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.

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)
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.

During this first part of the experiment, the plant will be grown from seed up to mature seed-bearing plants for 2-3 months on the ISS, with time-lapse video recording the growth process. The plants will be observed with relation to growth, development and production of flowers and new seeds with a special emphasis on spiralling growth (circumnutation) in the shoots. The plants are grown in special containers that automatically provide water and nutrients when necessary. On conclusion of the growth phase the plants will be dehydrated to collect seeds that will be returned to Earth for laboratory analysis. 1g experiments will also be carried out in the EMCS using its centrifuge. Ground control experiments will also be grown at the Norwegian USOC.

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)

Computed tomography (pQCT) measurement during second campaign of the WISE bed rest study in Toulouse, France. (Image: CNES/ Stéphane Levin)

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. Ruegsegger (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:

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.
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 microorganisms to different space and planetary UV climate conditions.


- **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.


- **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

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

PLEGPLAY
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).

**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:
- M.G. Thuillier (FR)
- 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)