Putting the International Space

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Station to Work

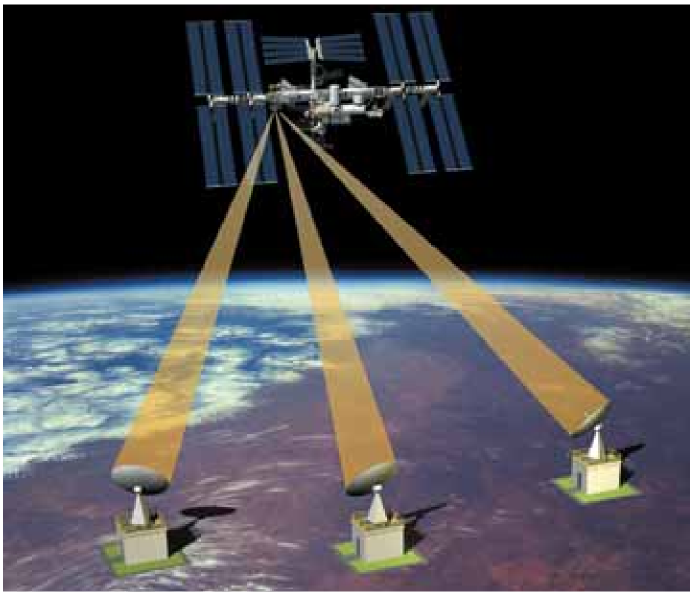
Introduction

The International Space Station (ISS) is the largest international cooperative science and technology project ever undertaken. Involving the United States, Russia, Japan, Canada and 10 ESA Member States, it is now rapidly becoming a reality in orbit, offering unprecedented access for research and applications under space conditions. Europe has invested heavily in this endeavour and plans to exploit that investment by a vigorous utilisation of the ISS for life and physical sciences research and applications, space science, Earth observation, space technology development, the promotion of commercial access to space, and the use of space for educational purposes.

In recent years, ESA has engaged in an intensive promotional effort to encourage potential user communities to exploit the novel opportunities that the ISS offers. It has also made significant financial commitments to develop both multi-user facilities for life and physical sciences studies in the Columbus Laboratory, and observational and technology exposure instruments using the external Columbus mounting locations, as well as giving financial support to promote commercial and educational activities.

ESA has now elaborated a European Strategy for the efficient utilisation of the ISS by European scientists and other users, which is being coordinated with the Agency's Member States contributing to the ISS Programme, and with the European Science Foundation (ESF). In cooperation with the European Commission, ESA is also fostering synergy with the European Commission's Framework Programmes in terms of shared R&D objectives. This article describes the plan that has been evolved to integrate all of these various elements.

Life and Physical Sciences

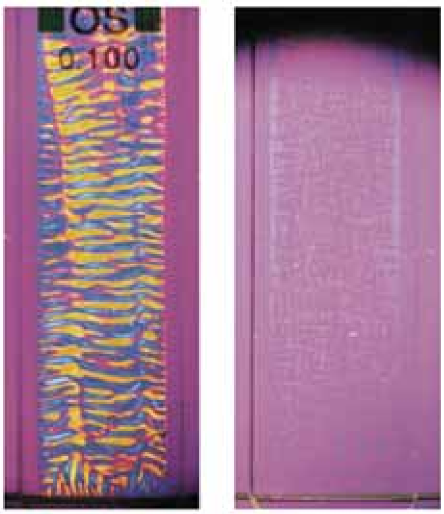


Research into cold-atom physics in space should lead to a factor 100 increase in atomic-clock frequency stability, with applications in fundamental physics, atmospheric physics and geodesy, navigation and telecommunications. This graphic shows the operational scenario for the Atomic Clock Ensemble in Space (ACES).

Through its microgravity programmes, ESA has supported space research in the life and physical sciences since the mid-1980s. Considerable scientific output has been achieved in such key areas as crystal growth, solidification physics, fluid sciences, thermophysical properties, molecular and cell biology, developmental biology, exobiology and human physiology. Many of these results have significant application potential, as demonstrated by the Agency's Microgravity Application Programme (MAP), which has attracted considerable interest not only from research institutes, but also from industry.

In the past three years, the Agency has received more than 700 new proposals in response to MAP Announcements of Opportunity. Among the more than 1000 scientists who are presently directly involved in approved projects, there are a significant percentage of newcomers, and the content of the proposals becomes ever more innovative. The existence of such a large and dynamic user community sets the stage for a strictly user-driven research strategy.

Society can rightly expect substantial benefits to flow back from research conducted on the ISS, given the heavy financial investments that have been made in its development and operation. In this respect, the strategy must encourage research likely to have good applications potential, but without interfering with the best science-driven peer-review process. An effective way to promote promising applications, therefore, is by teaming researchers from academia and industry, thereby fostering increased industrial engagement and benefits. Society will also expect to be regularly and reliably informed about the results of these ISS research activities, and here the role of the associated education and outreach activities is critical.



Exploring nature. Microtubules are important building blocks of biological cells. A recent experiment in space has shown that the self-organisation of these microtubules depends on gravity. This important finding has implications for understanding the biological functioning of cells. (Courtesy J. Tabony)

Developing the Research Plan

As part of the development process for the Research Plan, a comprehensive database of all peer-reviewed and accepted proposals was generated. To give structure to the Plan, ESA conducted a review of all proposals in hand as a result of recent Announcements of Opportunity (AOs). For defining the science and application objectives, it has taken the database of 'outstanding' and 'highly recommended' proposals that were presented to, and subsequently endorsed by, the Microgravity Programme Board. Then, with the aid of the Life and Physical Sciences Working Groups (LSWG, PSWG) and the Life and Physical Sciences Advisory Committee (LPSAC, formerly MAC), the proposals have been analysed in an iterative process that also involved the national delegations to the Microgravity Programme Board, as well as a Workshop organised by the European Science Foundation (ESF). Members of the European Low Gravity Association (ELGRA) have also provided inputs. The outcome of this process was the identification of four top-level objectives:

– Exploring Nature
– Improving Health
– Innovating Technologies and Processes
– Caring for the Environment.

In parallel, largely as a result of the ESF Workshop in November 2000 and after iteration with the LPSAC and its working groups, a set of Research Cornerstones was established to facilitate the Plan. These Cornerstones, which implicitly include the selected proposals as sub-elements, were then fleshed out in terms of the hardware development needed, the provision of flight opportunities, and the supporting ground-based work and future studies needed to implement the Plan. By carefully analysing all of the 'outstanding' and 'highly recommended' proposals, it was possible to allocate each of them to a specific Research Cornerstone and then, by examining the detailed activities within each proposal, to establish the appropriate relationship with the top-level objectives. This approach clearly showed that:

- the objectives set can indeed be met by means of research in the identified Cornerstones
- both the objectives and the Cornerstones are user-driven.

Implementing the Research Plan

Having established the Plan, with a total of 14 Research Cornerstones, the consequences for the space facilities being developed or about to be developed were addressed. This review highlighted the following programmatic consequences for ESA's European Life and Physical Sciences (ELIPS) Programme, which was approved at the Edinburgh Ministerial Council:

- There are research projects in all 14 Research Cornerstones that will require preparatory and supporting research activities, such as access to ground-based facilities, baseline data collection and bed-rest studies in the human-physiology area, the use of drop towers and aircraft in the materials, fluids, and combustion areas, and the assistance of User Support and Operations Centres (USOCs).
- There are research projects in many of the Research Cornerstones that will require continued use of the MFC facilities, namely the Materials Science Laboratory, the Fluid Science Laboratory, the Biolab and the European Physiology Modules, which will require new experiment containers/inserts to be developed and in some cases evolution/refurbishment of the facility in question.
- There are research projects in the majority of Research Cornerstones that will require use of non-ISS facilities, for example on Spacehab and Foton missions.
- There are specific research projects that will require the development of completely new facilities for the ISS.
- Some research projects will require the use of non-MFC facilities presently under development within other programmes.
- Many research projects, especially in the areas of materials, fluids, combustion and some areas of biology, will require sounding-rocket flights, particularly for preparatory work before the full ISS experiments are embarked upon.

The MFC and other facilities currently being developed to implement the Research Plan therefore include:

- Materials Science Laboratory (MSL): for industrial materials research, new materials development, and thermo-physical properties measurement, and including electromagnetic levitation for research into containerless processing
- Biolab : for cell-biology research and biotechnology
- Fluid Science Laboratory (FSL): for fluids research related to new materials and processes development
- European Physiology Modules (EPM): for biomedical research
- European Drawer Rack (EDR): for commercially developed payloads for research in the materials/fluid sciences
- European Modular Cultivation System (EMCS): for plant-biology research.

Soyuz-TMA1, carrying ESA astronaut Frank De Winne, moves in to dock with the ISS. This type of logistics flight is being used to bring experiments and the crew to operate them for early European utilisation of the ISS before Columbus is launched (photo NASA)

New facilities to be developed or presently under study include:

- Facility for Metal Foams: for research into metal foams
- Facility for Magnetic Fluids: for research into ferrofluids
- Facility for Complex Plasma/Cosmic- and Atmospheric-Particle Interaction
- Facility for Biotechnology Mammalian Tissue Culture.

In addition, two externally mounted payloads are required to meet the needs of scientists conducting research in the life and physical sciences:

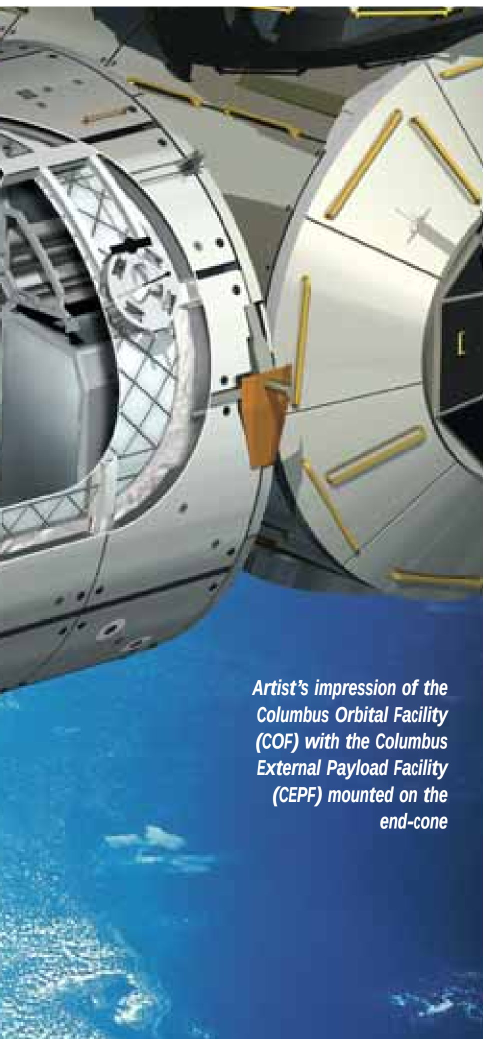
- The Atomic Clock Ensemble in Space (ACES): for studies to confirm that caesium clocks operated in space can have accuracies two orders of magnitude greater than on Earth
- The Matroshka (human phantom): for studying the radiation doses experienced by the internal organs of humans in space (to be located on the Russian segment of the ISS).

Space Sciences, Earth Observation, Technology, Commercialisation Promotion, and Education

The proposals in these five domains were evaluated by the appropriate ESA user programmes, using external peer-review groups and applying the criteria defined in the AO. The results were presented first to the ESA User Advisory Bodies and then to the User Programme Boards. Based on the list of peer-recommended and technically feasible experiments, the European Utilisation Board (EUB) arrived at a balanced set of four payloads, covering atomic physics, technology exposure, exobiology, and astronomy and solar physics. Two additional instruments for radiation monitoring and global transmission services were also selected, for accommodation on the Russian segment of ISS.

From left to right The Microgravity Facilities for Columbus (MFC) Racks: FSL, Biolab, EPM, EDR and ESR

The four main payloads will be accommodated on the Columbus module. Although Columbus is primarily designed for accommodating pressurised internal payload facilities that are accessible for astronaut intervention, there is also the Columbus External Payload Facility (CEPF), which is a framework mounted on the laboratory's end-cone with four attachment points, each with power, data and command links.



Artist's impression of the Columbus Orbital Facility (COF) with the Columbus External Payload Facility (CEPF) mounted on the end-cone

Space Sciences

Two observatory instruments are being developed for inclusion in the CEPF for the Columbus launch. One, the SOLAR observatory, will allow measurement of the Sun's spectral radiance with unprecedented accuracy. Its three instruments – SOVIM, SOLSPEC and SOL-ACES – cover virtually the whole electromagnetic spectrum from 17 to 3000 nm, in which 99% of all solar energy is radiated. The other, the Sky Polarisation Observatory SPOrt, is an astrophysical instrument that will measure the sky's polarisation in an as yet unexplored microwave frequency range (20–90 GHz). The scientific goals include the first polarisation map of our Galaxy at 22, 32 and 60 GHz, as well as full-sky measurements in the so-called 'cosmological window' (90 GHz) with unprecedented high sensitivity, thereby providing observational testing of today's cosmological theories.

In addition to these two instruments, a number of others are currently being studied for use or assembly on the ISS:

– Lobster-ISS can alert astronomers to such unpredictable events as the appearance of a new X-ray source or unexpected behaviour by a known source anywhere in the sky. It will be the first true imaging X-ray all-sky monitor and will be able to locate X-ray sources to within 1 arc-minute, allowing the swift identification of new transient sources. Lobster-ISS will produce a catalogue of 200 000 X-ray sources every 2 months. It will also observe the long-term variability of Active Galactic Nuclei (AGN) and stars, the mysterious and difficult-to-study X-ray flashes, and the highly topical X-ray afterglows of gamma-ray bursts.

– EUSO (Extreme Universe Space Observatory) is designed to study extreme-energy cosmic rays (EECRs) from space, using the Earth's atmosphere as a giant cosmic-ray detector. It will observe the flash of fluorescent light and the reflected Cerenkov light produced when an EECR interacts with the Earth's atmosphere. These cosmic rays, which are believed to be mostly protons, are very rare and are the most energetic particles known in the Universe. Direct imaging of the light track and its intensity variations will allow the event's position in the sky, as well as the total energy involved, to be reconstructed.

– ROSITA (Röntgen Survey with an Imaging Telescope Array) is designed to make a systematic all-sky survey in the medium-energy X-ray band (0.5 - 10 keV), with a sensitivity 100 to 1000 times higher than anything achieved previously.

– The XEUS (X-ray mission for Evolving Universe Spectroscopy) spacecraft will have higher throughput than XMM and better angular and spectral resolution, thanks to its 10 metre aperture and 50 metre focal length mirror optics. The total of eight mirror sections needed will be assembled in space using the ISS robotics infrastructure.

Earth Observation
A study is underway of a remote-sensing system for the ISS based on 'Rapid Eye'. The latter is a commercial system for agricultural applications and for observing man-made structures on Earth for insurance-verification purposes. The system consists of several free-flying cameras, one of which could be placed on the CEPF. Due to the inclination of the ISS's orbit, the system, which would achieve a ground resolution of 4 to 4.5 m, would provide varying observing times and observing angles. The planned ready-for-launch date for the Rapid Eye system is 2007.

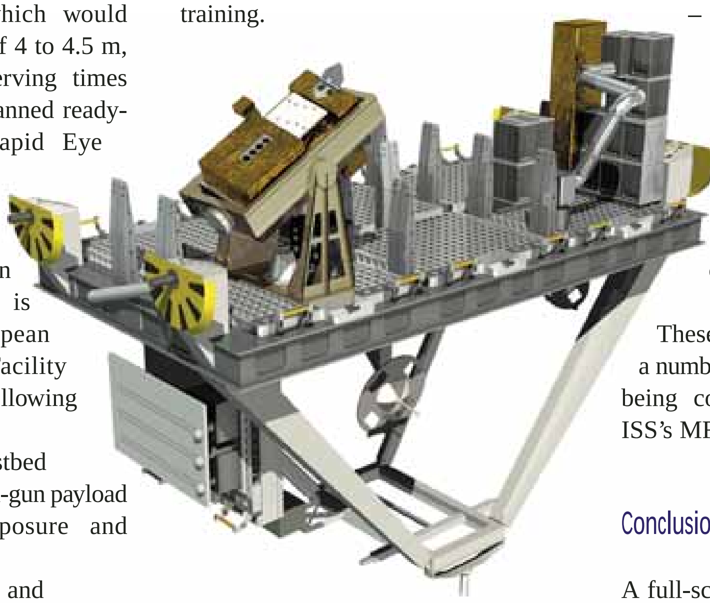
Technology
The main ISS accommodation for technology experiments is provided by the European Technology Exposure Facility (EuTEF), which houses the following five instruments/experiments:
– TRIBOLAB: a tribology testbed
– PLEGPAY: a plasma electron-gun payload
– MEDET: a material exposure and degradation experiment
– DEBIE-2: a debris detector, and
– FIPEX: a flux-probe experiment.

In addition to this technology-experiment hardware, the EXPOSE facility for exo-biology studies is also located on the EuTEF.

Commercialisation Promotion
ESA is offering access to the European part of the International Space Station (ISS) on a commercial basis. The idea is to allow European companies to increase their competitive advantage by using Low Earth Orbit as a platform for commercial R&D or other innovative activities based on sponsorship, product placement, education, and edutainment. ESA has therefore forged a strategic alliance with 12 European industrial space companies via a Cooperation Agreement for Promotion and Preparation of Commercial ISS Utilisation.

Promotion support to selected utilisation projects will include:

• Precursor flights opportunities, such as on parabolic aircraft flights and sounding rockets.
• Payload and payload technology development
• Payload facility development
• Payload support-equipment development
• ISS services such as transportation, payload processing, integration, operations and communications, and astronaut training.



The European Technology Exposure Facility (EuTEF)

The ESA MFC facilities will also be made available for life- and physical-sciences research by commercial customers. In addition, three particular instruments have already been identified for customer access as part of the 'Commercial Instruments' concept: a blood-pressure monitor, an atomic-force microscope for very high-resolution imaging of new crystals and materials, and the 'biochip', whichis an advanced system for analysing fundamental biological processes by measuring the levels of thousands of individual genes in parallel.

Education
In its evaluation of the proposed content of the ELIPS programme, the European Science Foundation stressed the importance of ISS education and outreach, for which the following activities have been undertaken or are planned by ESA:
– generation of multimedia and interactive teaching material for 8 to 18 year olds, including an ISS Education Kit for 8 to 12 year olds
– activities for students of 18 years and older, including the SUCCESS 2002 student competition, the Student Parabolic Flight Campaigns, and collaboration with teacher-training colleges.
– activities for teachers, including co-location in ESA for the creation of the ISS Education Kits.
– HAM radio contacts with schools during ISS Taxi Flights, web chats with European Astronauts, educational activities in European science museums, or travelling exhibitions, etc.

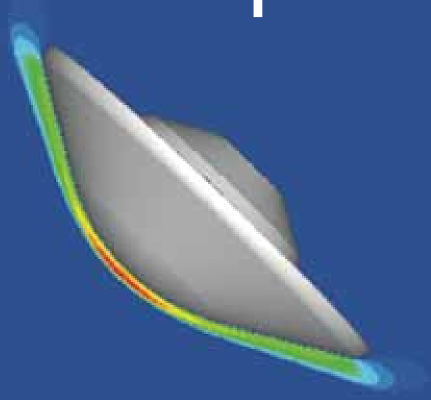
These activities are expected to lead to a number of education-related experiments being conducted by students using the ISS's MFC and other facilities.

Conclusion

A full-scale European Utilisation Plan has been elaborated for the ISS in a determined attempt to fully exploit Europe's significant investment through vigorous utilisation of its facilities for space life and physical sciences research and applications, Earth observation, space-technology development, the promotion of commercial access to space, and the use of space for educational purposes. A complete description of the Plan and the content, science targets and potential applications of all of the Research Cornerstones, can be found in ESA Special Publication SP-1270, titled *'The European Utilisation Plan for the International Space Station'*, which is available from ESA Publications Division.

1ST Announcement and Call for Abstracts

International Workshop on Radiation of High Temperature Gases in Atmospheric Entry



8-10 October 2003
Instituto Superior Técnico, Lisbon, Portugal

esa

www.esa.int

cnes
CENTRE NATIONAL D'ETUDE SPATIALES

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INSTITUTO SUPERIOR TÉCNICO

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esa Aurora Programme

http://www.esa.int/export/esaMI/Aurora/index.html

In the framework of ESA's Aurora programme and with the support of CNES, the Working Group "Radiation of High Temperature Gases" (WG RHTG) is organizing a workshop on Radiation of High Temperature Gases in Atmospheric Entry.Topics of interest include:

- Non Equilibrium Chemical Kinetics
- Hypersonic Flow
- Plasma Emission and Absorption
- Computational Fluid Dynamics
- Instruments and Facilities
- Flight Experiments
- Radiation Transfer
- Radiation emission & transfer database and models
- Re-building of selected radiative emission and absorption experiments
- Numerical axially-symmetric test-cases for flow and radiation emission and absorption calculations

For further information see the Workshop website at:

www.estec.esa.nl/conferences/

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