoria elegans*, and the complete lichens (*Rhizocarpon geographicum* and *Xanthoria elegans*) in situ on rock samples.

*Previous results from the Biopan exposure facility on the Foton-M2 mission in 2005 showed the ability for lichens to survive in exposed space conditions for 15 days.*

**Science Team:**
S. Onofri (IT), L. Zucconi (IT), L. Selbmann (DE), S. Ott (DE), J-P. de Vera (ES), R. de la Torre (ES)

**ADAPT** - This experiment concerns the molecular adaptation strategies of micro-organisms to different space and planetary UV climate conditions.

**Science Team:**

**PROCESS** - The main goal of the PROCESS (PRebiotic Organic ChEmistry on Space Station) experiment is to improve our knowledge of the chemical nature and evolution of organic molecules involved in extraterrestrial environments.

**Science Team:**
H. Cottin (FR), P. Coll (FR), D. Coscia (FR), A. Brack (FR), F. Raulin (FR).

**PROTECT** - The aim of this experiment is to investigate the resistance of spores, attached to the outer surface of spacecraft, to the open space environment. Three aspects of resistance are of importance: the degree of resistance; the types of damage sustained; and the spores repair mechanisms.

**Science Team:**

**SEEDS** - This experiment will test the plant seed as a terrestrial model for a panspermia vehicle i.e. a means of transporting life through the universe and as a source of universal UV screens.

**Science Team:**
D. Tepfer (FR), S. Leach (UK), A. Zalar (HR), S. Hoffmann (DK), P. Ducrot (FR), F. Corbineau (FR).
DEBIE-2
DEBIE, which stands for ‘DEBris In orbit Evaluator’ is designed to be a standard in-situ space debris and micrometeoroid monitoring instrument which requires low resources from the spacecraft. It measures sub-mm sized particles and has 3 sensors facing in different directions. The scientific results from several DEBIE instruments onboard different spacecraft will be compiled into a single database for ease of comparison.

Science Team:
G. Drolshagen - ESA, A. Menicucci - ESA

Dostel
Dostel (DOSimetric radiation TElescope) is a small radiation telescope that will measure the radiation environment outside the ISS.

Science Team:
G. Reitz - DLR (DE)

EuTEMP
EuTEMP is an autonomous and battery-powered multi-input thermometer for measuring EuTEF temperatures during the unpowered transfer from the Shuttle Cargo Bay to the Columbus External Payload Facility to which EuTEF is attached.

Science Team:
J. Romera – ESA

EVC
The Earth Viewing Camera (EVC) payload is a fixed-pointed Earth-observing camera. The main goal of the system is to capture colour images of the Earth’s surface, to be used as a tool to increase general public awareness of the ISS and promote the use of the ISS to the potential user community for observation purposes.

Science Team:
M. Sabbatini - ESA

FIPEX
It is important to build up a picture of the varying atmospheric conditions in low earth orbit where orbiting spacecraft are still affected by atmospheric drag. The density of the atmosphere is the major factor affecting drag and this is affected by solar radiation and the earth’s magnetic and gravitational fields. The flux of atomic oxygen is important as it shows different interactions with spacecraft surfaces, e.g. surface erosion. With the FIPEX micro-sensor system, it is intended to measure the atomic oxygen flux as well as the oxygen molecules in the surrounding area of the International Space Station.

Science Team:
Prof. Fasoulas, University of Dresden (DE)

MEDET
The aims of the Materials Exposure and Degradation ExperimenT (MEDET) are: to evaluate the effects of open space on materials currently being considered for utilization on spacecraft in low earth orbit; to verify the validity of data from the space simulation currently used for materials evaluation; and to monitor solid particles impacting spacecraft in low earth orbit.

Science Team:
V. Inguimbert – ONERA (FR), A. Tighe - ESA

PLEGPAY
The scientific objective of PLEGPAY (PLasma Electron Gun PAYload) is the study of the interactions between spacecraft and the space environment in low earth orbit, with reference to electrostatic charging and discharging. Understanding these mechanisms is very important as uncontrollable discharge events can adversely affect the functioning of spacecraft electronic systems.

Science Team:
G. Noci – Laben-Proel (IT)

Tribolab
This series of experiment covers research in tribology, i.e. the science of friction and lubrication thereof. This is of major importance for spacecraft systems. The Tribolab experiments will cover both experiments in liquid and solid lubrication such as the evaluation of fluid losses from surfaces and the evaluation of wear of polymer and metallic cages weightlessness.

Science Team:
R. Fernandez – INTA (ES)
External Experiments: SOLAR Facility

The SOLAR facility, will study the Sun with unprecedented accuracy across most of its spectral range. This study is currently scheduled to last for two years. SOLAR is expected to contribute to the knowledge of the interaction between the solar energy flux and the Earth’s atmosphere chemistry and climatology. This will be important for Earth observation predictions. The payload consists of 3 instruments complementing each other, which are:

**SOL-ACES**
The goal of the Solar Auto-Calibrating Extreme UV-Spectrometer (SOL-ACES) is to measure the solar spectral irradiance of the full disk from 17 to 220 nm at 0.5 to 2 nm spectral resolution. Solar EUV radiation strongly influences the propagation of electromagnetic signals such as emitted from navigation satellites. Providing the variability of solar EUV radiation with the accuracy of SOL-ACES will contribute to improving the accuracy of navigation data as well as the orbit forecasts of satellites and debris. By an auto-calibration capability, SOL-ACES is expected to gain long term spectral data with a high absolute resolution. In its centre, it contains 4 Extreme Ultra-Violet spectrometers. SOL-ACES is a new instrument that has never flown.

**SOLSPEC**
The purpose of SOLSPEC (SOLar SPECtral irradiance measurements) experiment is to measure the solar spectrum irradiance from 180 nm to 3000 nm. The aims of this investigation are the study of solar variability at short and long term and the achievement of absolute measurements (2% in UV and 1% above). The SOLSPEC instrument is fully refurbished and improved with respect to the experience gained in the previous missions (Spacelab-1, Atlas-1, Atlas-2, Atlas-3, Eureca).

**Science Team:**
M.G. Thuillier (FR).

**SOVIM**
The Solar Variability and Irradiance Monitor (SOVIM) is a re-flight of the SOVA experiment on-board Eureca-1. The investigation will observe and study the irradiance of the Sun, with high precision and high stability. The total irradiance will be observed with active cavity radiometers and the spectral irradiance measurement will be carried out by one type of sun-photometer.

SOVIM is interested in the basic solar variability in itself or in using this variability to study other physical phenomena, as e.g. solar oscillations. The basic reasons for irradiance changes are crucially important for the understanding of solar and stellar evolution.

**Science Team:**
C. Frohlich (CH).
Education Activities

ESA view education as an important facet of all Human Spaceflight missions, not only by promoting the important role of science and technology to the younger generation, but by fostering this interest through and after university. ARISS, which stands for Amateur Radio on the ISS, plays a key part in this vision. ARISS is an international association of national amateur radio societies of the countries participating in the ISS programme.

For the Columbus mission there will be two or more real time radio transmissions from the ISS, during which pupils in selected French primary schools will put questions to ESA astronaut Leopold Eyharts.

In addition to the ARISS contacts with the ISS, there are a number of other education activities based around the ISS assembly mission. For primary school children aged 8-12 years there will be an animated web lesson about the Columbus laboratory. For secondary school children there will be an online video lesson entitled ‘European Science Goes into Orbit’ focusing on Columbus as a unique, European science laboratory in space.

For university students an essay contest was launched in September 2007, the winner of which will attend the launch of the Columbus Laboratory at the Kennedy Space Center in Florida. The topic of the essay is the “Value of Human Spaceflight for European Citizens”. University course material related to engineering aspects of Columbus will also be available on the ESA Web portal. This material is planned to form part of an e-learning series of university lectures hosted at ESA’s ESTEC facility in the Netherlands. If crew time permits, a lecture from the ISS on a topic related to a scientific experiment is planned for a Joint European Masters Course in Space Science and Technology.

It is also foreseen for Leopold Eyharts to give a "live" lesson from space for primary and secondary level classes, focusing on nutrition, sleep and working on board the ISS. Both the latter activities are being planned by ESA in collaboration with CNES and CADMOS (Toulouse).

National web chats with ESA astronauts Hans Schlegel and Léopold Eyharts post-flight are also being organised.

Project Team
ESA-HME Education Office (NL)
ESA's Columbus Control Centre (Col-CC) will support the European Columbus Laboratory once it becomes an integral part of the ISS after its launch. It is situated at the German Aerospace Center (DLR) facility in Oberpfaffenhofen, near Munich, Germany.

The Control Centre will be the direct link to the Columbus Laboratory when in orbit. Its main functions will be 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 will also hold 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 will have 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 will be monitored and coordinated through the Columbus Control Centre. The Columbus systems will be 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 will be routed by the Columbus Control Centre, exercising its role as network operations centre. The engineering data will be archived at Col-CC whereas the scientific and relevant experiment and facility data will be distributed to de-centralised User Support and Operations Centres or USOCs, where these will be processed and archived.

The USOCs are based in national centres distributed throughout Europe and will be 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 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 Columbus Control Centre will also be 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 will host 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.
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) is due for launch early in 2008 by an Ariane 5 rocket from Kourou, French Guiana. The ATV Control Centre will coordinate and support 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 will be led by DLR flight directors and will be under the overall supervision of an ESA Mission Director based at DLR Oberpfaffenhofen. The Col-CC operations teams will be capable of supporting 7 day/week, 24 hours/day operations during the Columbus Launch and Assembly mission. Thereafter, the Col-CC operations will be tailored to the payload operations needs.

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.
User Support and Operations Centres (USOCs)

From the outset of the ISS Programme, a decentralised scheme for the utilisation of European payloads on board the ISS was envisaged. USOCs located in various participating countries will act as the link between the user community and ESA’s Columbus Control Centre in Oberpfaffenhofen in Germany, NASA’s Payload Operations Integration Center in Huntsville, Alabama, and the Mission Control Centre in Moscow.

During the pre-launch phase, the USOCs are concerned with activities such as ground model operations, experiment-procedure development, payload and experiment optimisation and calibration, and support to crew training activities. During the in-orbit payload operations, the USOCs will receive facility and experiment data and perform, in coordination with the Columbus Control Centre, the operations of the payloads for which they are responsible.

In addition, the USOCs will be responsible for the interaction with the scientists in the User Home Bases in disseminating experiment data to them, and receiving and processing requests for experiment scheduling and direct commanding.

Depending on the scope of the task assigned to a USOC, it can assume three basic levels of responsibility. The first level is to operate as an Experiment Support Centre, supporting users from the country in which the USOC is situated, in preparing and conducting an experiment.

The second level is to operate as a Facility Support Centre (FSC) supporting particular functions of an Agency-provided multi-user facility. The third level is to operate as a Facility Responsible Centre (FRC) with full responsibility for the operation of a complete payload facility.

For the Columbus facilities the relevant USOCs will be as follows:

**Biolab:** The Facility Responsible Centre for Biolab is at the Microgravity User Support Centre (MUSC) in Cologne, Germany. BIOTESC in Zurich, Switzerland will be acting as the Facility Support Centre.

**European Drawer Rack:** The Erasmus USOC at ESA’s ESTEC facility in Noordwijk, the Netherlands is the Facility Responsible Centre for the European Drawer rack with the Belgian USOC in Brussels and the Dutch Utilisation centre in Emmeloord acting as Facility Support Centres.

**European Physiology Modules:** The Facility Responsible Centre for the European Physiology Modules is at CADMOS (Centre d’Aide au Développement des activités en Micro-pesanteur et des Opérations Spatiales) in Toulouse, France with DAMEC in Odense, Denmark acting as the Facility Support Centre.

**Fluid Science Laboratory:** The Facility Responsible Centre for the Fluid Science Laboratory is at the Microgravity Advanced Research and Support (MARS) Centre in Naples, Italy. MARS will be supported by the E-USOC in Madrid, which is the Facility Support Centre for Fluid Science Laboratory Operations.

For the unpressurised external payloads, the Facility Responsible Centres will be based at ESA’s Erasmus USOC for EuTEF, at the Belgian USOC for SOLAR, and at CADMOS for ACES.
The European Astronaut Centre (EAC) of the European Space Agency is situated in Cologne, Germany. It was established in 1990 as a result of Europe’s commitment to human space programmes and is the home base of the nine European astronauts who are members of the European Astronaut Corps.

During the Columbus assembly and commissioning mission the Crew Medical Support Office, part of EAC will be responsible for medical support and monitoring of ESA astronauts Léopold Eyharts and Hans Schlegel. The medical support team is composed of flight surgeons, biomedical engineers and specialists in the field of psychology, exercise and rehabilitation.

For launch, landing, and specific events such as American EVAs, medical support is provided by the team from the Mission Control Center at the Johnson Space Center in Houston. Russian EVAs would be supported from the Mission Control Centre (TsUP) in Moscow.

During all mission phases medical support comes from the Medical Console Room at EAC. This is staffed with a biomedical engineer and a flight surgeon working on consoles within shift schedules.

The main tasks of the team are to monitor the biomedical and environmental conditions for the crewmembers; to interact with all Medical Operations Groups from the international partners; and to provide guidance and advice for all medical procedures, in-flight fitness and countermeasures. Among their tasks is the execution of a daily or weekly medical conference with the ESA astronaut, depending on the phase of flight. The medical support team also provides medical support to the astronauts’ families.
Kennedy Space Center
(Space Shuttle launch and post-flight operations)

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 takes over responsibility from the Mission Control Center in Houston.
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.
Mission Control Centre – Moscow
(Responsible for Russian ISS modules and Soyuz/Progress spacecraft launch, ascent and descent phases)

The Russian Mission Control Centre, also known as TsUP in Russian, is situated in Korolev (formerly Kaliningrad) near Moscow. TsNIIMash, the Russian acronym for the Central Research Institute for Machine Building, operates the centre on behalf of the Russian Federal Space Agency, Roscosmos.

It was built in 1973 and is the same location for the Mission Control Centre of the Mir and Salyut space stations and further contains the flight control rooms for the Progress and Soyuz launches.

Flight control personnel are organized into teams, and each function has a NASA counterpart at Mission Control Center, Houston. These functions include the Flight Director, who provides policy guidance and communicates with the mission management team. This consists of the Flight Shift Director, who is responsible for real-time decisions, within a set of flight rules; the Mission Deputy Shift Manager for the Mission Control Centre, who is responsible for the control room's consoles, computers and peripherals; the Mission Deputy Shift Manager for ground control, who is responsible for communications, and the Mission Deputy Shift Manager for crew training.

The spaceflights are actually managed by numerous experts in control, space technology, ballistics, telemetry, communications, automated control, tracking systems, and by experts of scientific institutions.

A huge visual display in the centre of the Main Control Room is used to show information such as the current position of orbiting spacecraft. There are several digital and character displays for actual mission elapsed time, counters, telemetry data, orbital characteristics, etc. Specific information comes directly to each individual controller’s computer display unit.
The ISS Payload Operations Center (POC) is located at the Huntsville Operations Support Center, which is on NASA’s Marshall Space Flight Center in Alabama. It is responsible for the overall control of scientific research activities on the ISS.

The Payload Operations Director at the POC is in charge of coordinating all payload activity, together with the Flight Director at Mission Control in Houston, international partners, crew and research facilities. From this interaction, timelines of scientific activity are drawn up.

The Payload Communications Manager at the POC coordinates voice communications between the International Space Station crew and the POC on payload matters, enabling researchers around the world to talk directly with the crew about their experiments.

There are further functions at the Payload Operations Center associated with separate elements of payload procedure. These functions cover the safety of experiments (and changes to them); coordinating experiment resources such as power; scheduling; prioritisation; and controlling and processing of voice, video and data channels. The authority for the control of payloads and hence experiments is distributed around the world. Each International Partner is responsible for the operation of its payloads in its on-orbit laboratory, as it falls within the given payload timelines, under the guidance of the POC.
Columbus Laboratory Agreements

*Columbus Development Agreement*

The approval of Europe’s participation in the ISS, which included Columbus, came in October 1995 at the ESA Ministerial Council in Toulouse, France. This approval lead to the signing of the €658 million contract to develop Columbus with prime contractor Daimler Benz Aerospace, (now part of EADS Astrium) in March 1996. At the time it was the largest single contract ever awarded by the Agency.

Maximum use was made of ‘common’ European and ISS items in the Columbus development in order to reduce costs. As they were the prime contractor for the MPLMs for the Italian Space Agency, Alenia Spazio (Now part of Thales Alenia Space) became a major subcontractor in the Columbus programme, with provision of the primary Columbus structure.

Another common item was the Columbus Data Management System, which used the same elements as those developed by ESA for the Russian Service Module (the ESA DMS-R contract). The contract for the Columbus Data Management System was one of only two classical subsystem contracts that were placed: the Data Management System with Matra Marconi Space and the Environmental Control and Life Support System with Dornier, both companies subsequently becoming part of EADS Astrium. All other units are subcontracted at the equipment/assembly level, thus eliminating a management layer in part of the programme.

In addition to the companies that became part of EADS (Aerospatiale, Daimler Benz Aerospace, Matra Marconi Space) and the companies that became part of Thales Alenia Space (Alenia Spazio, Alcatel Bell Space and Defense, Alcatel Space Industries, Officine Galileo), other contracting companies that were involved in the industrial consortium to develop Columbus include: Kayser-Threde, OHB and Draeger Aerospace from Germany; French companies Soterem and Secan; Italian companies Space Software Italia and Microtectica; Spanish company Sener; Spacebel from Belgium; Dutch companies Origin B.V. (now Atos Origin) and Hollandse Signaal AG (now part of Thales Nederland); the Swiss company CIR (now part of Sydral); Rovsing and Terma from Denmark; and Cap Gemini in Norway. There were also a few additional elements from non-European companies such as common ISS items including the hatch and Common Berthing Mechanism from Boeing.

*ESA/ASI Cooperative Agreement on Manned Spaced Modules*

In 1997, ESA and the Italian Space Agency (ASI) signed an agreement to cooperate on the development of manned space modules. Under this arrangement, ESA would provide the Columbus-derived Environmental Control and Life Support equipment for ASI’s three Multi-Purpose Logistics Modules, which were developed for NASA by ASI to be used as pressurised cargo containers to travel in the Shuttle cargo bay. In exchange ASI would provide the Columbus primary structure, derived from that of MPLM. In this way, each agency was relieved of the development of significant portions of major subsystems, thereby saving tens of millions of Euros.
**Columbus launch agreement**
The launch of Columbus is covered by a barter agreement with NASA signed on 5 March 1997. Originally Columbus would have been launched on an Ariane 5 though downsizing of the laboratory and the cost saving influence of using the MPLM principle structure for Columbus lead 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 provides two of the Station's three Nodes (ISS connecting modules), spares and sustaining engineering for the Laboratory Support Equipment items provided by ESA to NASA under the Early Utilisation Memorandum of Understanding and hardware/support for software development and integration in the NASA ground software test and integration facilities for the ISS. ESA also placed responsibility for developing Nodes-2 and -3 with ASI in order to utilise the same structural concept as the MPLMs and Columbus.

**Columbus Control Centre Agreement**
On 31 March 2003 ESA signed the 37.7 million euro contract to develop the Columbus Control Centre with DLR, the German Aerospace Center at Oberpfaffenhofen, near Munich, Germany. Under this contract DLR would be responsible for the design, construction, integration and configuration of the Columbus Control Centre, recruiting and training of the operations team, and qualification of the European operations ground infrastructure on behalf of ESA.

Following the first period of initial operations of the Columbus Laboratory, DLR will take responsibility under a further ESA contract for management of the centre and coordinate and support all on-orbit operations of the Columbus laboratory on behalf of ESA. This includes coordinating the different centres responsible for individual Columbus experimental facilities, and operations of the European communications network, including ATV communications support.

**ISS Exploitation Agreement**
With the development of Columbus nearing completion, plans were put into place governing European exploitation of the ISS. This led to the signing of a €1 billion contract between ESA and EADS Space Transportation (Now EADS Astrium). The contract covers initial exploitation activities, in particular preparations for the operations of Columbus. Regarding the initial exploitation activities, the contract dealt with the European experiment facilities for the International Space Station as well as with the experimental programme that will be executed by the astronauts onboard the Station. The contract also covers activities in the fields of the European flight control team and crew training, ground facility maintenance and engineering support for Columbus.

A part of the contract also covers the production of additional Automated Transfer Vehicles (ATVs), the European spacecraft, which will act as an ISS cargo ship, and further be used for reboosting the ISS to higher orbital altitudes to counter the effects of atmospheric drag and remove waste from the station. This contract was signed on 13 July 2004.
Columbus Payload Agreements

**Columbus Payload Rack Agreement**
ESA signed a hardware exchange agreement with NASDA (now JAXA). Within the framework of this Memorandum of Understanding NASDA provided ESA with 12 International Standard Payload Racks (ISPRs) for use in the Columbus laboratory on the ISS. In exchange ESA provides NASDA with one MELFI Freezer identical to those developed by ESA for NASA in the context of the Early Utilisation Memorandum of Understanding.

**Flight Unit 2 of MELFI at the Kennedy Space Center in Florida with the Expedition 11 Crew. JAXA is provided 1 MELFI freezer in exchange for 12 International Standard Payload Racks.**

**Biolab**
The prime contractor for Biolab is EADS-Astrium in France. Major subcontractors in the development include OHB in Germany who were responsible for producing the training model at EAC, and Rovsing in Denmark who were responsible for the science reference model at the Facility Responsible Centre. Other principle contracting companies for Biolab subsystems include Bradford Engineering in the Netherlands, NTE in Spain, Carlo Gavazzi Space and Ferrari in Italy, Verhaert and Logica in Belgium, and Rosys, Treff and Hamilton in Switzerland.

**Fluid Science Laboratory**
The prime contractor for the Fluid Science Laboratory is Alenia Spazio in Italy (Now part of Thales Alenia Space). The major subcontractors in the project include DASA (now part of EADS) and OHB in Germany, Verhaert in Belgium, Sener in Spain, and MARS Center and Carlo Gavazzi Space in Italy. A cooperative agreement added the Microgravity Vibration Isolation System, developed by the Canadian Space Agency.

**European Physiology Modules**
The prime contractor for European Physiology Modules is OHB in Germany. Major subcontractors include Carlo Gavazzi Space in Italy, Verhaert in Belgium, and EREMS in France. Cooperative agreements also added Cardiolab, developed by CNES and DLR.

**European Drawer Rack**
The prime contractor for the European Drawer Rack is Alenia Spazio (Now part of Thales Alenia Space) in Italy. Major subcontractors include OHB and Kayser-Threde in Germany, Bradford Engineering in the Netherlands and OCI in Switzerland.

**European Transport Carrier**
The industrial organisation for the European Transport Carrier is the same as for the European Drawer Rack.

**EuTEF**
The prime contractor for EuTEF is Carlo Gavazzi Space in Italy.

**SOLAR**
The prime contractor for SOLAR is Alenia Spazio (Now part of Thales Alenia Space) in Italy.

**ACES**
The prime contractor for the ACES payload is EADS-Astrium in Friedrichshafen in Germany.
Astronaut Flight Opportunities

The ISS Intergovernmental Agreement (see ISS General Information) provides the framework for design, development, operation and utilisation of the ISS. It was signed by the participating States on 29 January 1998.

The subsequent Memorandum Of Understanding signed between ESA and NASA on the same day, which covers relevant ISS responsibilities, obligations and rights includes the flight opportunities being used by Léopold Eyharts and Hans Schlegel.

Under this Memorandum Of Understanding between ESA and NASA one ESA astronaut is allotted to fly on the mission for Columbus assembly and system verification. This is the flight of ESA astronaut Hans Schlegel.

Leopold Eyharts will fly under another Article of the agreement, within which ESA has the right to provide permanent crew for the Station from the time it begins to share common ISS system operations responsibilities i.e. from the time that Columbus is commissioned at the Station. After this occurs 8.3% of the crew time available for utilisation will be allocated to ESA. Of the crew flight opportunities for the astronauts of NASA, CSA, ESA and The Government of Japan, 8.3 % will be available for ESA astronauts.
ESA astronaut Paolo Nespoli from Italy was the last European astronaut launched into orbit onboard the STS-120 Shuttle Discovery mission in October 2007 as a member of the ISS 10A assembly mission. During the mission one of his major tasks was as intravehicular activity (IVA) astronaut coordinating activities of the spacewalking astronauts during installation of the European-built Node 2 and relocation of the P6 truss section to the end of the port-side truss. Nespoli also undertook a European experiment programme as part of the European Esperia mission.

ESA astronaut Paolo Nespoli participating in a post insertion/de-orbit training session at the Johnson Space Center on 9 April 2007. (Image: NASA)

The STS-120 Shuttle mission marked the continued construction of the International Space Station. It also pre-empted the STS-122 mission in February 2008, which will see the European Columbus laboratory attached to the ISS. This mission also has important significance from a European perspective as it will include two astronauts who are members of ESA’s European Astronauts Corps. German ESA astronaut Hans Schlegel who will be a Mission Specialist for the ISS Columbus assembly mission and French ESA astronaut Léopold Eyharts who will become a member of the ISS Expedition Crew, taking over from NASA astronaut Dan Tani, who travelled to the ISS on the STS-120 Discovery flight.

ESA astronaut Léopold Eyharts during STS-122 training at the Johnson Space Center in May 2007. (Image: NASA)

The flights of Nespoli, Eyharts and Schlegel come in a long tradition of European astronauts who have flown on the Shuttle since ESA astronaut Ulf Merbold from Germany became the first European astronaut to fly on Shuttle in 1983.

Ulf Merbold became the first European to undertake a mission on the Space Shuttle (STS-9) on the 10-day Spacelab-1 mission between 28 November 1983 and 8 December 1983. Not only was this the first spaceflight of an ESA astronaut, it was the first flight of the European-built Spacelab and the first flight of a non-American on the Shuttle.

Spacelab was the first purpose-built space laboratory developed by Europe under a cooperation agreement with NASA. It was a modular research laboratory that would fit inside the Shuttle's cargo bay and built by a consortium of European companies. During the Spacelab-1 mission over 70 scientific experiments were conducted in a variety of fields including Astronomy, Solar Physics, Space Plasma Physics, Earth Observation, Material Science, Technology and Life Sciences. Working in two teams of three, the crew worked 12-hour shifts, allowing for 24-hour operations.

Between 1983 and 1998, Spacelab flew on the Space Shuttle a total of 22 times. Seven of these missions included European astronauts: ESA astronaut Wubbo Ockels, and German Aerospace Research Establishment (which became DLR) astronauts Reinhard Furrer and Ernst Messerschmid in 1985. Ulf Merbold undertook his second Spacelab flight in January 1992 (Spacelab IML-1 mission) followed two months later by Belgian astronaut Dirk Frimout. In 1993 DLR astronauts Hans Schlegel (now one of the ESA astronauts scheduled to fly on the STS-122 mission, which will transport the European Columbus laboratory to the ISS) and Ulrich Walter, and in November 1994 ESA astronaut Jean-Francois Clervoy, Jean-Jacques Favier (CNES) became the last European astronaut to fly on a Spacelab mission on Shuttle between 20 June and 7 July 1996.

Not only have Spacelab experiments made a major contribution to space science research, but also the knowledge and expertise gained by both ESA and NASA during the Spacelab missions has made a significant contribution to today's International Space Station programme.

Beyond the Spacelab missions, European astronauts have carried out a wealth of research and gained a wealth of experience aboard Shuttle in the past 20 years. Following the flight of Patrick Baudry on the Spartan-1 mission for CNES in 1985, there was a gap of seven years until the flight of ESA's and Europe's most experienced astronaut to have flown on the Space Shuttle, Claude Nicollier, who flew on Shuttle on four separate occasions. Nicollier's first flight was on STS-46 in 1992 together with Italian Space Agency astronaut
ESA astronaut Claude Nicollier who served on four separate Shuttle missions between 1992 and 1999. (Image: ESA)

Franco Malerba. This mission deployed the European Retrievable Carrier (EURECA) and the Tethered Satellite System (TSS-1). Nicollier’s second mission was on the first Hubble Space telescope servicing mission, STS-61 in December 1993. During the 11-day flight, the Hubble Space telescope was captured and restored to full capacity through a record of five spacewalks by four astronauts. His third flight was on STS-75 Columbia (22 February to 9 March 1996) together with ESA astronaut Maurizio Cheli and Italian Space Agency astronaut Umberto Guidoni. This mission was a 15-day flight, with principal payloads being the reflight of the Tethered Satellite System (TSS) and the third flight of the United States Microgravity Payload (USMP-3).

The TSS experiment produced a wealth of new information on the electrodynamics of tethers and plasma physics before the tether broke at 19.7 km, just shy of the 20.7 km goal. Scientists on the ground were able to devise a programme of research making the most of the satellite’s free flight while the astronauts’ work centred on research related to the USMP-3 Microgravity investigations.

In December 1999 Nicollier was part of the STS-103 mission together with ESA astronaut Jean-François Clervoy who was on his third flight on the Shuttle. This was the third Hubble Space
telescope mission. During this eight day mission, Nicollier carried out his first spacewalk or EVA, of 8 hours 10 minutes duration to install a new computer and one of three fine guidance sensors. He is the first European to obtain EVA experience on a Shuttle flight.

Between the third and fourth flights of Nicollier, who retired in March 2007, four European astronauts undertook missions on the Shuttle. Jean-François Clervoy was on the 6th Shuttle flight to Mir in May 1997 and Jean-Loup Chrétien (CNES) on the 7th Shuttle/Mir flight (25 September 97 – 6 October 1997). Pedro Duque, now Director of Operations of the Spanish User Support and Operations Centre in Madrid, flew as Mission Specialist on the Space Shuttle Discovery, STS-95 mission (29 October to 7 November 1998). This nine-day mission was dedicated to research in weightlessness and the study of the Sun. Michel Tognini, currently Head of ESA’s European Astronaut Centre, flew on the STS-93 mission, which took place from 22-27 July 1999. During this mission his primary task was to assist in the deployment of the Chandra X-Ray Observatory, and to conduct a spacewalk if needed. The Chandra X-Ray Observatory is designed to conduct comprehensive studies of the universe, and the telescope will enable scientists to study exotic phenomena such as exploding stars, quasars, and black holes.

With the passing of the millennium, Gerhard Thiele became the first European astronaut to fly on Shuttle. From 11-22 February 2000, Thiele participated as mission specialist in the STS-99 Mission. The Shuttle Radar Topography Mission (SRTM) was dedicated to the first, three-dimensional, digital mapping of the Earth surface on a nearly global scale. He was responsible for SRTM operations, including the deployment and retraction of the 200-foot high boom from Endeavour’s cargo bay upon which one of the flight’s radar systems was mounted. Thiele was also one of two spacewalking crew members, in the event contingency spacewalk would have been required during the flight.

From 19 April to 1 May 2001, Umberto Guidoni participated in the Space Shuttle’s STS-100 mission, being the first European on board the International Space Station. On that flight, the Space Shuttle delivered elements and equipment required for the ongoing assembly of the International Space Station. In particular, it carried the Multi-Purpose Logistics Module (called Raffaello), provided by the Italian Space Agency and loaded with laboratory outfitting equipment, as well as the Space Station Remote Manipulator System (SSRMS), the Canadian robotic arm that is, and will be, used extensively to assemble the Space Station.

From 5-19 June 2002 Phillipe Perrin served as a mission specialist on the STS-111 mission.
onboard Space Shuttle Endeavour. The 14-day STS-111 mission exchanged the ISS Expedition Crew and delivered a Canadian-built mobile base system for the Station’s robotic arm. During the Mission Perrin carried out three successful spacewalks. On the first two Extravehicular activities, he helped to install the mobile base system and on the third, he performed a late-notice repair of the Station’s robotic arm by replacing one of its joints. He spent a total of about 19 hours outside the station. During that mission, he was also arm operator and berthed the MPLM back into the orbiter payload bay towards the end of the mission.

ESA astronaut Thomas Reiter inserting radiation sensors in the European Matroshka experiment in December 2006 in the Zvezda Service Module on the ISS. (Image: NASA)

On 4 July 2006 ESA astronaut Thomas Reiter was launched to the ISS on the STS-121 Discovery flight. He became the first European and ESA astronaut to become a member of an ISS Expedition Crew remaining on the ISS for nearly six months. During his time on the ISS he carried out relevant ISS tasks as well as an ESA experimental programme as part of the European Astrolab mission.

ESA astronaut Christer Fuglesang from Sweden followed Reiter onboard the STS-116 Shuttle Discovery mission in December 2006 as a member of the ISS 12A.1 assembly mission and undertaking the European Celsius mission. During the mission he undertook three spacewalks in connection with installation of the P5 truss section of the ISS and reconfiguration and activation of the ISS thermal control system and power supply. Thomas Reiter was on the return journey of the STS-116 flight with Fuglesang, which landed on 22 December 2006.

ESA astronaut Christer Fuglesang during the second EVA on the ISS 12A.1 assembly mission in December 2006. Attached by a footplate to the Station’s robotic arm, Fuglesang is relocating a piece of EVA hardware to a different location on the ISS truss to clear the way for activities on the third EVA. (Image: NASA)
The following information provides an overview of different steps in the development of the Columbus Laboratory and related issues.

1995
At the ESA Ministerial Council meeting in Toulouse in October the programme for European participation in the International Space Station is approved. This includes the Columbus Orbital Facility (Columbus Laboratory) and the Microgravity Facilities for Columbus.

1996
ESA signs the 658 million euro contract with prime contractor DASA (now part of EADS Astrium) to develop the Columbus laboratory.

1997
The Preliminary Design Review starts in October to evaluate the Columbus Orbital Facility system design. ESA propose attachment points for external research payloads. On 8 October the Columbus Orbital Facility Launch Barter Agreement is signed between ESA and NASA. Under this agreement ESA will provide additional hardware and services for the International Space Station to NASA, including Nodes 2 and 3 in exchange for the European laboratory module being launched on the US Space Shuttle.

1998
The Columbus Preliminary Design Review is completed on schedule. This leads to the start of Critical Design Reviews for equipment and subsystems. Interfaces are defined with NASA between Columbus and the Shuttle, the overall ISS and the payload racks which house for example the Columbus experiment facilities.

The Meteoroid and Debris Protection System panels for Columbus are tested up to impact velocities of 7 km/sec. Primary structure manufacturing is underway. The performance of the module’s water loop was tested in late 1998.

1999
Cabin ventilation was verified in February 1999 on a mock-up of the Columbus interior, using the fans and ducting hardware. Fire-suppression tests were conducted in March 1999 on mechanical mock-ups of the relevant areas.

Earlier problems with the laboratory mass have now been resolved and the associated design changes incorporated. Data management interface tests between Columbus and the ISS are conducted successfully.

2000
A full-scale mockup of Columbus, with all external features incorporated, has been tested in the NASA/JSC Neutral Buoyancy Facility, and astronauts have verified that all planned and contingency EVA activities can be carried out.
Columbus Neutral Buoyancy testing at the Johnson Space Center in the USA in 2000.

Manufacture of the flight unit primary structure is complete and pressure and leakage testing have been successfully carried out. The subsystem critical design reviews are now complete. Following successful completion of the launch and on-orbit modal survey tests on the flight model, the test configuration has been disassembled and integration of the flight harnesses, ducting and plumbing has started.

2001
The system Critical Design Review and the independent NASA Safety Review II have been conducted successfully. The accommodation of the European external payloads on the Columbus External Payload Facility has been agreed with NASA. Under this agreement, ESA will free the three positions on the Express Pallet at the S3 truss site and retains exclusive rights to use the Columbus External Payload Facility location for approximately 4.5 years.

The Columbus flight-unit integration began at Alenia Spazio’s (now part of Thales Alenia Space) premises in Turin in March 2001 with the integration of the Pre-integrated Columbus Assembly (PICA), which comprises all mechanical items, such as: primary and secondary structures; thermal-control system and environmental control & life-support system equipment; harness, ducting and plumbing; illumination, crew support equipment; and external protection like multi-layer insulation and micrometeoroid and debris-protection items.

The first test jointly performed with NASA and the ISS prime contractor Boeing on data communications exchange between Columbus and the rest of the ISS was successfully completed in June 2001. The ISS Assembly Sequence is updated in June though the Columbus launch remains scheduled in October 2004.

The Pre-integrated Columbus Assembly (PICA) being loaded into an Airbus Super Guppy for transport to Bremen in 2001.
After completion of the flight-unit mechanical integration phase at Alenia Spazio in Turin, the Pre-integrated Columbus Assembly is delivered to EADS Astrium in Bremen on 27 September for the start of flight-unit final integration. This involves integrating all functional elements into the Columbus module, including: power distribution units; communications equipment (including video and audio communication); data-management equipment, and flight-application software.

Integration of functional components at EADS in 2002.

The Pre-integrated Columbus Assembly (PICA) being lowered onto the Columbus integration stand at EADS in Bremen after arrival from Alenia Spazio in Turin. (Image: EADS Astrium)

2002
Integration of almost all the internal functional components of the Columbus flight unit is now complete, and the closeout plate of the starboard end-cone has been installed and wired up. The first functional system testing on the flight unit has been performed successfully.

The Columbus Crew Trainer has been successfully integrated into the Columbus Mechanical Mock-Up at the European Astronaut Centre in Cologne and has been used to support the first ISS Advanced Crew Training session between 26 August and 6 September 2002. This included hands-on training sessions, covering the systems and subsystems of the Columbus module and its four principle ESA experiment facilities.

Integration of functional components at EADS in 2002.

Columbus mechanical mock-up at the European Astronaut Centre in Cologne, Germany. (Image: ESA)

The core members of the Flight Control Teams and the nomination of the lead Flight Directors for the Columbus launch mission have been defined.

2003
Grounding of the Shuttle fleet following the STS-107 Columbia accident on 1 February causes a long-term delay in the ISS assembly launch sequence.
On 31 March ESA sign a contract with DLR to develop the Columbus Control Centre.

Thermal and electromagnetic compatibility tests are performed successfully on the flight model of the Columbus Laboratory. Following completion of the qualification test campaign on the flight model of the Columbus laboratory, qualification and flight safety reviews are completed. The flight models of Biolab, the European Physiology Modules and the Fluid Science Laboratory are assembled.

2004

Columbus testing has shown that the audible noise level is well below the requirement level, making it the quietest module for the ISS. The European Drawer Rack flight model interface testing with Columbus was successfully completed in February. The flight models of the experiment facilities have been delivered.

The External Payload Facility has been attached to the end-cone of the module. Training models of all experiment facilities have now been delivered to the European Astronaut Centre in Cologne.

ESA and EADS Space Transportation sign the contract, which covers initial ISS exploitation activities, in particular preparations for the operations of Columbus.

Columbus operations preparation is progressing and a second table-top simulation is successfully performed at the Columbus Control Centre. System Validation Tests are completed in August with the Columbus Control Centre connected to the User Support and Operations Centres and the Columbus Laboratory flight module with the experiment facilities integrated.

All four active Columbus payload facilities have been integrated into the Columbus flight model, which has successfully completed both the individual payload Integrated Functional Testing and the Integrated System Test. Testing of the...
2004

First NASA payload rack installed in Columbus, the Human Resource Facility, was successfully completed in October. The inauguration of the Columbus Control Centre in Oberpfaffenhofen in Germany took place on 19 October.

All payload facilities have been removed from Columbus and returned to their developers for flight readiness completion, and the Columbus laboratory has entered a hibernation phase. Numerous training courses have been held at the European Astronaut Centre (EAC), including Columbus User-Level Training for ground support personnel (February), and for an international class of astronauts (March); and Columbus Payload Advanced Training for Facility Responsible Centre personnel and EAC biomedical engineers (March).

The final round of Columbus system acceptance testing is completed. Columbus has been weighed and is some 350 kg below specification mass. The flight models of the European Physiology Module, Biolab, Fluid-Science Laboratory and the European Drawer Rack, including the Protein Crystallisation Diagnostic Facility, have been delivered to EADS in Bremen, Germany where they have been integrated into Columbus and have successfully completed interface testing.

The flight models of the two Columbus External Payloads, SOLAR and EuTEF, have been delivered and successfully integrated and interface tested on Columbus, and subsequently returned to their developers final integration testing. The first Columbus simulation in the Integrated Simulation Set-Up was performed in October. The simulation was run on the Columbus Trainer at EAC, with the Flight Control Team in the Columbus Control Centre commanding the module.

On 25 October, NASA confirm baseline of 18 more Shuttle flights to the ISS. Subsequent evaluation of ISS final configuration and assembly sequence establish feasibility of advancing the launch of Columbus and its payloads by two flights.

2005

2006

The Heads of Agency meeting takes place at the Kennedy Space Center in Florida on 2 March. In the subsequent press conference it is announced that 16 more Shuttle flights are needed to complete ISS assembly. ESA Director General Jean-Jacques Dordain also confirms the
advancement of the Columbus launch to flight seven in the sequence bringing the launch date forward to the second half of 2007.

Columbus is loaded into a container at EADS Astrium in Bremen, Germany and transferred into an Airbus ‘Beluga’ aircraft at Bremen airport on 28 May for delivery to the USA. After landing in Florida on 30 May, Columbus is delivered to the Kennedy Space Center on the following day.

On 2 June a ceremony takes place at the Kennedy Space Center to welcome the new module. In August the Incoming inspection campaign is finished, which included a module leak check in the Operations and Checkout Building vacuum chamber at the Kennedy Space Center.

2007

From January to April payload processing takes place at the Space Station Processing Facility of the Kennedy Space Center. All the payload facilities inside Columbus go through procedures to ready them for launch. Between April and August the European Transport Carrier, is integrated for launch and this includes integration of items to go to the ISS such as the European developed Flywheel Exercise Device. Flight trunnions are also installed. These are used to keep Columbus fixed in the Shuttle cargo during launch.

After September, water loop degassing takes place on Columbus and the module is pressurised. It is then placed in a canister ready for shipment prior to launch.
ISS Intergovernmental Agreement

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), Russian Federal Space Agency (FKA or Roscosmos, formerly Rosaviakosmos), the Canadian Space Agency (CSA) and the Japanese Space Agency (JAXA, formerly NASDA), 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 is ESA’s Research laboratory. 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 will be permanently stationed at the International Space Station attached to another European-built module, Node 2. It is planned for launch with Shuttle Atlantis in February 2008.

Automated Transfer Vehicle (ATV)

The Automated Transfer Vehicle is Europe’s unmanned supply vehicle for the ISS. It will take up to 9 tons of cargo to the ISS, boost the station to a higher orbiting altitude and remove up to 6.5 tons 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 will include pressurised cargo, water, air, nitrogen, oxygen and attitude control propellant. The first launch is planned for no earlier than February 2008.

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.

Ownership for Node 2 was, and for Node 3 will be, transferred to NASA within the framework of a barter agreement between ESA and NASA.

**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 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 2009.

**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 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.

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.
Credits

This document has been compiled, produced and written by the Coordination Office of the European Space Agency’s Directorate of Human Spaceflight, Microgravity and Exploration Programmes 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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