Exploring with Columbus

A Guided Tour of the Science on Europe's Space Laboratory on the ISS

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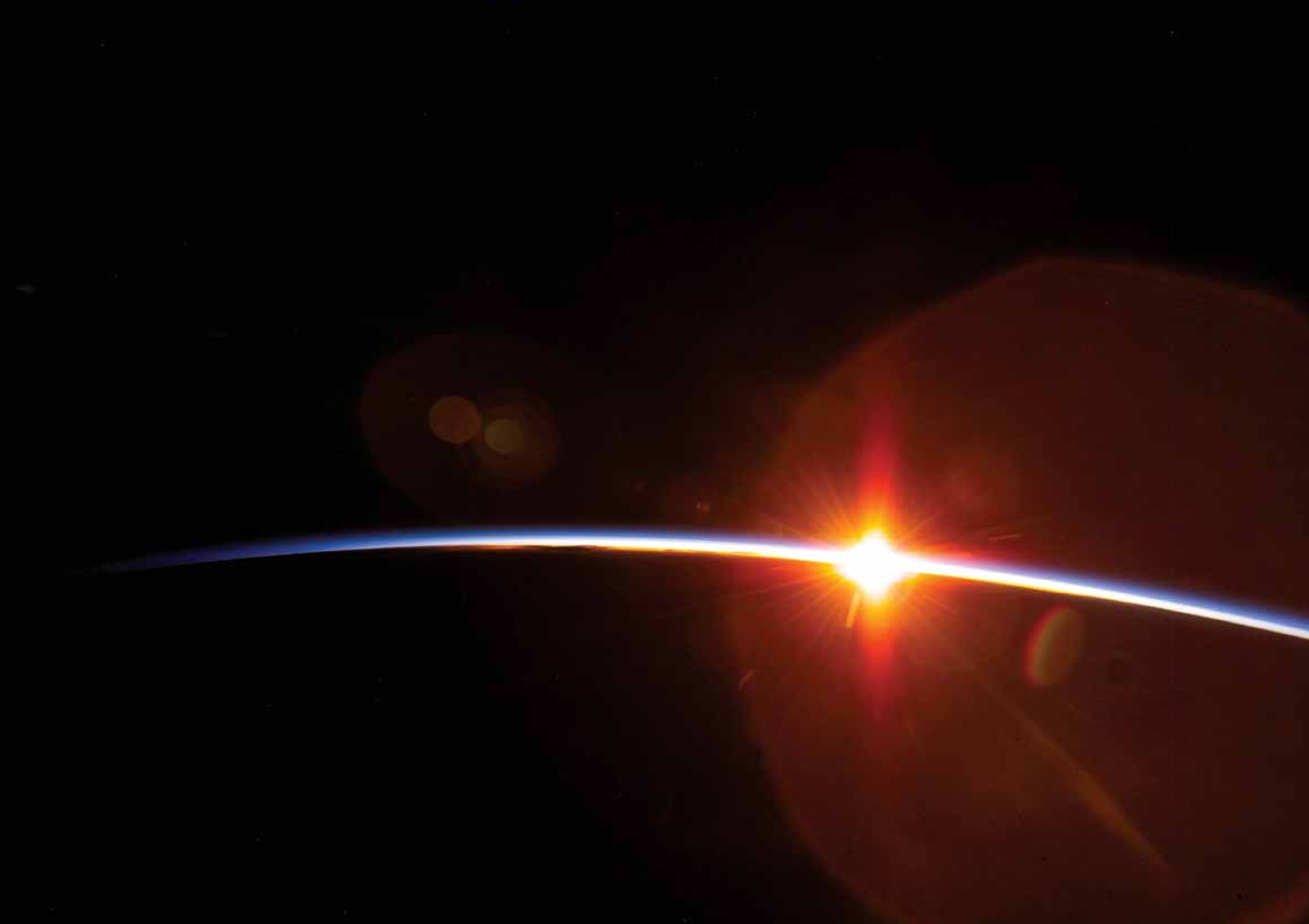


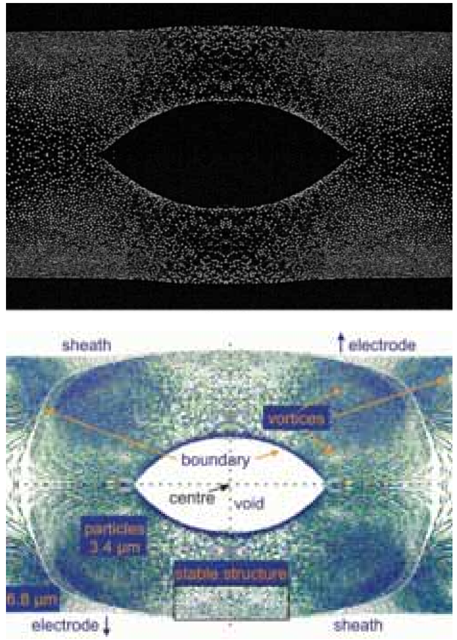
Exploring Nature

Life as we know it has evolved under the 'normal' gravity level we find on our home planet. Human evolution – the way our body functions, and the way we perceive nature and the world around us – has been dominated by our Earth-based frame of reference.

While scientists such as Galileo, Newton, Laplace and Einstein deduced the laws of nature and the effects of gravity, until very recently we were unable to do real experiments in circumstances where gravity does not play a role. Only in the last 50 years has space been accessible to humans, and to experiments that study the effects of gravity on physical and biological processes.

The questions we pose are profound, and address many fundamental aspects of science, such as:

- what are the basic ingredients of life, and how can living organisms survive the harsh space environment?
- how do cells sense gravity, and how does that influence the growth of plants and the functioning of animal and human bodies?
- how does the human body react to the space conditions and how does it adapt to this new environment?
- what are the physical properties of liquid metals, (critical) fluids, complex plasmas and quantum systems?
- what can we learn of the dynamic behaviour of fluid motion, mixing and two-phase systems when undisturbed by buoyancy and convection?
- how are solidification, boiling and chemical reactions influenced by gravity?



A 3-D complex plasma can be observed only in weightlessness. The PK-3 Plus facility, which was used during the Astrolab mission in 2006, enables the simulation of a number of basic molecular phenomena and unravels new fundamental processes.

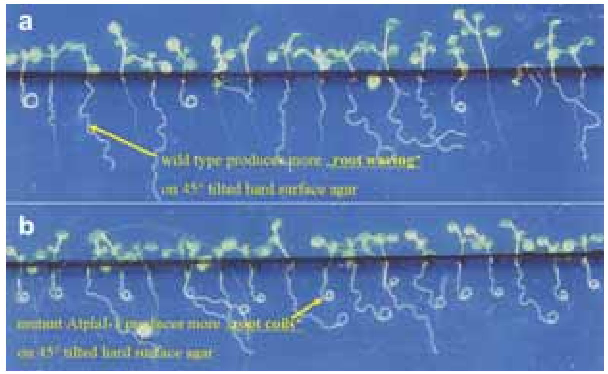
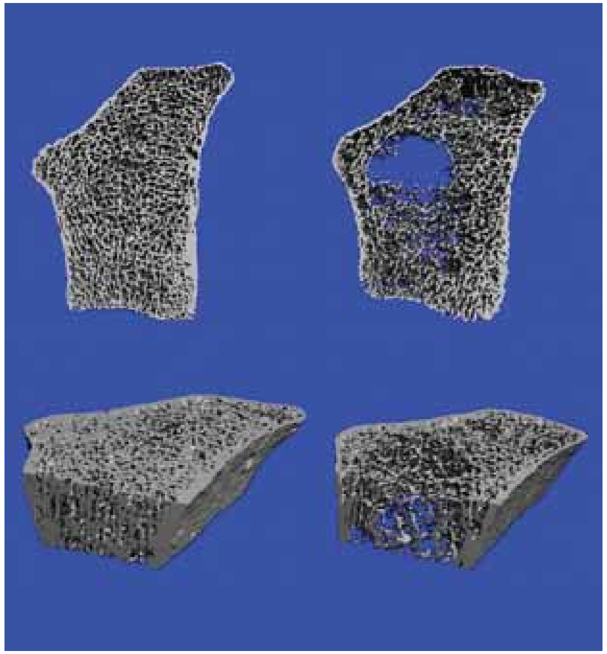


Image from a ground-based test of the Biolab 'WAICO' experiment, to be launched with the Columbus laboratory, to look into the waving and coiling of *Arabidopsis* roots.



Normal bone (left) and osteoporitic bone (right). In space, accelerated bone loss occurs in otherwise healthy subjects. Research in this area holds benefits in medical applications on Earth and in future human spaceflight. (Scanco Medical AG)

ESA astronaut Frank De Winne on the ISS during the Neurocog experiment, a neuroscience experiment that investigated the role of sensory information in human spatial perception.

Research and Development

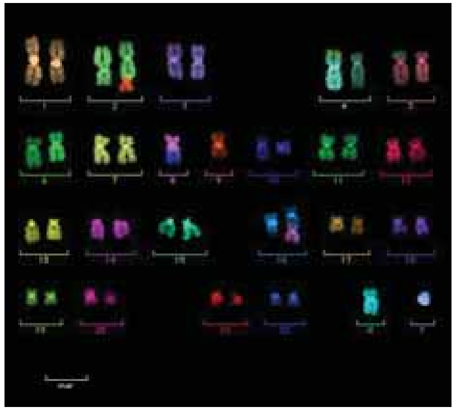
While the fundamental scientific questions are fascinating in themselves, the results can also help to improve our daily lives on Earth. Projects are now addressing issues that are relevant for future healthcare, or that will contribute to better, cleaner or more efficient processes in industry.
With these projects, European experiments aboard the International Space Station (ISS) will:

- contribute to the understanding, diagnosis and treatments of many common diseases (cardiovascular disorders, osteoporosis, equilibrium problems, immune system deficiencies).
- develop advanced medical techniques for remote or emergency situations.
- detect trace contaminants in air, water and food.
- investigate new production and processing techniques for the chemical, petrochemical, biochemical and semiconductor industries.
- research advanced high-performance materials for automotive, medical and industrial applications. Possibilities include the development of more efficient aircraft engines, power generators and fuel cells.

More than 120 European companies as well as a great number of hospitals are involved in this research. Part of the funding is provided by ESA, but the European Union, industry and institutes involved pay almost two-thirds of the total costs, highlighting the importance and interest of this research.

Research could help to develop advanced materials for producing more efficient aircraft engines.

A commercial version of the Nitric Oxide Monitor, which is used on the ISS to monitor the inflammation of astronauts' airways. On Earth, this helps the early detection of conditions such as asthma.



Many experiments assess the physiological effect of spaceflight. Shown is a multi-fluorescent chromosome map of a cell exposed to cosmic radiation.

ESA astronaut Thomas Reiter, working with the European Matroshka on the ISS. Matroshka, which simulates a human torso, has been used since February 2004 to measure radiation dosage outside and, at the moment, inside the ISS.

Preparing for Human Exploration

Sending humans into space and operating complex equipment will teach us important aspects of future human spaceflight beyond Earth orbit, such as to the Moon or Mars. Several ESA projects are addressing these issues. They will help Europe to:

- maintain astronaut physical and mental health and performance.
- protect crews and systems against radiation.
- develop advanced life-support systems and recycling systems.
- investigate nutritional requirements and food production in space.
- develop new high-performance, lightweight and durable materials for propulsion, landers and habitats.
- develop operational systems that work in different (partial) gravity conditions.
- investigate *in situ* resource utilisation schemes.

First test of the Mars500 long-duration isolation facility.

ESA astronaut Phillipe Perrin assessing the Flywheel Exercise Device for maintaining muscle and bone mass in space. The flight model will be carried to the ISS with the Columbus laboratory.

Plant growth experiments are important not only for future food production in space but also for biological life-support systems. ESA astronaut Frank De Winne is with a plant-growth experiment on the ISS.

ESA astronaut Paolo Nespoli inside the European-built Node-2 on the ISS.

ESA astronaut Christer Fuglesang next to the Altcriss cosmic ray detector on the ISS.

ESA astronaut Pedro Duque working on the PROMISS experiment in the European-built Microgravity Science Glovebox on the ISS. PROMISS used advanced optical diagnostics to investigate the growth processes of proteins during weightless conditions.

Exploring the ISS

Even before the docking of the European Columbus laboratory to the ISS, ESA has made good use of the experimental conditions aboard this outstanding international research facility in orbit. Through cooperation with the other partners in the ISS programme, mainly Russia and the United States, European scientists have carried out an initial series of experiments.

Since 2001, 165 European experiments have been performed. Some were part of nationally-funded flights of ESA astronauts to the ISS (Umberto Guidoni, Claudie Haigneré, Roberto Vittori, Philippe Perrin, Frank De Winne, Pedro Duque, André Kuipers and Paolo Nespoli). Others were conducted during ESA flights to the ISS (Thomas Reiter and Christer Fuglesang). Finally, some ESA experiments were carried out by NASA astronauts, Russian cosmonauts and 'space participants' Mark Shuttleworth, Gregory Olsen, Anousheh Ansari, Charles Symonyi and Malaysian astronaut Sheikh Muszaphar Shukor.

These early experiments focused on human physiology, where sufficient test subjects are essential. Some biology and physics experiments were also carried out.

Simultaneously, ESA developed and deployed a suite of smaller instruments on the ISS to carry out these experiments.

These activities have allowed ESA and the scientific community to be well-prepared for the approaching Columbus era.

ESA astronaut André Kuipers (inverted) being assisted by Russian cosmonaut Gennadi Padalka with the SUIT experiment during the DELTA mission on the ISS.

ESA astronaut Thomas Reiter handling an insert from the European-built Minus Eighty Degree Laboratory Freezer for the ISS (MELFI), used to store sensitive life science samples at low temperatures.

Thomas Reiter during a live call with the physics students at the Columbus Control Centre in Oberpfaffenhofen in Germany.

The SUCCESS Contest 2007 invited students to propose their own experiments for flight to the ISS.

Explore to inspire

All children gaze at the stars and wonder what might be out there and what it would be like to go beyond. Sharing our knowledge and experience in Human Spaceflight with pupils and students in Europe is the aim of ESA's Human Exploration Education Programme.

The ISS is a perfect platform for vivid demonstrations of the very foundations of certain scientific principles. Since 2003, education has been an important part of all six ISS missions involving ESA astronauts. This is set to expand after the arrival of the European Columbus laboratory.

Demonstrations have been filmed in orbit and distributed to schools as DVD lessons, the SUCCESS competitions have provided university students with the opportunity to fly their experiments on the ISS, and children and students alike have had the chance to put questions to the astronauts in space through live radio contacts. Live lessons and lectures on Columbus will follow.

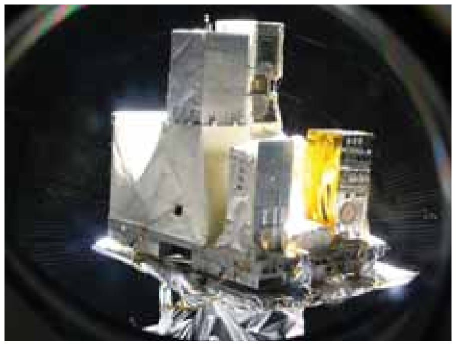
The knowledge and experience within ESA has provided the means to produce a wide range of educational materials using different media, across all age groups and covering the European curricula. The Education Programme has great importance in fostering the ideas of the young people who will become the scientists and engineers of tomorrow and shape the future of the knowledge-based European society.

ESA's primary and secondary Education Kits are produced in the 12 languages of ESA's Member States.

ESA astronaut Pedro Duque demonstrates basic principles for 'ISS DVD Lesson 1: Newton in Space'

The Seeds in Space experiment starts via an inflight call with Dutch-ESA astronaut André Kuipers. Over 70 000 schoolchildren in the Netherlands and Germany simultaneously started the seed growth experiment.

The Columbus module being transferred into the cargo bay of Space Shuttle *Atlantis* on 11 November 2007.



The European Technology Exposure Facility (EuTEF) is one of the external facilities of the Columbus laboratory. It will house experiments needing exposure to open space.

Columbus: the European Science Laboratory

From December 2007, ESA's Columbus laboratory will be attached to the ISS. This is an essential expansion of the Station's research capabilities, not only for Europe, but for all of the International Partners in the ISS programme.

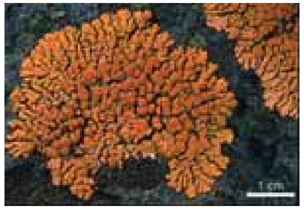
Columbus will be outfitted with major research facilities that allow scientists and industries to address the main research objectives with unprecedented capabilities. These facilities will be complemented by smaller experiment equipment for specific measurements. Outside of the closed environment, exposure facilities will house experiments in exobiology, solar physics and technology for exploration.

All of the research equipment developed by ESA is designed with a high degree of automation and modularity. For each experiment, specific features are provided by inserts that make use of the common infrastructure (data-handling, advanced diagnostics, thermal environment, etc.) offered by the facility. The facilities themselves can be upgraded to ensure that the most up-to-date technology is always available for experiments.

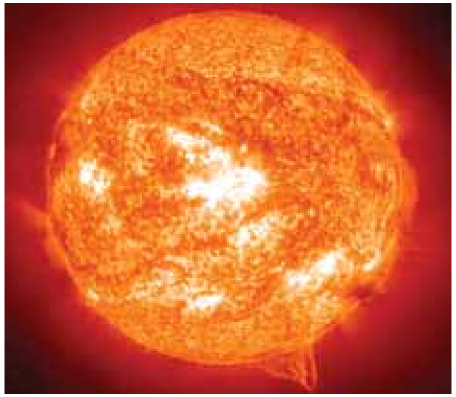
What makes Columbus unique is not only the high sophistication of its facilities, but also the fact that everything fits together in one Shuttle flight. Unlike some of the other ISS modules, Columbus will be able to deliver science from the very start.

Two of the major ESA research facilities installed in Columbus: (A) Biolab, for biological experiments, and (B) the Fluid Science Laboratory (FSL).

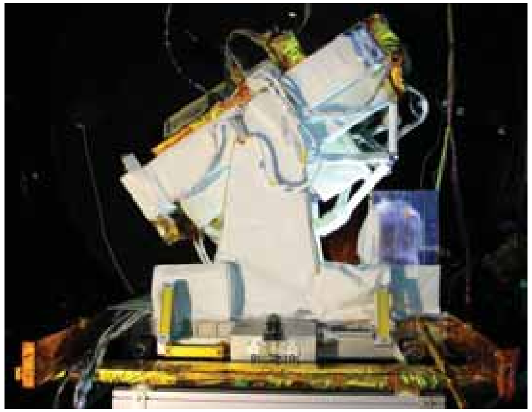
The other two major Columbus research facilities: (left) the European Physiology Modules (EPM) for human physiology research and (right) the European Drawer Rack (EDR), a flexible experiment carrier for a large variety of scientific disciplines.



EuTEF will use *Xanthoria elegans* to test the limits of survival of organisms such as lichens and fungi under extreme space conditions for about 1.5 years.



The Sun imaged by the ESA/NASA SOHO satellite.



The SOLAR facility, on the Columbus External Payload Facility (CEPF), is a European facility dedicated to solar physics with three advanced spectrometers.

European Science on the ISS in 2008

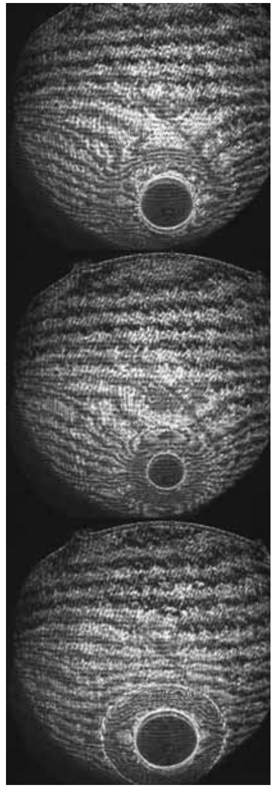
With Columbus attached to the ISS, ESA utilisation rights in terms of crew time, upload, power and so on will become available for European scientists. Although the ISS will still be under assembly during 2008, ESA has been able to plan an impressive amount of science even in this period.

In total, some 100 experiments will be carried out in the first year of operation of Columbus. This more than triples the annual amount of ESA experiments carried out aboard the ISS in the pre-Columbus period.

These experiments address all the major research areas: biology, exobiology, human physiology, fluid physics, fundamental physics, technology and solar physics. Thanks to Columbus' advanced research facilities, some of these experiments are a quantum leap in complexity and science data collection.

The participation of the European scientific community in these experiments is impressive. Almost 180 scientists from all the major European countries, including some of the new European Union Member States, are participating in these projects. Thus, even during its first year, Columbus will prove to be a significant contribution to the European research infrastructure in space, with promising longer term possibilities.

The core of the FSL Geoflow experiment. Geoflow is of importance in such areas as flow in the atmosphere and the oceans, and the movement of Earth's mantle on a global scale.



Interferometry images observed during FSL Geoflow ground tests, showing convection patterns.

The Electromagnetic Levitator, jointly developed by ESA and the German space agency, permits the accurate measurement of the properties of highly reactive liquid metal alloys. It will be flown to the ISS after 2008.

The complexity of human physiology experiments in space will increase. Pictured is Pedro Duque conducting the Cardiocog experiment during his Cervantes Mission. This experiment is contributing to the understanding of cardiovascular disorders.

Scientific Exploration Beyond 2008

The launch of the Columbus laboratory is a major milestone for Europe, of course, but the years beyond are also very important for European scientists. In particular, the ISS will be able to house six crewmembers permanently beginning in 2009. This will increase the crew time available for European experiments by a factor of 4–5.

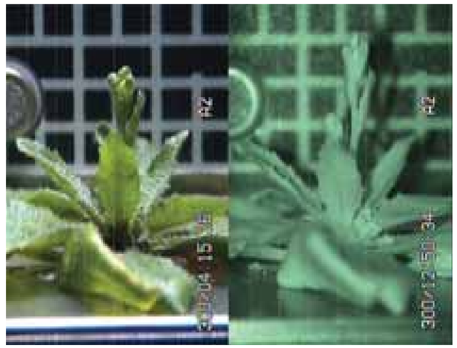
As a consequence, the complexity of the experiments planned for this period will increase. For example, more elaborate experiments in human physiology will be performed, and experiments in material sciences.

There are challenges further ahead. After 2010, when the US Space Shuttle is no longer available, new techniques will be required. To this end, ESA is developing new technologies for onboard analysis of samples in order to reduce the download requirements and increase the science return time.

Interestingly, these new technologies, which include telepresence, telemedicine and advanced diagnostic tools, are also extremely interesting for Earth applications and future exploration missions.

The capabilities and operational challenges of ISS and Columbus will thus keep Europe at the forefront of scientific and technological development. Long-term ISS operations will provide Europe with the skills for future human space exploration endeavours beyond low Earth orbit.

NASA astronaut Clay Anderson working with the European Modular Cultivation System (EMCS) on the ISS in July 2007. The facility is undertaking biological experiments, principally addressing the effects of gravity on plant cells, roots and physiology.



Plant growth images taken inside the EMCS pictured under light conditions (left) and dark (right) using infrared light.

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For further information on the European Space Agency: www.esa.int