The ESA Payloads for Columbus

– A bridge between the ISS and exploration

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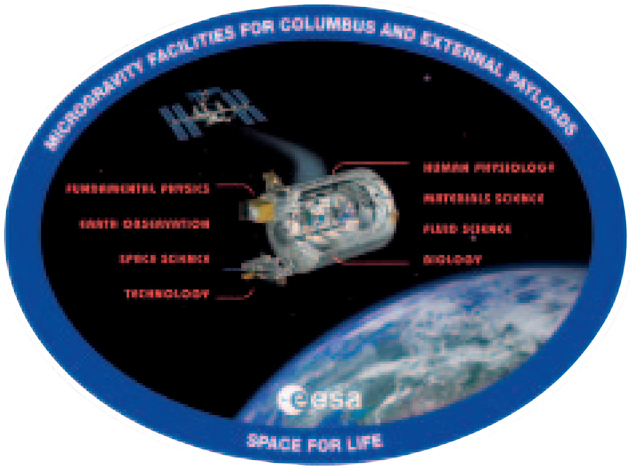


As part of the European contribution to the International Space Station (ISS) Programme, ESA has developed a number of complex, pressurised and unpressurised payloads for conducting scientific investigations in a variety of disciplines, such as the life and physical sciences, technology and space science. The majority of these payloads will already be installed in ESA's Columbus Laboratory when it is launched in 2006. Many of them are ready for flight, whilst the others are approaching final acceptance. The development of these payloads and their utilisation on the ISS can be considered as a bridge to ESA's future Exploration activities.

Introduction

When the ESA Member States confirmed their participation in the International Space Station (ISS) Programme back in 1995, it consisted of both ISS infrastructure elements (e.g. Columbus Laboratory, Automated Transfer Vehicle and others) and utilisation elements (e.g. Microgravity Facilities for Columbus, European Drawer Rack, External Payloads and others).

Once in orbit, Columbus will be outfitted with several multi-user payloads, located both inside and outside the Laboratory. The experiments that will be performed using these payloads will provide a much-needed boost to the European scientific and industrial community. Equally importantly, they will greatly increase the competitiveness of European industry by fostering innovative research, which is a major priority for both ESA and the European Union. The utilisation of these multi-user payloads will also contribute to the preparation of the Agency's new Exploration Programme.

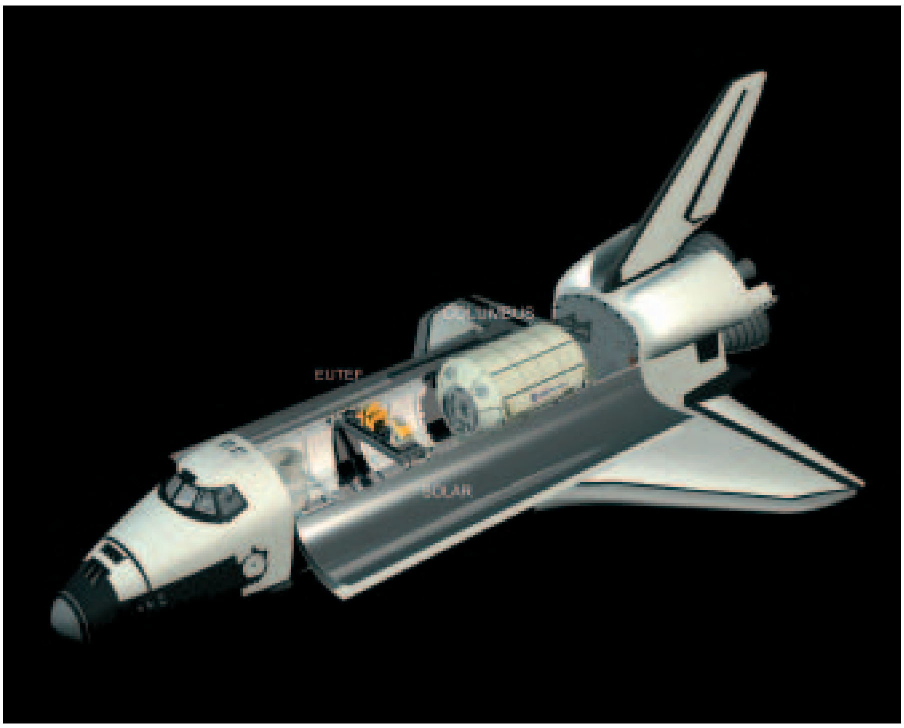
When Columbus is launched by NASA's Space Shuttle (Fig. 1) in 2006, it will be outfitted with the following payloads:

Pressurised payloads:
(a) Biolab
(b) Fluid Science Laboratory (FSL)
(c) European Physiology Modules (EPM) Facility
(d) European Drawer Rack (EDR)
(e) European Transport Carrier (ETC)

Unpressurised payloads:
(f) SOLAR
(g) EuTEF.

Payloads (a), (b) and (c) are being developed within the Microgravity Facilities for Columbus (MFC) Programme, while (d), (e), (f) and (g) fall under the Utilisation Programme.

Together with the pressurised payloads, there will be an allocated stowage volume (e.g. one quarter of the stowage rack for each facility) to upload a minimum set of spares for maintenance, as well as the necessary experiment hardware in terms of containers,



The Space Shuttle Flight-1E launch configuration cartridges, etc. All this equipment will be contained in the European Transport Carrier (ETC). Once in orbit, the Columbus Laboratory can accommodate up to ten active payload racks.

In the framework of the Space Station Agreements with NASA, ESA is allocated 51% usage of the Columbus Laboratory, which is equivalent to five active rack locations, the other five rack locations being allocated to NASA.

Physical and Life Science research under microgravity conditions embraces a wide range of disciplines, including fundamental physics, physical chemistry, fluid science, solidification physics (e.g. crystal growth, and metallurgy), biology, biotechnology, human physiology and medicine, making it the largest European user of the Space Station. The ESA Microgravity Life and Physical Science Programme's primary goal is to offer European scientists the possibility to perform materials and fluid sciences, biology and human-physiology experiments in space using mainly the pressurised payloads.

The ESA ISS Utilisation Programme is designed to offer the capability to conduct experiments in additional disciplines, such as space science, technology, Earth observation and fundamental physics, primarily using the unpressurised payloads

Each active multi-user payload is supported by a dedicated Science Team, composed of respected European scientists, who advise the Agency on the scientific requirements to be fulfilled by each payload. They also review the facility design to ensure that it can meet those requirements.

The ESA Columbus External Payload Facility (CEPF) will provide four locations for the unpressurised payloads (i.e. platforms to accommodate external payloads). The initial set of multi-user payloads are: SOLAR, which is a solar observatory with three scientific instruments, and EuTEF, which is an ensemble of nine individual instruments dedicated to in-orbit technology experiments.

In order to select experiments for the pressurised payloads, Life and Physical Science Announcements of Opportunity (AOs) have been released over the past few years, resulting in the selection of several batches of peer-reviewed experiments for each payload. New experiment solicitation AOs are planned every 1 to 2 years. The selection of instruments for the unpressurised payloads follows a similar approach, but then via the user Directorate, such as Space Science, Earth Observation or Technology.

The Pressurised Payloads

The starts of the main development phases (Phase-C/D) for these payloads were staggered over a two-year period, from 1997 to1999, depending on the level of maturity reached during the definition phases. The industrial contracts were awarded to major European prime contractors, such as EADS Astrium (F) for the Biolab, Alenia Spazio (I) for the FSL, and EDR and OHB Systems (D) for the EPM.

The flight models of Biolab, FSL and EPM underwent verification of their Columbus interfaces using the Rack-Level Test Facility (RLTF) at EADS-ST in Bremen (D) in 2003. They completed their qualification in 2004 with their delivery for the Integrated System Test (IST) and the end-to-end System Validation Test (SVT) that was successfully performed inside the flight model of the Columbus Laboratory in Bremen. Their final integration into Columbus is planned to be completed by autumn 2005.

The training models of Biolab, FSL, EPM and EDR have already been delivered to the European Astronaut Centre in Cologne (D), and the engineering models will be delivered to the User Support Operations Centres (USOCs) in the course of 2005, in order to retrofit the late changes introduced into the flight models as a result of the scientifically required upgrades.

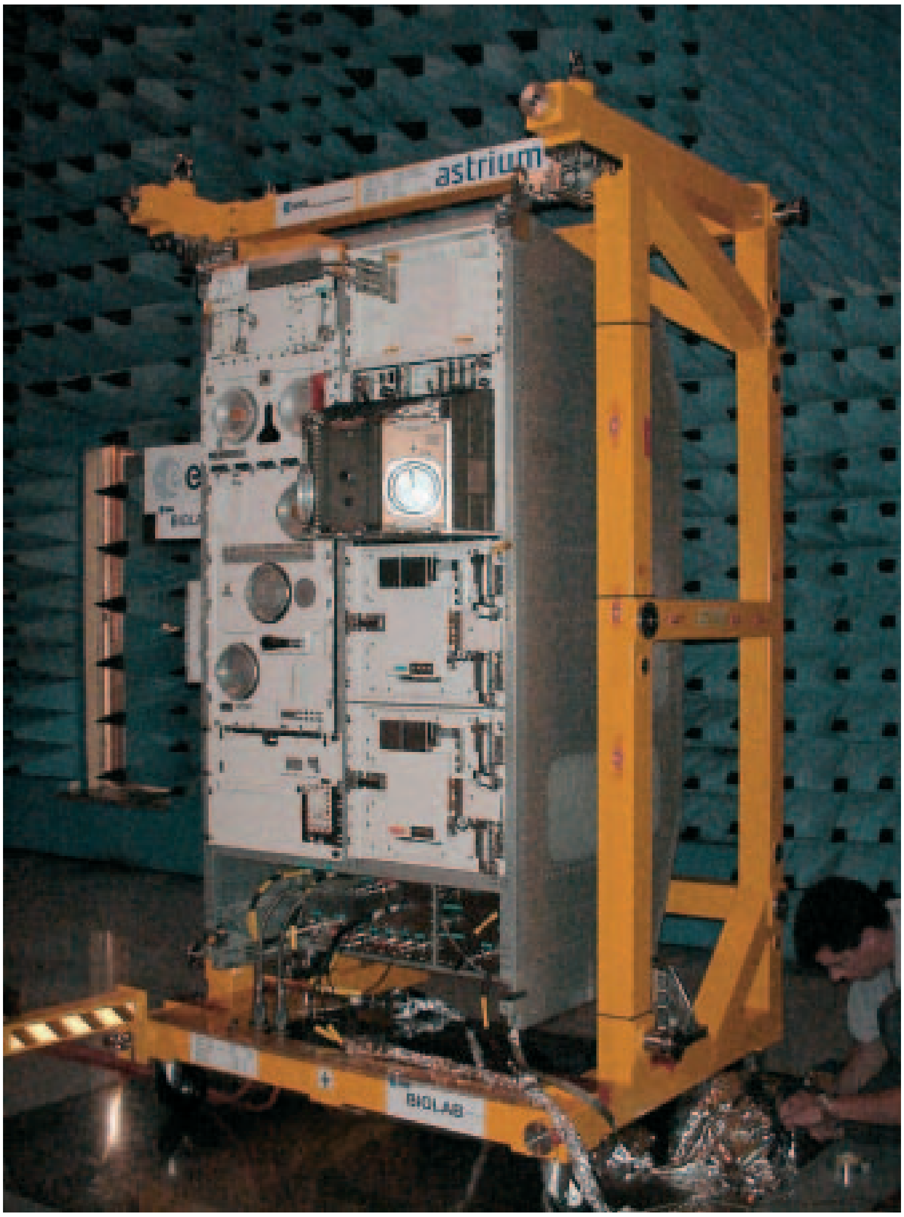
The specific features of each multi-user payload are as follows:

Biolab

Scientific objectives

Life Science experiments in space are aimed at identifying the role that microgravity plays at all levels of life, from the organisation of a single cell to the

The flight models of the pressurised payloads inside Columbus during IST testing in Bremen



The flight model of Biolab

nature of gravity resisting and detecting mechanisms in the more highly developed organisms, including man. Whilst the effects of microgravity on humans will also be investigated by other payloads (e.g. EPM), it is important to start the investigation with the smaller elements of the biological structure. At the science community's behest, ESA has always had a strong involvement in supporting the investigation of biological samples, with for example the Biorack on the Space Shuttle and the Biobox on a Russian carrier. The scientific results from these flights can certainly influence our everyday lives, particularly in the areas of immunology, bone demineralisation, cellular signal transduction and cellular-repair capabilities. Such results could eventually have a strong bearing on crucial products in the medical, pharmacological and biotechnological fields.

The current Biolab concept is that of a multi-user payload for conducting biological experiments on cells, micro-organisms, small plants and small invertebrates, as well as research in biotechnology. The design respects the science recommendations, the outcome of the scientific and feasibility study performed (i.e. Phase-A/B), the experience gained from payloads flown previously, and the requirements and possibilities offered by the utilisation of the Space Station.

Payload operation

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

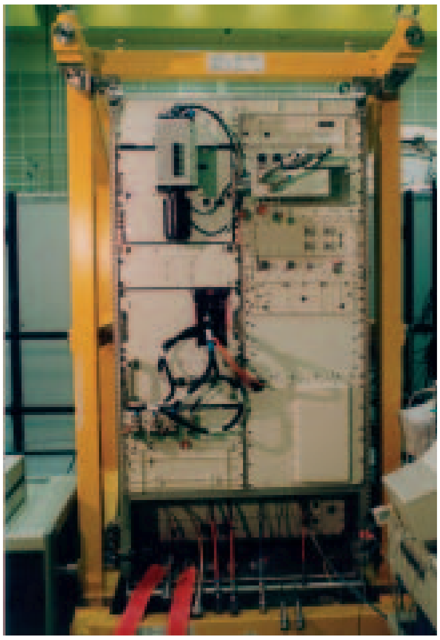
The biological samples are contained in standard 'Experiment Containers', which have standard external interfaces with the Biolab, an approach that has been well proven with the Biorack. The internal volume available to experimenters is 60 x 60 x 100 mm^3 for the standard container; a larger one is also available.

Fluid Science Laboratory (FSL)

Scientific objectives

Fluid-science experiments in space are designed to study dynamic phenomena in the absence of gravitational forces. Under microgravity conditions, such forces are virtually eliminated, including their effects in fluid media (e.g. gravity-driven convection, sedimentation and stratification and fluid static pressure). This allows fluid-dynamics effects that are normally masked by gravitation to be studied, such as the diffusion-controlled (rather than convective-flow-dominated) heat and mass transfer in crystallisation processes.

The absence of gravity-driven convection eliminates the negative effects of



The flight model of the FSL

density gradients (inhomogeneous mass distribution), which always arise on Earth in processes involving heat treatment, phase transitions, diffusive transport or chemical reactions (i.e. convection in earthbound processes is perceived as a strong perturbing factor, the effects of which are seldom predictable with great accuracy and dominate heat and mass transfer in fluids).

The ability to control such processes is still limited; their full understanding requires further fundamental research by conducting well-defined model experiments for the development and testing of related theories under microgravity. This will allow the optimisation of manufacturing processes on Earth.

ESA has already been involved in the study of fluid-science phenomena under microgravity conditions for several years, notably with the BDPU (Bubble, Drop and Particle Unit), which has already been flown twice on Spacelab missions, providing valuable results.

Payload operation

The kernel of the FSL payload is made up by the Optical Diagnostics Module (ODM) and the Central Experiment Modules (CEM), into which the Experiment Containers (EC) (see figure) are sequentially inserted and operated. Together, these modules represent the Facility Core Element (FCE), which is complemented by the functional subsystems for system and experiment control, power distribution, environmental conditioning, and data processing and management. The FCE will be suspended using the Microgravity Vibration Isolation System (MVIS) provided by the Canadian Space Agency. It will improve the microgravity conditions during experiment processing by reducing the residual dynamic forces present on the ISS. The MVIS will offer unique research capabilities to both European and Canadian scientists.

European Physiology Modules (EPM)

Scientific objectives

Human Life Science experiments in microgravity not only increase our knowledge of how the human body reacts to long exposure to weightlessness, but also contribute to a better understanding of Earth-related problems such as: cardiovascular, neurophysiology, ageing processes, osteoporosis, balance disorders, biomedical research, cancer research and muscle wasting during limb immobilisation (casts) and bed-rest.

Investigations into the effects of microgravity on the human body have been conducted for many years and ESA in particular has successfully flown related facilities (e.g. Sled, Anthrorack, etc.) on several Spacelab missions.

To be able to a make proper evaluation of the data collected onboard the Space Station, it is essential that reference (or baseline) data be collected both prior to the mission and after the crew returns to Earth. For this purpose, the EPM will include a Baseline Data Collection (BDC) system composed of functional replicas of the instruments on board. The BDC will be easily transportable to ensure that it can be available at the crew's location shortly before their launch and immediately after their landing.

NASA is developing a similar payload known as the Human Research Facility (HRF). It consists of two racks, the first of which was launched early in the ISS assembly sequence; the second will be launched with the Shuttle's return to flight, in advance of the Columbus Laboratory. ESA and NASA plan to collocate these two payloads within Columbus, thereby allowing the execution of experiments utilising scientific instruments from both payloads and increasing the scientific return.

Payload operation

The EPM payload is a multi-user facility intended to support research in the area of human physiology in a weightless environment. It consists of a complement of Science Modules plus the infrastructure, the Carrier, needed to support the coordinated operation of these modules. The Carrier provides the data handling, thermal control and mechanical accommodation to the Science Modules, nine of which can be active at any one time.

The Science Modules are accommodated in standard-sized drawers (4 and 8 PU, where 1 PU = 4.45 cm) and interface

The flight model of the EPM

to the rack via a standardised guide system that simplifies Module installation and exchange in orbit. All rack-mounted Science Modules are cooled via a ducted air system provided as part of the Carrier.

Two Science Modules will be launched inside the EPM:

(a) *Multi-Electrode Electroencephalogram Mapping Module (MEEMM)*
Developed by ESA, the MEEMM is dedicated to non-invasive studies of brain activity by measuring EEG and evoked potentials in the stationary and a bulatory modes (e.g. sleep studies). In addition, the MEEMM can be used for EMG measurements to investigate muscle deconditioning/atrophy.

(b) *Cardiolab (Cardiovascular Laboratory)*
Developed by CNES (F) and DLR (D), Cardiolab's main objective is to study the cardiovascular system, particularly its central and peripheral regulation, and its short- and long-term adaptation to altered gravity levels. Research areas include the autonomous control of heart rate, and circulation and fluid volume regulation.

The EPM will also carry a NASA stowage container that will include HRF instruments.

Future modules under development include the Bone Analysis Module (BAM) for the investigation of bone loss in space, an issue of paramount importance in terms of conducting the long-duration missions required by the Exploration Programme, and a Portable Pulmonary Function System (PPFS).

European Drawer Rack (EDR)

The EDR is a multi-user payload, providing the infrastructure to accommodate and service experiment modules housed in International Subrack Interface Standards (ISIS) drawers and in standard Shuttle-type Mid-Deck Lockers (MDLs). The main drivers in its design are modularity and standardisation of experiment interfaces. The use of the standard drawers and lockers will ensure quick experiment turnaround, thereby increasing the number of flight opportunities for the user community.

The training model of the EDR

Payload operation
The EDR provides accommodation for small and modular experiments accommodated in ISISs and MDLs with access to the Columbus Laboratory services. A fundamental goal of the EDR is to support the accommodation of smaller sub-rack payloads (so-called 'Class II payloads' - the experiment modules) through the provision of accommodation resources and flight opportunities when quick turnaround is required. The EDR has been designed for maximum user-friendliness and flexibility of experiment accommodation and operation.

Future pressurised payloads

New payloads such as the Electro-Magnetic Levitator (EML) and Plasma Physics payloads are currently being defined to respond to the evolving requirements of the scientific community.

The Unpressurised Payloads

The ESA external payloads are a unique asset since no other ISS Partner will have comparable capabilities in place. Several multi-user payloads are already in an advanced stage of development, including SOLAR, EuTEF and ACES, and more are under definition, such as SPOrt-Plus, EUSO, Lobster, ASIM, and ROSITA. The first ESA external payload, Matroshka, is already in orbit attached to the Russian Service Module and is fully operational.

In-orbit transfer of the unpressurised payloads from the Shuttle to the Columbus External Payload Facility, and vice-versa, will be performed by Extra Vehicular Robotics (EVR) using the ISS Robotic Systems, i.e. the Space Station Robotic Manipulator System provided with the Special-Purpose Dexterous Manipulator. For SOLAR and EuTEF, the transfer will be carried out by the astronauts, via EVAs, as the EVR will not yet be operational.

The current status of the individual payloads is as follows:

SOLAR
SOLAR will measure the Sun's spectral irradiance over a wide energy range and with unprecedented accuracy. Apart from contributing to solar-physics research, SOLAR is expected to contribute to our knowledge of the interaction between the solar-energy flux and the Earth's atmospheric chemistry and climatology, which will be important for future environmental predictions.

The payload accommodates three complementary science instruments able to measure the solar flux across the electromagnetic spectrum, from the extreme ultraviolet to the infrared:
– SOVIM (SOlar Variability & Irradiance Monitor, developed by the Observatory of Davos (CH), covering the near ultraviolet (UV), visible and thermal regions of the spectrum and the total solar irradiance
– SOLSPEC (SOlar SPECtral Irradiance measurements, developed by CNRS (F), with support from BIRA (B), covering the 180 – 3000 nm range with high spectral resolution, and studying the solar variability
– SolACES (SOlar Auto-Calibrating

EUV/UV Spectrophotometers, developed by the Fraunhofer Institute, (D)) measuring the extreme UV and UV spectral region.

Manufacture of the flight models of the three instruments has been completed and they have already been tested, showing performances meeting or even exceeding specification.

The three instruments will be pointed towards the Sun using a multi-purpose, two-degree-of-freedom, Coarse Pointing Device (CPD) that compensates for the Space Station's orbital motion.

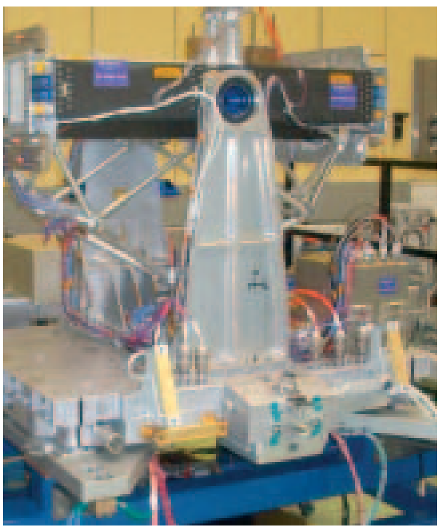
The prime contractor for SOLAR is Alenia Spazio (I).

Integration of the SOLAR proto-flight model is in progress and will be completed by summer 2005. Integration with a launch carrier for the unpressurised payloads that will share the accommodation in the Shuttle together with the Columbus Laboratory will begin at Cape Canaveral four to five months before launch.

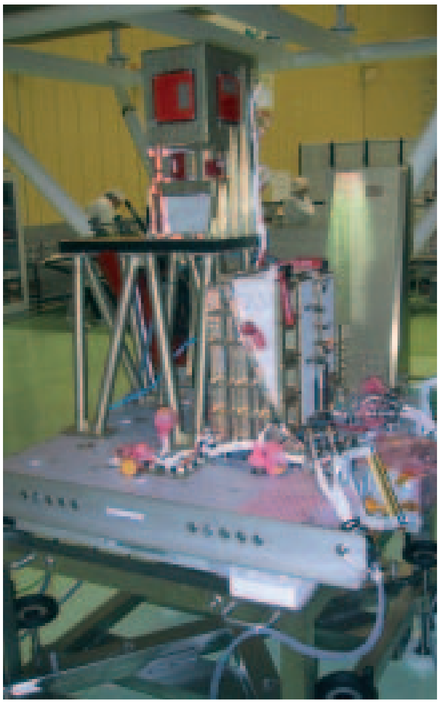
EuTEF

The European Technology Exposure Facility is a programmable, fully automated multi-user payload. A modular architecture provides uniform interfaces for up to nine instrument modules, all of which can be operated simultaneously. The following instruments are currently under development:

- TRIBOLAB: a Tribology Testbed, developed by INTA (E)



SOLAR model during Columbus interface testing in Bremen



The flight model of EuTEF

- PLEGPAY: a Plasma Electron Gun Payload, developed by Laben (I), used for protection against charged particles
- MEDET: a Material Exposure and Degradation Experiment, developed by CNES/ESA/ONERA/University of Southampton (UK)
- DEBIE-2: a debris detector, developed by ESA/Patria Finavitech (SF)
- FIPEX: a Flux Probe Experiment, developed by the University of Stuttgart (D)
- EXPOSE: an exobiology facility, developed by Kayser-Threde (D)
- DOSTEL: a dosimetric radiation telescope, developed by DLR (D)
- EuTEMP: a EuTEF temperature measurement device, developed by ESA/EFACEC
- EVC: an Earth Viewing Camera, developed by ESA/Carlo Gavazzi Space (I), for outreach activities.

The EuTEF flight unit, including the first set of instruments, is currently being integrated and will be completed by summer 2005. The prime contractor is Carlo Gavazzi Space (I).

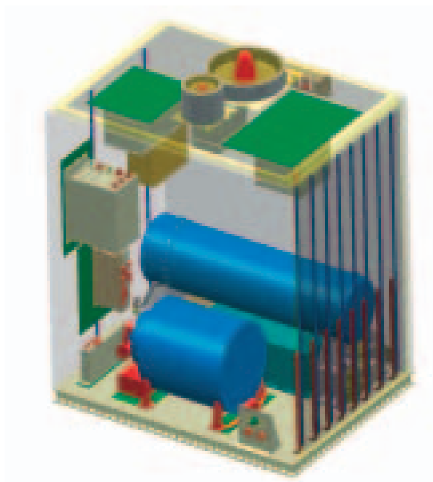
ACES

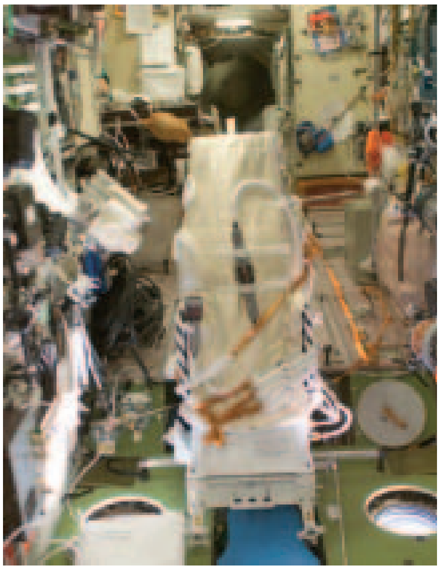
The Atomic Clock Ensemble in Space payload will test a new generation of atomic clocks in space. Important experiments will be performed in several scientific domains including, fundamental physics (cold atoms), high-precision geodesy, and global network synchronisation.

The payload supports two clocks working in unison. The cold-caesium-atom clock PHARAO (Projet d'Horloge Atomique par Refroidissement d Atomes en Orbite) is funded by France and developed by CNES. The Space Hydrogen Maser (SHM) is funded by Switzerland via ESA's PRODEX programme (Programme de Dévelopment d'Experiences scientifiques) and developed nationally by the Observatory of Neuchâtel. Both clocks will be characterised and compared in a microgravity environment to explore their ultimate performances in space.

The ACES payload is being developed and integrated by an industrial team led by EADS-ST based in Friedrichshafen (D). Unique to ACES is the possibility for worldwide participation involving a global array of User Home Bases (UHBs) procured by national time and frequency scientific institutes. The payload is currently in Phase-C/D, involving the

The ACES payload





The Matroshka phantom in orbit

development, manufacture and verification of engineering and flight hardware. ACES will be ready for launch no earlier than 2010.

Matroshka
Matroshka is a human dummy for studying the radiation doses to which astronauts' bodily organs are exposed during Extra-Vehicular Activities (EVAs). It consists of a simulated human upper torso, outfitted with special radiation-measurement devices.

Matroshka was transported to the ISS on Progress flight 13P on 29 January 2004 and installed on the outside of the Russian 'Zvezda' module. The scientific results are providing important information about astronaut radiation exposure during EVA. It is planned to retrieve Matroshka by the end of 2005, exchange its sensors onboard the ISS, and then re-expose it outside 'Zvezda' for further investigations.

SPOrt-Plus
This payload will include the grouping of the SPOrt science instrument with an additional instrument(s), currently being evaluated by ESA, able to share the same accommodation requirements.

SPOrt (Sky Polarization Observatory), an astrophysical instrument selected by ESA and developed by ASI (I), is designed to measure the sky polarisation in the unexplored microwave frequency range from 20 to 90 GHz. The scientific goals include production of the first polarisation map of our Galaxy at 22, 32 and 60 GHz, and full-sky measurements of unprecedented accuracy in the so-called 'cosmological window' at 90 GHz.

The SPOrt science instrument design phase (Phase-B) has been completed, and the main development phase (Phase-C/D) will be initiated by ASI in 2005. The prime contractor is Alenia Spazio (I). The earliest launch opportunity is foreseen 18 months after Shuttle flight 1E.

Future unpressurised payloads
Extreme Universe Space Observatory (EUSO)

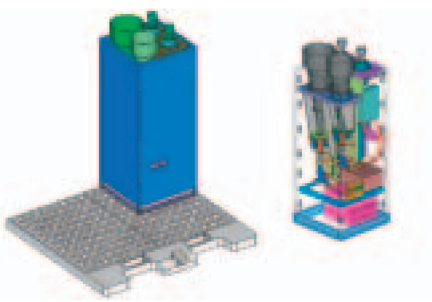
EUSO is devoted to the investigation of the highest energy processes present and accessible in the Universe. By using the Earth's atmosphere as a giant cosmic-ray detector, EUSO will observe the flash of fluorescence light and the reflected Cherenkov light produced when an Extreme-Energy Cosmic Ray (EECR), with energy greater than 3×10^{19} eV, interacts with the Earth's atmosphere. EUSO will take advantage of the continuous Earth-pointing provided by the lowest balcony of the Columbus External Payload Facility and, by looking to nadir with a 60-degree field of view, will detect around 1000 such events per year, allowing a sensitive search for EECR-producing objects.

A worldwide consortium of investigators from the USA, Japan and several European countries, led by IASF-CNR of Palermo (I), is developing the Observatory. It consists of a UV telescope, with a lightweight double-Fresnel-lens optics system, a highly segmented focal-surface detector array, sophisticated onboard image processing, a Lidar, and an atmospheric sounding device that will provide 'real-time' knowledge of the atmospheric scattering and light-absorption properties.

The EUSO study phase (Phase-A), completed in July 2004, demonstrated that it is indeed possible to transport and accommodate such a large payload – 2.5 m in diameter and 4 m long – on the ISS. However, in view of the large amount of resources required to implement the mission, continuation of the project is currently under discussion.

The EUSO payload

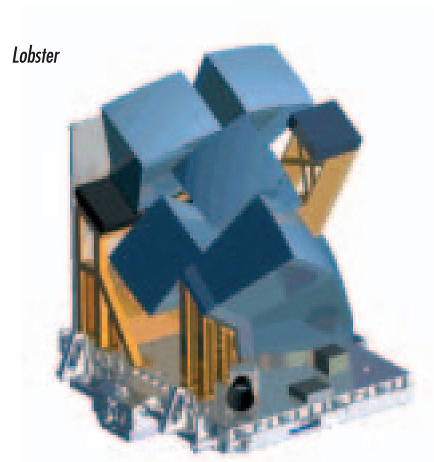
The SPOrt instrument



Lobster

Lobster is an all-sky monitoring package operating in the soft-X-ray band (0.1 – 3.5 keV), with a main instrument consisting of

Lobster

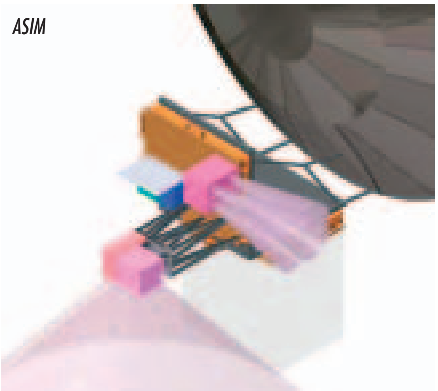


six microchannel-plate X-ray telescopes accommodated on the Columbus External Payload Facility. It uses a novel microchannel-plate arrangement to provide an extremely wide field of view, allowing it to generate a catalogue of about 250 000 sources every two months with a spatial resolution of a few arc-minutes.

The instrument is being developed by the University of Leicester (UK) together with various co-investigators. The instrument design study (Phase-A) was completed in early 2005.

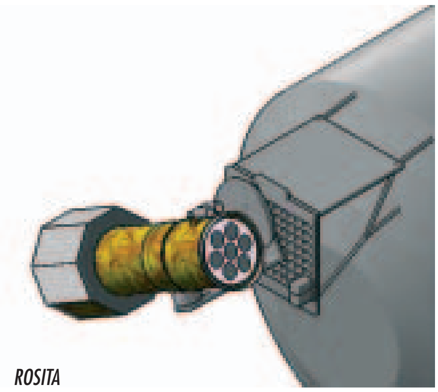
Röntgen Survey and Imaging Telescope Array (ROSITA)
ROSITA will perform an all-sky survey and imaging mission in the medium-energy X-ray range up to 10 keV, with unprecedented spectral and angular resolution. The telescope, supplied by MPE-Garching (D), will consist of a replica of the Wolter-I mirror systems already flown on ABRIXAS, and a novel detector system, currently under development, based on the XMM pn-CCD technology. The feasibility of accommodating this large payload – about 1 m in diameter, 2.5 m long and weighing more than 500 kg – has been preliminarily demonstrated in the context of a pre-Phase-A study performed by the ESTEC Concurrent Design Facility.

Atmosphere Space Interactions Monitor (ASIM)
ASIM will study the high-altitude optical emissions from the Earth's stratosphere and mesosphere using two types of instruments: an optical Miniature Multi-


ASIM

spectral Imaging Array (MMIA) with four imagers, and a single module of a Miniature X- and gamma-ray Sensor (MXGS). The instrument is being developed by DNSC (DK).

The ASIM pre-Phase-A study, completed by the ESTEC Concurrent Design Facility in October 2004, confirmed the feasibility of the payload. The Phase-A study has been initiated in 2005.


ROSITA

The Challenges

Developing state-of-the-art pressurised payloads has meant meeting several major challenges. They have to comply with very challenging scientific requirements established by the science teams, and must also include the greatest possible degree of automation in order to minimise crew involvement. Telescience operation from the ground allows the scientists to interact directly with their experiments in space, while the high level of modularity means that the payloads can be refurbished in-orbit rather than having to be returned to the ground. This minimises the upload requirements for the scientific experiments.

Cooperative endeavours such as MVIS and Cardiolab have added value to the programme. MVIS will greatly enhance the FSL, providing good isolation for experiments from the Station's microgravity disturbances, while Cardiolab will offer a wide range of physiology instruments for cardiovascular studies in space.

The ESA External Payload Programme was initially based on the NASA Express Pallet Programme. The payloads were originally designed for launch and retrieval with the Express Pallet System and when NASA suspended this programme ESA had to face a completely new situation. The unpressurised payloads were relocated to the Columbus External Platform by means of a dedicated payload adapter called the Columbus External Payload Adapter (CEPA). This had important impacts on payloads already under development.

As far as the development of SOLAR is concerned, it called for innovative design solutions for the Coarse Pointing Device (CPD) and the science instruments. The CPD's structural design was particularly challenging because of the demanding combination of mechanical and structural requirements (loads, stiffness, mass, pointing requirements, return to Earth after a 1.5 to 3-year long mission). The design therefore involved the use of composite materials, supported by test campaigns to characterise the materials and processes being used in orbit for the first time.

The main development challenge for EuTEF was linked to the spread in maturity of the nine instruments that make up the payload. Difficulties experienced with the instruments' development had to be resolved by work-around solutions on the platform side.

Other important challenges are being met during the development of ACES and the other external payloads.

Both the pressurised and unpressurised payloads have been developed within very tight financial budgets set by ESA. Contracts totalling more than 50% of the overall budget have been awarded to several small- and medium-sized enterprises (SMEs), developing skills in these companies that will be exploited in future programmes, even outside ESA.

A Bridge between the ISS and Exploration

The ESA pressurised payloads incorporate state-of-the-art technology with an optimum blend of automation and human intervention. They are the most complex and productive payloads yet built for the ISS and are the result of the shared expertise and close cooperation of the ESA and Industry teams. The technology and know-how developed will have immediate applications in ESA's Exploration Programme, which is seeking to expand human frontiers through activities linked to evolution beyond the current ISS or to technology preparation for Moon/Mars missions. Research into human physiology conducted with the EPM payload will be fundamental to understanding the limits of human endurance in weightlessness (e.g. bone loss) and the development and verification of appropriate countermeasures.

A further contribution to the Exploration activities will come from the unpressurised payloads, such as the research into radiation effects on astronauts conducted with Matroshka, which has already been in orbit for a year. The EuTEF payload for conducting in-orbit technology experiments can be used to test new technologies, as well as for exobiology research, required by the Exploration Programme. All of the payloads developed will provide ESA with unique operational and sustaining-engineering experience that is also important for Europe's future Exploration Programme.

Conclusions

Pressurised and unpressurised payloads are being delivered to the ISS that not only meet, but in many cases exceed even today's challenging technical requirements. The robustness built into their designs, through modularity and in-orbit upgrade capabilities, will allow them to be operated in orbit for at least 10 years, well beyond the planned retirement of the Space Shuttle in 2010. With its unpressurised payloads on the ISS, ESA will have the unique capability of installing and operating complex instruments that can not only look down on the Earth, but also peer out into the far distant cosmos. They will offer unique opportunites to European scientists.

First Announcement

Sixth ESA/CNES International Workshop: Applications of Pyrotechnics in Space Systems
25/26 October 2005, ESA/ESTEC, Noordwijk, The Netherlands

The main aim of this Workshop will be to stimulate discussion and exchange of ideas, and to promote contacts between all those involved in or affected by the use of pyrotechnics in space systems.

The main theme of this particular Workshop will be: 'Engineering Reliability: What it means and how it is quantified'. It is planned to devote a full day to statistics, focussing on the standards and requirements, the best analysis methods, the available tools, and the results of recent work. Lectures will be given by professional statistics consultants, who will be happy to discuss statistical solutions and assist participants with problems related to reliability quantification.

There will be presentations by invited speakers and time will be allocated for questions and discussion to explore topics more fully. More such opportunities will be available during the several breaks. Presentations will also be given on contract work performed for ESA and CNES in their respective R&D programmes. Topics to be covered will include: Reliability and Statistical Methods, Pyrotechnic Composition and Pyrotechnic Device Lifetime, Shock Measurement and Testing, Approaches to Cost Reduction, Release-Nut Development, Pyrotechnic-Valve Development, Laser Ignition, Subsystem Design, Computer Simulation, Spacecraft Solid Propulsion, Testing, Standards for Pyrotechnics (ECSS, ISO, GTPS, etc.), Databases, Information Media, and current and future ESA and CNES activities. Suggestions are welcome regarding other topics to be included and should be sent to the address below.

No fee will be charged for this ESA/CNES Workshop. Registration and accommodation arrangements can be made once the Preliminary Programme has been published. Forms for these purposes will be available in both paper and electronic form.

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