Forewords

The International Space Station is the largest international cooperative science and technology project ever undertaken, involving the United States, Russia, Japan, Canada and 10 member states of the European Space Agency. It is rapidly becoming a space-based reality, offering unprecedented access for research and applications in space conditions. Europe has invested heavily in this endeavour and plans to exploit that investment through a vigorous utilisation of the ISS for space life and physical sciences and applications, space science, Earth observation, space technology, the promotion of commercial access to space and the uses of space for educational purposes. The initial plan for that intensive utilisation is presented in this document.

I believe that anyone reading the document will be convinced of the strength and resolve of that commitment. The intensive solicitation and encouragement of the user communities in life and physical sciences and applications, space science, Earth observation and technology to use both internal and external opportunities offered by the Columbus laboratory provides ample evidence of that. In addition, the financial commitments by ESA to develop multi-user facilities for the life and physical sciences in Columbus and observational and technology exposure instruments using the external Columbus locations, plus financial support to promote commercial and educational activities, further demonstrate ESA's commitment.

Together with the resources and research facilities of all the Partners, the ISS offers a unique world-class laboratory to the user community that will be ready for full exploitation in the near future and available to scientific, industrial and commercial users for more than a decade.

I recommend this comprehensive document to anyone interested in Europe's detailed planning for ISS utilisation.

Jörg Feustel-Büechl
Director of Human Spaceflight, ESA

Since the advent of the Space Age, research in some of the physical sciences has taken advantage of the microgravity conditions offered by spaceflight. Most of the technologically advanced nations have pursued space physical sciences research in recent years and Europe has been no exception. Some of the research can be conducted on unmanned platforms, in particular the exploration of the Solar System environment. Other research programmes benefit greatly from the added flexibility that astronauts can provide (for example, the repair of the Hubble Space Telescope) or they can be designed from the outset with this flexibility in mind. For instance, unmanned spacecraft always remain at the 'old' technological level defined at their time of construction and eventually have to be replaced, whereas a space station facility can have a modular design so that regular upgrades of research modules and even new operations are possible. The International Space Station offers such a step forward in terms of quantity of experimental hardware and duration and frequency of access that it will, in the coming years, become the major space platform for space physical sciences research and applications derived from that research.

This document covers ESA's plan for the utilisation of the ISS for a whole range of disciplines in which the space physical sciences play a leading role. It is interesting to note that the space physical sciences have undergone a major evolution in recent years in two areas. Firstly, along with the classical materials sciences such as crystal growth and fluid physics, new research areas have entered the field, including cold-atom and quantum fluid physics, complex plasmas and dust particle physics. This, I believe, is an exciting development that introduces more (interdisciplinary) competition and strengthens space physical science as a whole. Secondly, the trend towards a (more aggressive) pursuit of applications-oriented research involving the active cooperation of industry and scientists (as exemplified by the current 43 Microgravity Applications Projects sponsored partly by ESA) is healthy and promising. Both of these trends are well in evidence in this document. The clear and demonstrated interest of a large community of scientists in Europe and beyond to use the ISS for research and applications in this area is also well documented.

This publication therefore provides a comprehensive overview of all these aspects and for that reason I highly recommend it.

Professor Gregor Morfill
Max-Planck Institut für Extraterrische Physik,
Garching, Germany

Member of the ESA Space Station User Panel
(SSUP)

Space life sciences has become an integral part of space research in recent years, and Europe has been at the forefront of that research through both the life sciences programmes of the European Space Agency and European national programmes. The strong growth in this area in recent years is evidenced by the increase in both quantity and quality of publications in peer-reviewed journals.

Europe, as a Partner, has made substantial investments in the development of the International Space Station ISS. It now plans to play a significant role in the exploitation and utilisation of ISS and with the upcoming launch of the Columbus laboratory in 2004 the opportunities for progressing that life sciences research in space will be greatly enhanced.

The last decade has brought a wealth of results in life science and has proved that high-quality science can be done in space. The problem of the influence of gravity on the evolution, development and functioning of the central nervous system (perception, action, spatial orientation, memory), and the main physiological functions, such as the cardiovascular system, respiration, reproduction and bone regulation, have to be more explored. Long-term exposure to microgravity of humans and animals is a unique means of solving this fundamental problem.

If we think about the longer-term perspectives of human activities in space and the inexorable extension of those activities to the human exploration of the Solar System, it becomes clear that the life sciences research that will be carried out aboard the Space Station and the supporting ground-based work will play a pivotal role in advancing our knowledge of how humans can survive and adapt to long-term exposure to space conditions.

It is also expected that medical research conducted aboard the ISS and the instruments and procedures derived from it will bring benefits for the improvement of the health of humans here on Earth. Most of the instruments developed for the Mir space station or the US Shuttle have stimulated new technologies for functional exploration in physiopathology.

Even in the case of tele-operated instruments with the use of robots, we have to increase our knowledge of the brain's mechanisms for adapting the laws of movement in different conditions of gravity. For instance, the physiology of exposure to 'mini-gravity' is still to be studied.

This document presents a comprehensive overview of ESA's plan its utilisation of the ISS. I believe that life scientists will be impressed at the central role accorded to life sciences research on the ISS, covering such diverse topics as integrated physiology, bone and muscle physiology, neuroscience, cell and developmental biology, plant physiology, biotechnology, preparation of human planetary exploration and the origin, evolution and distribution of life. All of these sub-disciplines will, to a greater or lesser extent, benefit from experimental work to be carried out on the Space Station.

To all those interested in the future of Europe's space life sciences and the role of the ISS in that, I warmly recommend this document.

Professor Alain Berthoz
Director, Laboratoire de Physiologie de la Perception et de l'Action
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Executive Summary

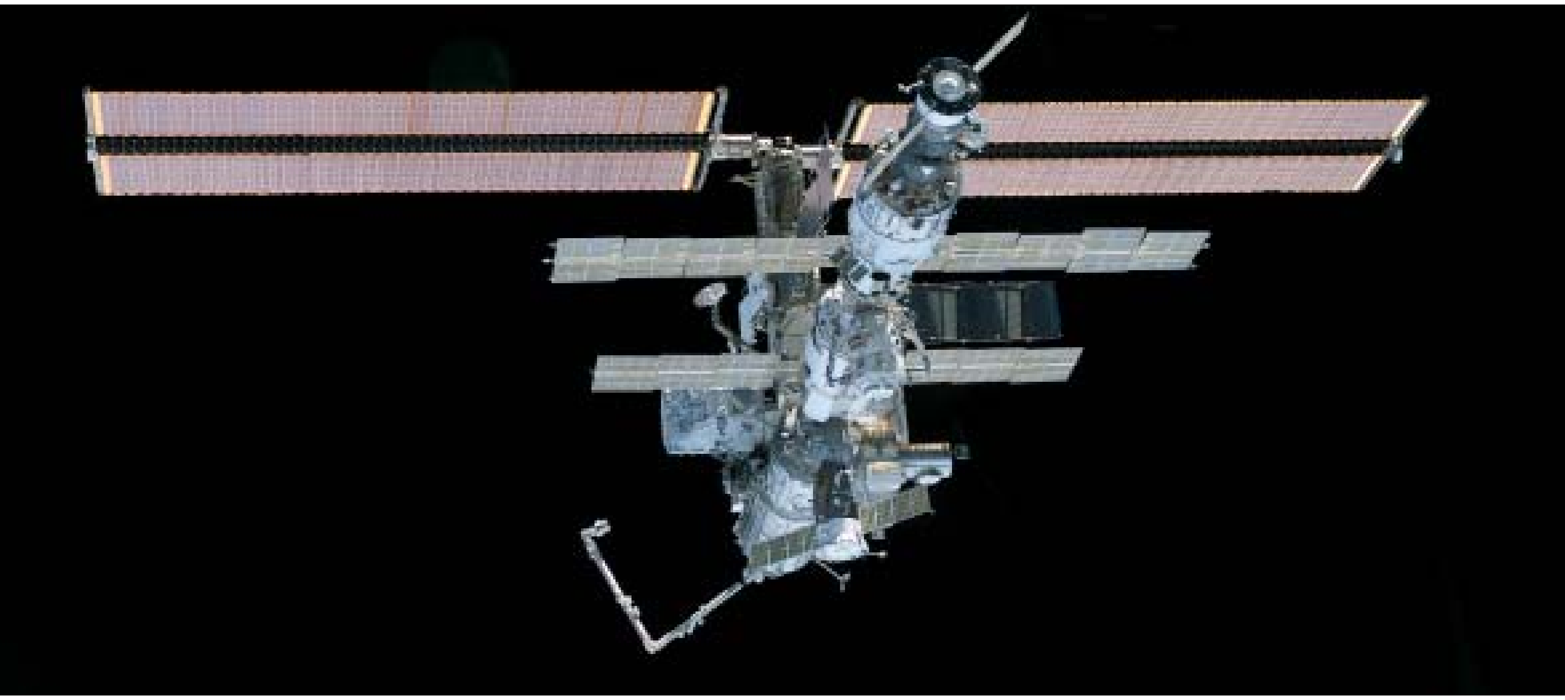
[Europe] should now concentrate on optimising use of the ISS as a European research infrastructure for all disciplines in space science – especially life and physical sciences, applied research, technology development and validation – and as a powerful educational tool and as a test bed for the 'next step' in human space exploration: the exploration of the solar system.

from the ESA/European Commission Joint Strategy for Space

This document lays out the ESA priorities concerning utilisation and related activities on the International Space Station (ISS) and the resources required to implement these priorities. The document was developed in the course of 2002 and pulls together in a comprehensive and coherent fashion the established ESA priorities for ISS utilisation in the disciplines of Life and Physical Sciences, Space Science, Earth Observation, Technology and Commercial and Educational activities. It was established in the context of a critical assessment by all ISS Partners of their research priorities in the light of potential stringent future resource (e.g. crew time and up/down load) limitations on ISS. Also during 2002, NASA installed a Research Maximisation and Prioritisation (ReMap) Task Force to reassess its priorities for the NASA Office of Biological and Physical Research. Russia, Canada and Japan undertook similar activities.

In the Life and Physical Sciences, ESA has, in preparation for the 2001 ESA Council meeting at Ministerial Level and through regular Announcements of Opportunity (AOs), defined its research objectives and priorities for the ISS. They are defined by disciplines and associated research cornerstones in a Research Plan developed in close consultation with ESA's Life and Physical Science Advisory Committee (LPSAC). The development of onboard facilities for all research cornerstones is almost completed, at a cost of several hundred million EUR. Preparatory ground-based research has also been initiated in some 43 cornerstone-oriented Microgravity Application Projects (MAPs). Some 300 experiments have been selected, of which more than 100

The ISS configuration as of June 2002. (NASA)



This European zero-g Airbus provides short-duration access to microgravity conditions for a wide variety of experiments, ranging from precursor experiments for ISS to student experiments. Droptowers and sounding rockets provide additional short-duration opportunities.

are research projects for execution aboard the ISS. Almost 200 experiments are selected for preparatory research in short-duration missions and on the ground.

All of the experiments result from solicitation through ESA or internationally coordinated AOs and have been evaluated and assessed in a rigorous, international and independent peer review. Only experiments marked 'outstanding', 'highly recommended' and 'recommended' (about 30% for all submitted proposals) have been retained for flight and execution on the ISS. By this process of coordination and selection, the prioritisation and maximisation of ESA's research for the initial period after the launch of the Columbus module has already been achieved. In total, 113 high-mark experimental research projects have through this process been prioritised for initial execution on the ISS for the various research disciplines.

In the Space Science, Earth Observation and Technology areas, the priorities for ISS utilisation have been established based on the peer-reviewed results of an AO for Externally Mounted Payloads completed in 1997. The evaluation of the proposals in these disciplines was organised by each ESA user programme, using external peer review groups, and applying the criteria defined in the AO.

This process resulted in the selection of originally five major payload packages for external mounting on a US external location (covered by the ESA/NASA Early Utilisation Agreement) covering atomic physics, technology exposure, exobiology and astronomy, solar physics and remote fire detection. Four of the five payloads are under development, the fire detection payload having been withdrawn owing to lack of funding.

A detailed analysis determined how much crew time will be required to carry out the 113 projects in the Life and Physical Sciences: some 650 crew hours for Physical Sciences, and 1243 crew hours for Life Sciences. In total, 1893 crew hours will be required to carry out the so-far prioritised experiments in the first period after the launch and commissioning of the Columbus module. The requirements coming from the Space Science, Earth Observation, Technology and the other projects have also been analysed. For external experiments, no crewtime will be required because they will be operated from the ground using telescience.

ESA has selected and prioritised its research projects for a 6/7-person crew on the ISS and has committed the corresponding budgets for facility developments and preparatory activities. European investigator teams are conducting preparatory ground-based and short-duration space experiments awaiting the opportunity to start their long-duration research aboard the ISS.

The report describes the ESA Research Plan for Life and Physical Sciences, and the planning for research in Space Science, Earth Observation, Technology and commercial and educational activities. It also covers the AO and peer review process, the international coordination of research and a comparison of the resource requirements of prioritised projects against the available resources for ESA. There are four annexes: the ESA-developed utilisation hardware for the pressurised (inside module) environment; hardware for the external (attached to module) environment; ESA's ISS Experiment Database, which lists all accepted experiments for direct execution on the ISS, plus preparatory experiments; and finally a list of common acronyms.

1

Introduction

In the framework of ISS utilisation activities, ESA promotes, coordinates and supports the preparation and implementation of multidisciplinary utilisation, with emphasis on applications-oriented research in Life and Physical Sciences in the space environment.

Within the broader objective of manned space exploration, ESA's Directorate for Manned Spaceflight and Microgravity is responsible for the development, operation and utilisation of the European contribution to the International Space Station (ISS) programme, in partnership with Canada, Japan, Russia and USA.

ESA has elaborated a European strategy for the efficient utilisation of this new research tool by European scientists. This strategy is coordinated with the ESA member states contributing to the programme, and through the European Science Foundation (ESF). Additionally, in cooperation with the European Commission (EC), ESA fosters the synergy of research and development objectives shared with the EC Framework Programmes.

Europe's Research Plan in Life and Physical Sciences is based on four top-level objectives broadly in line with the societal objectives identified by the ESA Ministerial Council and the EC. The Research Plan, which establishes 14 Research Cornerstones within the six main disciplines, is summarised in Section 2.

Section 3 gives ESA's plan for the utilisation of ISS for Space Science, Earth Observation, Technology, Commercialisation Promotion and Education.

Section 4 describes the AO and Peer Review Process and International Coordination in the Life and Physical Sciences, and shows how this process has led to prioritisation of Europe's research on ISS. This section also describes the coordination with the ISS Partners for implementing the space component of the research activities, designed to avoid duplication of efforts and to ensure efficiency on a global scale.

Section 5 provides a summary of ESA's research requirements to execute all prioritised research projects in all disciplines.

In order to provide the infrastructure to allow the implementation of baselined and planned scientific and applications research activities, ESA is developing an extensive array of hardware, ranging from the pressurised Columbus laboratory and the Automated Transfer Vehicle (ATV) to the experimental facilities such as Biolab, Fluid Science Lab, Materials Science Lab, European Physiology Modules, European Modular Cultivation Facility, European Drawer Rack, Protein Crystallisation Diagnostics Facility and the ACES atomic clock payload, plus other external observation payloads and support hardware such as the Microgravity Science Glovebox and various freezers and refrigerators. The experimental facilities for the pressurised environment (inside module) are described in Annex A.

The experiments and facilities for the non-pressurised (external to module) environment are described in Annex B. In total, the hardware described in the Annexes represents a large investment by Europe in order to exploit the Space Station fully as intended in the invitation by NASA for Europe to participate in the programme.

Annex C is a copy of the database listing all the experiments selected for flight. The database contains only experiments that were judged as 'outstanding', 'highly recommended' or 'recommended'. It represents about 25% of the proposals submitted in response to AOs issued in 1995-2001. This database is the result of Europe's Research Prioritisation carried out over the last 3 years.

Annex D is a list of common acronyms in the context of ESA planning for ISS utilisation.

2

The ESA Research Plan for Life and Physical Sciences and Applications on ISS

2.1 Background and Strategic Context

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

Whereas flight opportunities in previous decades were too scarce to pursue little more than one-off experiments, the possibilities of regular and continuous access and the nature and capabilities of the ISS facilities call for a longer-term strategic approach.

The ISS is a multi-partner undertaking involving researchers from a variety of global partners, and the harmonisation of science objectives, at least from a European perspective, is clearly highly desirable. This would minimise duplication and the wasteful use of resources, and maximise cooperation and the benefits of friendly competition.

In view of the fact that the ISS offers globalised, competitive research opportunities, any plan must encompass peer-reviewed best-science organised as far as possible at a global level. This process began with the issue of global Research Announcements in the life and physical sciences areas organised between the ISS Partners, but it needs strengthening and rigorous pursuit.

In addition to the new environment offered by the ISS, the user community has changed considerably in recent years. In the past 3 years, more than 700 new proposals have reached ESA in response to AOs. Among the more than 1000 scientists who are presently directly involved in approved projects, there is a significant fraction of newcomers. Also, the topics addressed are increasingly innovative, covering mainstream science or practical applications on Earth. Such a large and dynamic user community sets the stage for a strictly user-driven research strategy.

The life and physical sciences experiments to be carried out on the Station will exist within wider scientific and societal contexts. From a scientific perspective, life and physical sciences activities in space are descended from their ground-based

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. The picture shows the operational scenario for the Atomic Clock Ensemble in Space (ACES).

mother disciplines. Any research plan must take account of this by ensuring that the space activities do not become isolated from the much wider non-space mother disciplines; it must ensure a strong two-way flow of information about scientific results, flight opportunities and the general status of the space activities within the mother discipline. In this connection, peer-reviewed publications and other outreach activities towards the mother discipline community are needed.

Society will expect benefits to flow back from ISS research in view of the heavy investments made in the Station's development and operation. The plan must encourage research likely to have applications potential but not interfere with the best-science peer review process. An effective way to promote applications is by teaming researchers from academia and industry, thus increasing industrial engagement and benefits. Society will also expect to be informed of the results of the research; again, the role of education and outreach is fundamental.

The ISS is becoming a large space-based reality and offers unprecedented access to space conditions. Europe has invested heavily in ISS development and will be expected by its partners to bear significant system operations costs during the Station's lifetime. Therefore, a Research Plan for the optimised conduct of life and physical sciences and applications research aboard the Station by Europe is mandatory. This plan outlines such an approach for the vigorous utilisation of the ISS by one of its major users – the combined disciplines of space life sciences and physical sciences and the related applications activities.

2.2 Objectives of the Plan

The key objectives of this Research Plan are to:

— lay out the overall science and applications objectives in life and physical sciences in space for Europe in the next 5 years, with an outlook of 10 years.
— define a mechanism to monitor and adapt the contents of the Research Plan continuously based on the demands of the user community.
— identify an implementation approach to meet the objectives and, in particular, define how the top-level science and application objectives are translated into a Programme Proposal for an ESA programme in life and physical sciences and applications.

2.3 Development and Evolution of the Research Plan

This Research Plan has been set up in the course of 2000-2001 and is intended as a general outline of the research objectives for life and physical sciences and applications in space for the next 5 years, with an outlook of 10 years. Its contents are not confined to ESA, but rather reflect the objectives and priorities in life and physical sciences of all European users and entities involved in space research.

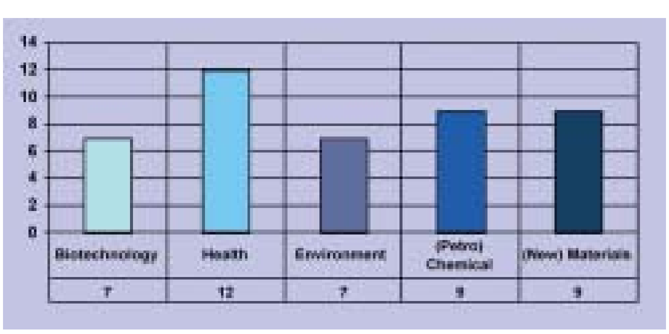
The input from the user community has been the major driver of the Research Plan. That this has been possible is a token of the growing strength of the scientific community in Europe. In the last 5 years, scientific results in life and physical sciences using space as a tool have led to high-quality publications. This progress can be attributed to the following factors:

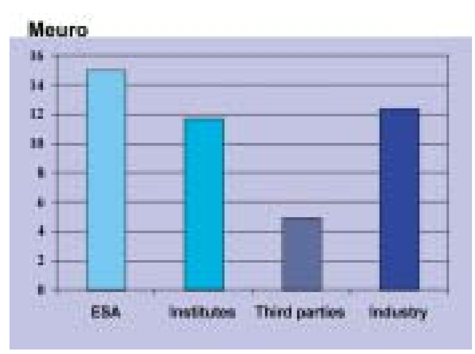
— the very strict peer-review system put in place by ESA and its international partners.
— the accumulated scientific results of the past two decades of life and physical sciences in space, which has exceeded a critical mass and is now attracting researchers from adjoining disciplines.
— the coordination at European level between researchers, leading to full research programmes, rather than to individual space experiments.

In any scientific discipline, basic research is the starting point for progress. For that reason, basic research in life and physical sciences in space has received continuous support. As experience shows, outstanding results from fundamental research readily attract the interest of high-standing non-space scientists. New ideas will follow from scientifically excellent proposals in the pure sciences, and, after gestation, they will find their way into novel practical applications. It is a sign of maturity that an increasing proportion (presently around 40%) of applied research proposals are received in response to AOs. The present research strategy, therefore, describes both basic and applied research topics.

In order to give structure to the Research Plan, ESA conducted a review of all the proposals in hand as a result of recent AOs. In defining the science and application objectives, the Executive took the database of Outstanding and (Highly) Recommended proposals that were recommended by the peers and subsequently endorsed by ESA's Microgravity Programme Board. 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 were structured along the lines of pyramids, with the

Left: the topics addressed in the set of application-oriented research projects. Almost 125 European (non-space) industries are participating in these projects. Right: the distribution of the financial contributions towards the costs of the application-oriented projects. The industries and research institutes each contribute almost a third of the total project costs.





individual proposals at the base and top-level objectives at the apex. This was an iterative process, in which the Microgravity Programme Board delegations and a workshop organised by the European Science Foundation (ESF) were involved. Also, members of the European Low Gravity Association (ELGRA) provided inputs. This led to the identification of four top-level objectives and four corresponding pyramids. At mid-level in the pyramids, the research priorities were identified and at the bottom typical outstanding or highly recommended proposals were given.

It was realised that, although useful for understanding the Plan's structure, this graphic representation had some limitations. For example, it did not evidence the overlap and multi-disciplinarity present at all levels within and between the pyramids. Nevertheless, it was decided to retain the four top-level objectives since these are clearly rooted in the database of proposals.

In parallel, and chiefly as a result of an ESF workshop in November 2000 and iteration with the LPSAC and its working groups, a set of Research Cornerstones was established orthogonal to the top-level objectives and necessary to facilitate the plan. These cornerstones (which implicitly include the proposals as sub-elements) were then detailed in terms of the required hardware development, provision of flight opportunities, future studies and supporting ground-based work needed to implement the plan.

2.4 Top-Level Objectives

The top-level objectives identified within this process are:

Exploring Nature

Using the conditions of weightlessness or radiation available in space will reveal findings in fundamental life and physical sciences that can change our understanding of Nature. In addition, research will be supported in preparation of human planetary exploration missions, which are expected to be one of the major endeavours of this century.

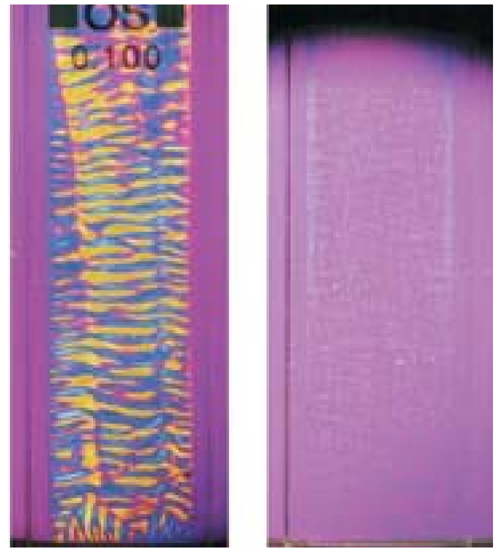
Improving Health

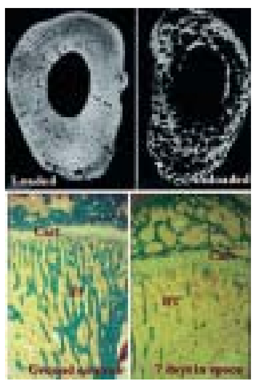
Performing human physiology experiments using astronauts on the ISS will contribute to solving health problems on Earth as a result of ageing, disease or disability, such as osteoporosis and cardiovascular problems. The focus will be on understanding the underlying physiological processes, testing drugs and countermeasures and developing advanced, tele-operated, diagnostic techniques.

Innovating Technologies and Processes

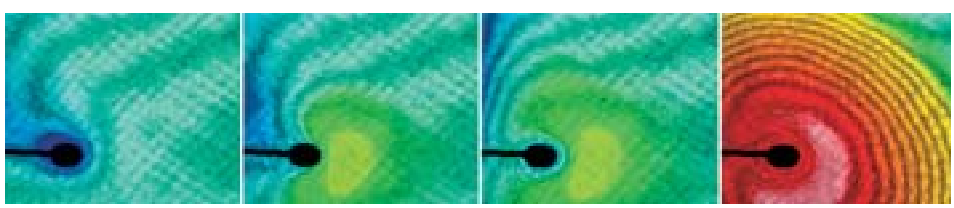
Studies in material sciences and fluid physics mostly deal with the liquid state of matter, with properties that can sometimes be masked by gravity-induced effects. Results of these studies are often relevant for modelling and understanding processes in the (petro)chemical, biotechnology and metallurgical industries, as well as for developing new technologies and materials.

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)

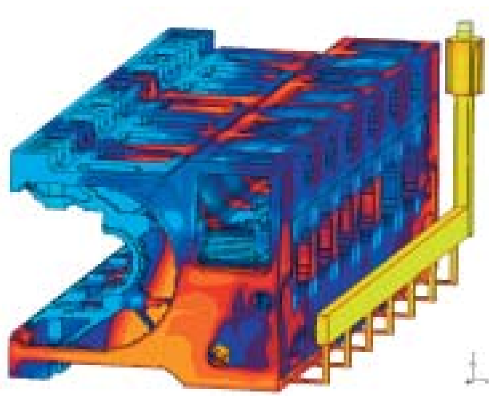




Improving health. Space research can improve our understanding of physiological changes such as bone loss. This research may lead to better medications and countermeasures against diseases such as osteoporosis. The images compare loaded and unloaded bones and the changes in the bones of rats after a week in space. (Courtesy A. Zallone & L. Vico)



Caring for the environment. More efficient combustion of fuels on Earth would reduce atmospheric pollution. Research in microgravity without convection can lead to improved combustion. The inherent transport phenomena needed for modelling and optimising the process are best studied in weightlessness. The illustration shows false-colour interferograms of a self-igniting suspended n-heptane droplet in microgravity. From left to right: cool vapour around the droplet; bright green cool flame; cool flame expanding; hot ignition.



Innovating technologies and processes. Studies in materials science are often relevant for modelling and understanding processes in, among others, the metallurgical industry. Space research can improve the casting process used, for example, to produce car-engine blocks. Shown is the temperature distribution of a block-casting simulation. The accuracy of the simulation depends strongly on the parameters measured in the microgravity environment.

Caring for the Environment
Combustion experiments in space reveal details of the burning process that cannot be obtained on Earth and are relevant for improving the efficiency and environmental load of engines and power plants. The development of life-support systems for spacecraft will lead to technologies for waste treatment, rapid detection of microorganisms, and food production.

The details of the definitions given here are a result of a dynamic process and will therefore evolve. As part of the Research Plan and at regular intervals Research Announcements of Opportunity (AO) will be published, indicating these top-level objectives of the programme. These AOs will lead to a new response from the user community at more detailed levels. The typical time scale of variation of these user inputs is in the order of typically a few years and changes in topics of interest are introduced rather rapidly.

It is expected that the top-level objectives will have a typical time scale of variation of 5-10 years, which is compatible with the horizon of the Research Plan and the first phase of the programme based on it.

In view of the fact that the top-level objectives are used as inputs to the AOs, a feedback loop is created in the form of an interaction with peers and advisory bodies. Although top-level objectives are used as themes for the AOs, proposals in other discipline-relevant innovative areas will also be considered.

2.5 The Research Cornerstones

At the request of ESA, the European Science Foundation through its European Space Science Committee (ESSC) organised a workshop in November 2000 reviewing the scientific contents of the draft Research Plan and the proposed new programme. In this workshop, a mix of independent and involved scientists, observers of the three involved ESF Standing Committees (Physics and Engineering Science Council, PESC; Life and Environmental Science Council, LESC; and the European Medical Research Council, EMRC) discussed and commented on the scientific objectives. The outcome consisted of several recommendations and the identification of Areas of European Excellence for each of the disciplines involved. The final report was endorsed by the Standing Committees and finally approved by the ESF Board on 12 March 2001.

ESA had asked the ESF to pay particular attention during the workshop to the identification of Areas of European Excellence per discipline. The output was subsequently discussed in the LPSAC and led to the formulation of the following Research Cornerstones within the six disciplines. These Cornerstones are described below in some detail.

Fundamental Physics
— investigate ***Complex Plasmas and Dust Particles Physics***, with emphasis on understanding the 3-D behaviour of particles in a plasma reproducing fundamental molecular phenomena, and aggregation

processes in a vacuum or atmospheric environment requiring weightlessness.

— study ***Cold Atoms and Quantum Fluids***, with special significance given to the development and utilisation of a cold-atom clock in space, which can attain accuracy levels unreachable on Earth.

Fluid and Combustion Physics

— study the ***Structure and Dynamics of Fluids and Multi-Phase Systems***, such as critical fluids, binary and ternary systems and granular materials, that are non-uniform on a macroscopic scale in the Earth's gravitational field. Of singular interest are fluid flows in a central geometry and the evolution of multi-constituent systems such as foams and emulsions.

— perform ***Combustion*** experiments with gas, liquid and solid fuels, to investigate quantitatively phenomena superimposed on Earth with buoyancy convection.

Material Sciences

— measuring ***Thermophysical Properties*** of liquid metals will use the possibilities of containerless-sample processing under conditions attainable only under weightlessness.

— by eliminating gravity-induced effects, ***New Materials and Processes*** can be gained from experiments in space. This encompasses understanding the mechanisms of crystal growth and solidification of metals, inorganic and organic materials, and biological macromolecules.

Biology

— in ***Biotechnology*** investigate, under conditions of weightlessness, transmembrane and intracellular flux of mediators controlling cell potency and differentiation as well as cell-matrix interaction.

— in ***Plant Physiology*** study mechanosensory elements, e.g. genes and proteins, involved in gravitropism.

— in ***Cell and Developmental Biology*** examine the effects of an altered gravitational environment on the development of the cell and the whole organism, including reproduction, with emphasis on signal transduction, gene expression and neural development.

Physiology

— in ***Integrated Physiology*** study the effects of low gravity and other extreme conditions on whole-body regulations, e.g. in the cardio-vascular-respiratory and sensori-motor systems.

— use conditions of reduced gravity to learn about the effects of load on functional elements of ***Muscle and Bone Physiology***, e.g. muscle atrophy and bone mass turnover.

— understand in the field of ***Neuroscience*** the effects of gravity on control of posture, locomotion and cognition.

Astro/exobiology and Planetary Exploration

— in ***Origin, Evolution and Distribution of Life*** study the survivability of organisms under extreme conditions on Earth, in space and in (simulated) planetary environments.

— in ***Preparation for Human Planetary Exploration*** quantify the effects of radiation doses and investigate the impact of isolation in high-stress environment on humans. In addition, develop the scientific knowledge base for identification and utilisation of *in situ* resources. Also study the life support requirements for long-duration planetary missions.

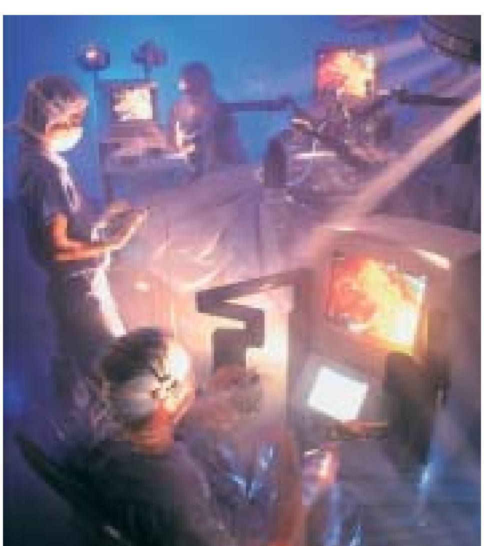
Table 2.1 provides a more detailed description of these Research Cornerstones. These detailed descriptions were worked carefully with the working groups and with the LPSAC to identify in detail and with a reasonable degree of specificity the envisaged science targets to be reached in each Research Cornerstone and the potential applications of the research.

Having established the 14 Research Cornerstones and the detailed scientific research targets in each, as well as the potential applications of the activities within that research area, the analysis went on to determine the cross linkage between each Cornerstone and the top-level objectives established as described above. By analysing the total of ‘Outstanding’ and ‘Highly Recommended’ proposals, each proposal was allocated to a specific Research Cornerstone. By examining the detailed activities within the proposals, the relationship with the top-level objectives was established. The linkage between objectives and Cornerstones was quantified by allocating the strength of the linkage as either a ‘Contribution’ or an ‘Essential Contribution’. By this method it was possible to break down the numbers of proposals over the top-level objectives and over the range of Research Cornerstones. This process gave clear evidence that:

— the objectives can be met by means of research in the identified Cornerstones.

— the objectives and the Cornerstones are user-driven.

This, therefore, is a distillation of the Research Plan as far as the basic thrust of the scientific research supported by ESA in the life and physical sciences, including the applications that will flow from it. The next section covers the implementation of that plan in terms of programme elements of the ESA programme in life and physical sciences and applications, now designated ELIPS and approved at a level of €171.4 million in November 2001.



Advances in telemedicine driven by space research, covering areas such as remote diagnosis and monitoring of surgical intervention, also have applications in ground-based health care.

Table 2.1. The Research Cornerstones.

	Research Cornerstone	Description	Science Targets	Potential Applications
Fundamental Physics	Complex Plasmas and Dust Particle Physics	Understand the 3-D behaviour of particles in complex plasmas and aggregation processes that require weightlessness.	Enhance theoretical description of complex plasmas, including self-ordering and phase transition phenomena. Improve modelling of the interaction of proto-planetesimals, their optical properties and of the behaviour of pollutants in the atmosphere.	Develop novel plasma coating techniques. Nucleation and growth of novel substances for solar cells and plasma screens. Improved modelling of Earth climate and environment.
	Cold Atoms and Quantum Fluids	Study properties and applications of cold atoms, including Bose-Einstein condensates.	Develop and operate a cold-atom clock in space. Check limits of validity of theories of relativity and quantum electrodynamics.	Improved accuracy of absolute time measurements. Increased accuracy for navigation and geodesy systems.
Fluid and Combustion Physics	Structure and Dynamics of Fluids and Multiphase Systems	Study of multiphase systems, their phase transitions and related dynamics, critical and supercritical fluids, granular materials. Geophysical fluid flows.	Quantify heat transfer, mass exchange and chemical processes in multiphase systems and supercritical fluids. Measure diffusive processes in mixtures. Study the stability of foams and emulsions. Describe dynamic coupling in granular materials under vibration.	Develop reactors for supercritical oxidation of industrial contaminants. Develop high-efficiency heat exchangers. Improve reactor design in industrial plants. Design improved oil recovery techniques.
	Combustion	Study combustion phenomena that are dominated on the ground by buoyancy convection.	Quantify fuel droplet and spray evaporation, auto-ignition and combustion processes. Detail the process of soot formation in flames and the conditions for flammability of solid fuels.	Improve efficiency of electrical power plants. Reduce emissions of engines. Improved flammability test procedures.
Materials Sciences	Thermophysical properties	Use the extended possibilities of containerless processing in space to measure critical properties of highly reactive liquid metals.	Measurements, and with higher accuracy, of the properties of stable and metastable (undercooled) liquid metals.	Increase the reliability of numerical simulation and control of casting facilities in the metallurgical industry.
	New Materials, Products and Processes	Understand the physics of solidification and crystal growth of metals, organic and inorganic materials, and biological macromolecules.	Quantify the influence of the growth conditions on the homogeneity and the defects in crystals, including protein crystals. Enhance numerical models of the microstructure formation in metals and alloys.	Improve and validate models for predicting grain structures in industrial castings. Develop processes towards new metallurgical products. Improve efficiency of production of industrial crystals.

...continued ...

Table 2.1. The Research Cornerstones (continued).

	Research Cornerstone	Description	Science Targets	Potential Applications
Biology	Biotechnology	Investigate in weightlessness transmembrane and intracellular flux of mediators that control cell differentiation.	Improve knowledge of the relation between material flux at the cell-medium interface and gene expression. Improve the properties of recombinant products. Quantify interfacial transfer and especially interfacial turbulence and control of the membrane porosity.	Develop artificial functional tissues and targets for drug screening. Develop a bioreactor for tissue engineering e.g. cartilage for implantation. Develop novel micro-encapsulated drugs and cells.
	Plant Physiology	Study mechanosensory elements involved in gravitropism.	Identify mechanosensory and signalling elements determining gravitropism. Identify gene interactions important in the gravistimulus response chain.	Improvement of plant growth and mechanical properties of plants. Develop techniques for plant survival and growth in space.
	Cell and developmental biology	Study the effect of gravity on cell and whole-body development and reproduction.	Study altered gene expression in an altered gravitational environment e.g. micro-arrays. Improve understanding of the impact of the cytoskeleton architecture on signal transduction e.g. functional genomics. Understand the effect of gravity on the development of the vestibular and sensori-motor systems in vertebrates.	Design pharmacological substances for animal and human applications relevant to human development. Develop techniques and pharmacological substances for cell and tissue regeneration e.g. neuronal repair.
Physiology	Integrated Physiology	Use the extreme conditions of space to study the effect of gravity and stress on vegetative regulations.	Study cardio-vascular control, e.g. blood pressure regulation, under microgravity. Investigate the influence of sensori-motor and proprioceptive inputs on cardio-vascular control. Study the dependence of energy uptake on exercise and load.	Develop miniaturised, automated devices for medical diagnostics. Improve techniques and devices for medical applications e.g. sports medicine. Improve protocols for post-traumatic rehabilitation. Improve treatment of stress-related disease.
	Muscle and Bone Physiology	Use absence of or reduced gravity to study the effects of load on the human musculo-skeleton.	Study effects of changes in load on muscle atrophy and plasticity. Understand and quantify bone-mass turnover as a function of e.g. local blood perfusion and mechanical stress.	Develop devices and protocols and protocols for medicine. Improve means for diagnostics, prevention and treatment of osteoporosis. Improve rehabilitation after long-term incapacitation, particularly involving bed rest.
	Neuroscience	Understand the effects of gravity on control of posture, locomotion and cognition.	Investigate the interaction of the vestibular system with other inputs relevant to locomotion and posture (e.g. vision, proprioception). Understand cognitive strategies in the absence of gravity.	Develop devices and protocols and protocols for medicine. Improve means for diagnostics, prevention and treatment of osteoporosis. Improve rehabilitation after long-term incapacitation, particularly involving bed rest.

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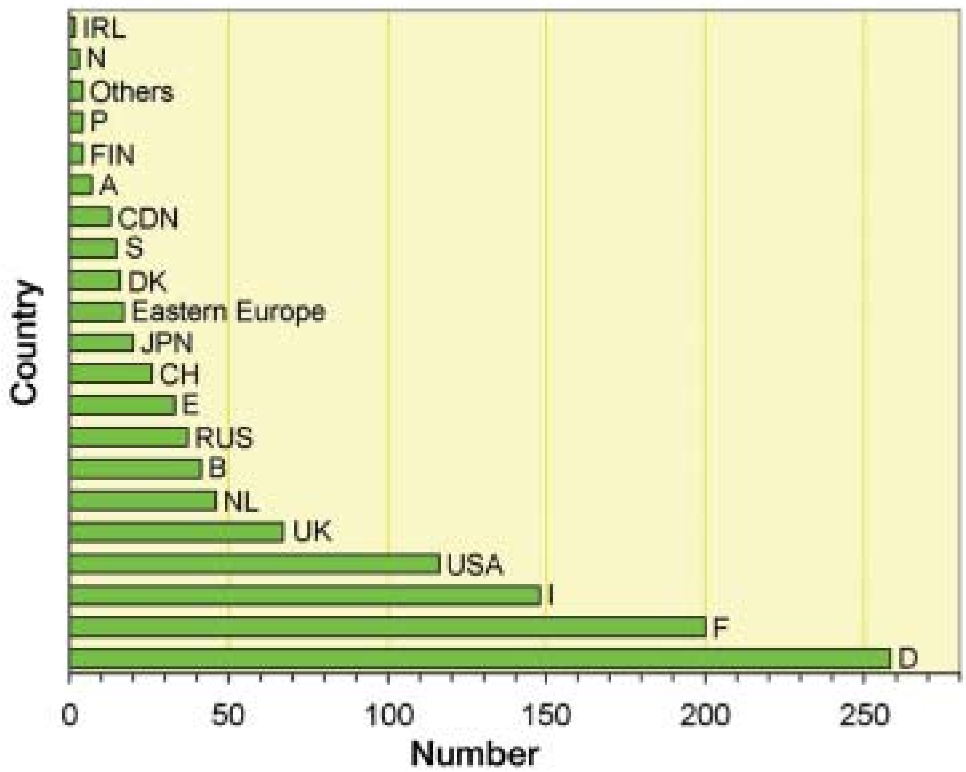
Table 2.1. The Research Cornerstones (concluded).

	Research Cornerstone	Description	Science Targets	Potential Applications
Astro/exobiology, Planetary Exploration	Origin, Evolution and Distribution of Life	Study the survivability of organisms under extreme conditions on Earth (extremophiles) and in space.	Investigate the contribution of space conditions including radiation to the formation of prebiotic molecules. Identify the conditions for survivability of micro-organisms from and in space including planetary surfaces. Identify markers and tools to search for extinct and extant life.	Identify novel enzymes and bacteria from extreme physical and chemical environments with industrial application e.g. biocatalysis.
	Preparation of Human Planetary Exploration	Study novel aspect of human planetary expeditions.	Quantify radiation risk for human beings and understand the specific biological action of space radiation. Study effects of isolation in high-stress environments. Quantify needs for consumables during missions. Perform simulation tests on *in situ* resource utilisation potential.	Develop advanced radiation sensors and countermeasure devices. Develop technology for telemedicine/telesurgery in remote areas. Develop protocols for handling stress effects. Develop methods for *in situ* resource utilisation. Develop life-support systems for use in space and other isolated environments. Develop the technologies for identification and utilisation of *in situ* resources.



Distribution of the 1077 scientists involved in the approved projects that form the scientific and industrial basis of ELIPS.

2.6 Implementation

Following the establishment of the Plan and a subdivision into 14 Cornerstones (Table 2.1), the proposals and the typical technical requirements of research projects in the various Research Cornerstones were reviewed and the demands of the Cornerstones on the existing, being-developed or to-be-developed space facilities was established. The chief results with programmatic consequences for the ELIPS programme were:

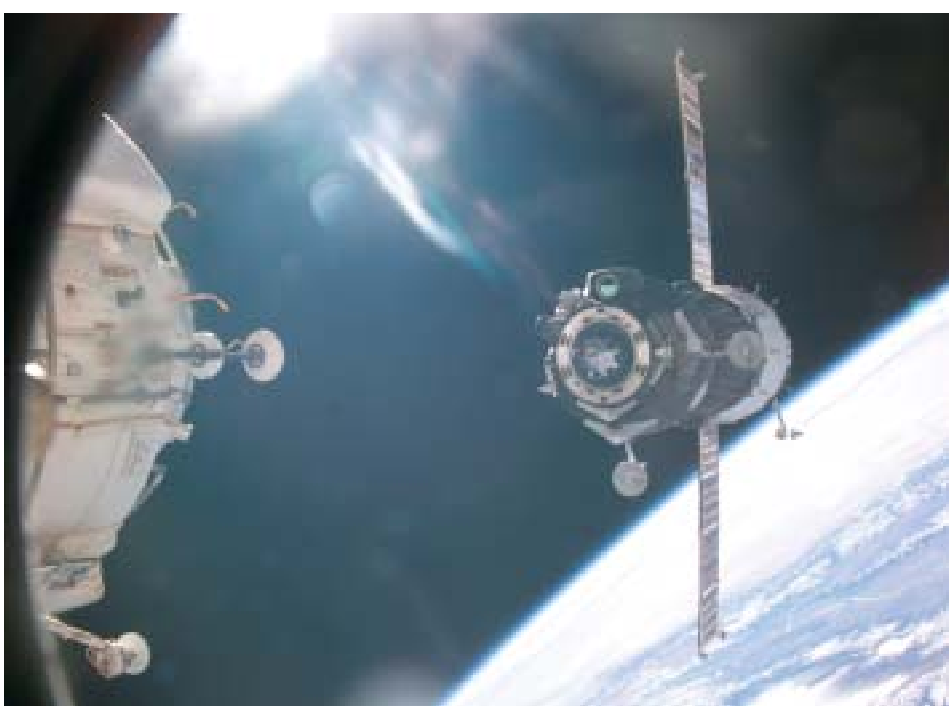
- there are research projects in all 14 Research Cornerstones that require preparatory and supporting research activities such as access to ground-based facilities, baseline data collection and bedrest studies in the human physiology area, the use of droptowers and aircraft in the materials, fluid and combustion areas and the support of user support and operations centres (USOCs).
- there are research projects in many of the Research Cornerstones that will require continued use of the Columbus Materials Science Lab, Fluid Science Lab and Biolab, which will require new experiment containers/inserts to be developed and in some cases evolution/refurbishment of the facility (which also probably applies to the European Physiology Modules).
- there are research projects in the majority of Research Cornerstones that

will require use of non-ISS facilities on e.g. Spacehab and Foton missions.
— there are specific research projects that require the development of completely new facilities for Space Station.
— some research projects require the use of non-Microgravity Facilities for Columbus (MFC) presently under development within other programmes.
— many research projects, especially in the areas of materials, fluids, combustion and some areas of biology, require sounding rocket flights, particularly for preparatory work before the full Space Station experiments are embarked upon.

Coupled with these conclusions are a number of points regarding the Research Plan, its objectives and underlying philosophy that require additional programme elements:

— the objective of having a programme based on best-science and strict peer review means that provision must be made for the support of experts and advisory groups.
— the objective of having a mechanism to continuously monitor and adapt the contents of the Research Plan based on the demands of the user community means that regular Research Announcements have to be made, the collective results being used to update the plan in a user-

Soyuz-TMA1, carrying ESA astronaut Frank De Winne, moves in for docking 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 in late 2004. (NASA)



driven manner. The expert and advisory groups referred to in the previous bullet are intimately involved in the peer-review process.

— the objective of having a user-driven, highest science quality programme means that there should be provision for user information centres and activities to help potential users optimise their experiments and gain knowledge of other experiments. There should also be virtual institutes to encourage and facilitate networking between scientists, and education and outreach activities to publicise the achievements to the broader scientific community and the public. These last two were highly recommended by the ESF in its report.

— the objective of incorporating a longer-term perspective in the programme means that provision must be made for topical teams that prepare the future science and future studies that prepare the future research facilities.

— the objective of ensuring that society can expect benefits eventually from this research means that the programme should dedicate at least one element to the support of applications projects.

3

ESA's Plan for the Utilisation of ISS for Space Science, Earth Observation, Technology, Commercialisation Promotion and Education

3.1 Introduction

From the onset of its utilisation preparation activities, ESA has, at the request of its Council and on the recommendation of its external advisory bodies, aimed at multidisciplinary utilisation of the ISS. To this end, the disciplines needing external accommodation of mostly observational and remote-sensing instruments are also included in the ESA planning for ISS utilisation. The disciplines concerned are mainly Space Science (in particular Astronomy and Solar Physics) and the various subdisciplines of Earth Observation and activities in Technology, Commercialisation Promotion and Education. The solicitation and selection of experiments in the first of these two disciplines are left to the ESA Directorates of Science and Earth Observation.

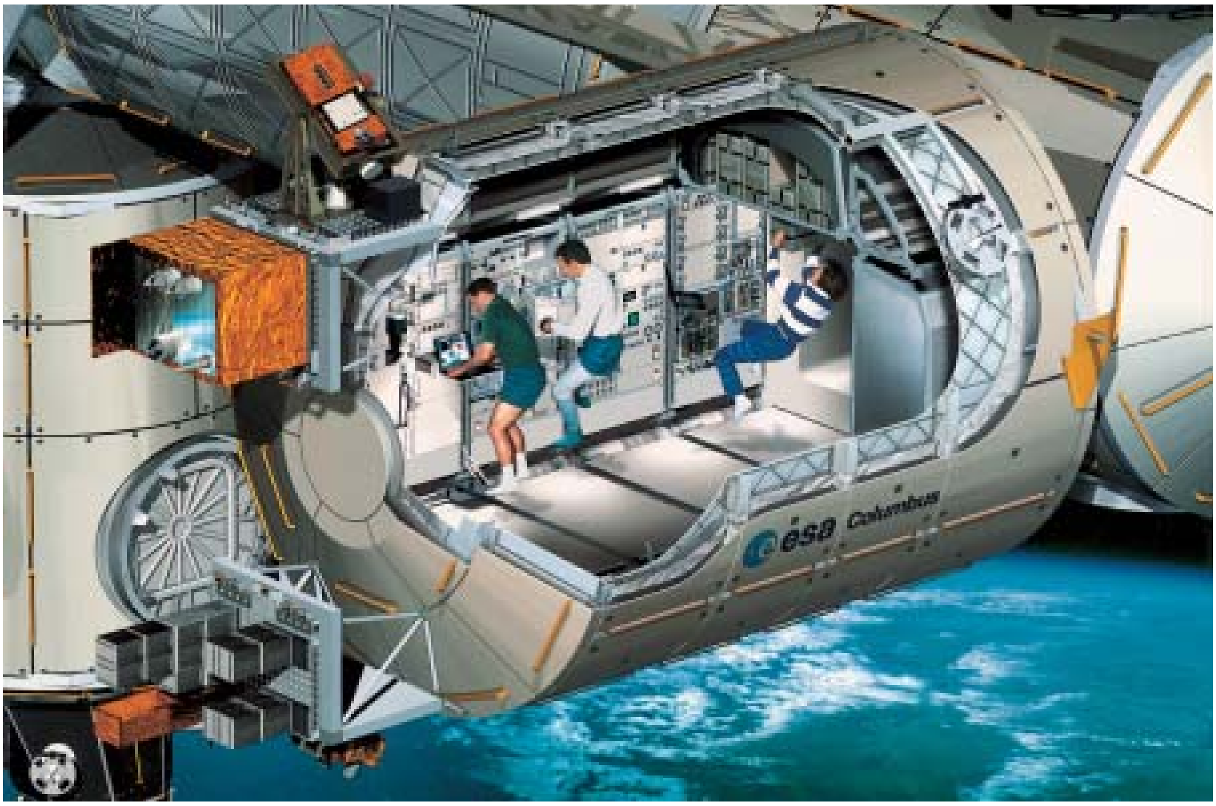
In the Space Science, Earth Observation and Technology areas, the first payloads for ISS utilisation were established based on the peer-reviewed results of an AO for Externally Mounted Payloads completed in 1997. The evaluation of the proposals in these disciplines was organised by each ESA user programme, using external peer-review groups, and applying the criteria defined in the AO. The results of the peer review were presented to the ESA User Advisory Bodies and ultimately to the User Programme Boards. In parallel, a technical team, including industrial contractors, assessed the technical aspects of the proposals. Based on the list of peer-recommended and technically feasibly experiments, the Executive worked iteratively with the European Utilisation Board (EUB) to arrive at a balanced set of experiments/instruments taking the following aspects into consideration:

— funding support by Member States for the experiments proposed;
— compatibility with accommodation and/or operations constraints;
— expected readiness of payloads to meet the delivery dates for flight;
— interdisciplinary aspects, the ESA Space Station User Panel (SSUP) having recommended a fair balance between the disciplines.

This process resulted in the selection of five payload packages for external mounting on a US external location (covered by the ESA/NASA Early Utilisation Agreement), covering cold-atom physics, technology qualification, exobiology and astronomy, solar physics and remote fire detection. Later, the fire detection (Earth observation) instrument was cancelled for lack of development funds, and the remaining instruments (now under full development) were moved to an external site on Columbus because of delays with the US external platform. Finally, as a result of the AO, two additional instruments in the areas of radiation biology and global transmission services were selected for accommodation on the Russian segment.

3.2 Columbus External Science and Technology

Within the multidisciplinary utilisation of the ISS, there is the possibility for observational and remote-sensing research instruments requiring external accommodation. Academic and commercial research institutes involved in disciplines such as astronomy, solar physics, various subdisciplines of Earth



The Columbus module with the CEPF on the end-cone. (ESA/D. Ducros)

observation and technology have shown interest in external accommodation sites for their experiments.

The Columbus module, though primarily designed for accommodating pressurised internal payload facilities that are accessible for astronaut intervention, also offers external accommodation sites. This is made possible by the Columbus External Payload Facility (CEPF), which is an external framework mounted on the module's starboard end-cone with four attachment points, each with power, data and command links.

The Columbus module is located on the starboard side of the ISS, opposite Japan's Kibo module, and is attached to Node-2. Consequently, the CEPF attachment points provide payload locations in the ISS zenith, nadir and starboard directions. Two locations allow for zenith-looking payloads, two for nadir-looking payloads. The CEPF technical capabilities are described in Annex B.

3.3 Space Science

This discipline exploits the capabilities of the ISS for solar physics and astrophysics.

Solar Physics
SOLAR is a monitoring observatory that allows measurements of the solar spectral irradiance with unprecedented accuracy. Apart from scientific contributions to solar and stellar physics, knowledge of the 'solar constant' and its variations (the interaction between the solar energy flux and the Earth's atmosphere) is of great importance for atmospheric modelling, atmospheric chemistry and climatology.

The SOLAR observatory consists of three complementary instruments and covers almost the whole electromagnetic spectrum (17-3000 nm) in which 99% of the solar energy is radiated. The three instruments are:

— SOVIM (Solar Variable & Irradiance Monitor) covers near-UV, visible and thermal regions of the spectrum; developed by the Observatory of Davos (CH);
— SOLSPEC (Solar Spectral Irradiance measurements) covers 180-3000 nm range with high spectral resolution; developed by CNRS (F);
— SOL-ACES (Solar Auto-Calibrating EUV/UV Spectrophotometer) measures the extreme-UV and UV spectral regime (17-220 nm) with moderate spectral resolution; developed by the Fraunhofer Institute (D).

SOLAR's technical aspects are given in more detail in Annex B.

Astrophysics
The SPOrt Sky Polarisation Observatory has the main goal of measuring the sky polarisation in an unexplored microwave frequency range (20-90 GHz). The scientific goals include the first polarisation map of the galaxy at 22, 32 and 60 GHz, as well as full-sky measurements in the 'cosmological window' (90 GHz) at unprecedented high sensitivity. Its angular resolution of 7° is chosen to lie in the most promising range in terms of the expected Cosmic Microwave Background (CMB) polarisation/anisotropy ratio. This would provide a further observational test on cosmological theories, supplementing the results from current and future CMB experiments both in space and from the ground. These two investigations/instruments are under development. SOLAR will will fly on the CEPF with the Columbus launch in October 2004, and SPOrt is expected to be placed on CEPF in 2006.

SPOrt's technical aspects are given in more detail in Annex B.

In space science, in addition to the instruments under development described above, a number of studies for using ISS are also underway:

X-Ray All-Sky Monitoring
A proposal for an X-ray all-sky monitoring instrument called Lobster-ISS was submitted to ESA's Directorate of Science in response to the call for Flexi-Mission proposals (F2 and F3) issued in October 1999. In this call, proposals based on the utilisation of Columbus and other ISS elements were solicited. Unlike a conventional satellite, which orbits the Earth pointing in the same direction unless commanded otherwise, the ISS orbits rather like

an aircraft, keeping its main axis parallel to the local horizon. This is a great advantage for an all-sky monitor since it means that the field of view automatically scans most of the sky during every 90-minute ISS orbit.

Lobster-ISS can alert astronomers to unpredictable events such as the appearance of a new X-ray source or the unexpected behaviour of a known source anywhere in the sky, thus enabling scientists to react rapidly to new phenomena. It will be the first true imaging X-ray all-sky monitor in the 0.1-3.5 keV band and it will be able to locate X-ray sources to within 1 arcmin to allow swift identification of new transient sources. Lobster-ISS will produce a catalogue of about 200 000 X-ray sources every 2 months that will be speedily made available to the astronomical community via the internet. As well as providing an alert facility, the high sensitivity will allow many topics to be studied using Lobster-ISS data alone. These include the long-term variability of active galactic nuclei and stars, the mysterious and difficult-to-study X-ray flashes, and the highly topical X-ray afterglows of gamma-ray bursts.

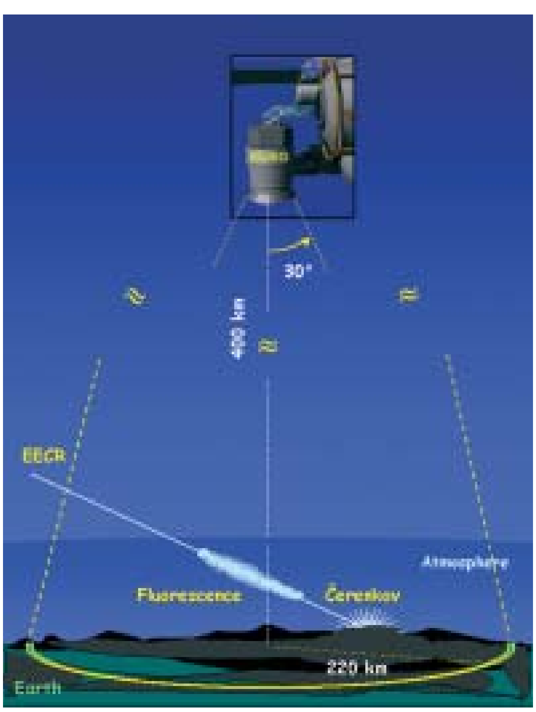
Further technical details on this instrument are given in Annex B.

Extreme Energy Cosmic Rays

The Earth is continuously bombarded by high-energy particles known as cosmic rays. Understanding the origin of the most energetic cosmic rays ($>5 \times 10^{19}$ eV) is one of the great challenges in astrophysics. Although these extreme energy cosmic rays (EECRs), believed to be mostly protons, are very rare (only around 1 per square kilometre per century!), they are the most energetic particles known in the Universe. Because they are so rare, only about 30 such events have been found using different ground-based air shower detectors in the past 30 years. There has been no convincing identification of any of these events with a likely astronomical source.

A proposal for an Extreme Universe Space Observatory (EUSO) was submitted to ESA's Directorate of Science in response to the call for Flexi-Missions (F2 and F3) issued in October 1999.

EUSO promises to study EECRs from space by using the Earth's atmosphere as a giant detector. EUSO will observe the flash of fluorescent light and the reflected Cerenkov light produced when an EECR interacts with the atmosphere and the ground. Direct imaging of the light track and its intensity variations will allow the sky position of the event, as well as the overall energy, to be reconstructed.



The EUSO observation scenario.

Further technical details of EUSO are given in Annex B.

All-Sky Survey at Medium Energy X-ray Bandwidth
The aim of ROSITA (Roentgen-Survey with an Imaging Telescope Array) is the systematic all-sky survey in the medium-energy X-ray bandwidth (0.5-10 keV), thereby complementing the results of the Rosat survey at 0.1-2.5 keV. The sensitivity provided by ROSITA will be 100-1000 times higher than achieved by previous surveys.

ROSITA was submitted to ESA as an unsolicited proposal and is awaiting its final approval and the authorisation for a Phase-A feasibility study.

Further technical details on ROSITA are given in Annex B.

ROSITA and Lobster are complementary and, when operated simultaneously, will provide an unprecedented survey of the sky in the band 0.1-10 keV.

XEUS
The future European X-ray astronomy interests lead to an XMM successor: XEUS (X-ray mission for Evolving Universe Spectroscopy). Building upon ESA's XEUS baseline concept, an industrial study, funded jointly by the Directorate of Science and the Directorate of Human Spaceflight, analysed XEUS' critical technical and operational aspects in more detail and found it feasible.

The next-generation X-ray astronomy requirements in general are higher throughput and better angular and spectral resolution, requiring very large aperture mirror optics, larger than any existing launcher is able to launch. Therefore their assembly has to take place in space. The most attractive option is to use the ISS as a workbench. The Station serves as a point of assembly of the Mirror Spacecraft (MSC), which also represents a whole group of other discussed, very large free-flying spacecraft as candidate 'Visiting Vehicles' for ISS services.

XEUS requires X-ray optics of 50 m focal length. In order to achieve this and still be able to approach the ISS, the mirror and the detectors are carried on two separate spacecraft (MSC; Detector Spacecraft, DSC) flying in formation. For orbit-transfer manoeuvres, MSC and DSC can dock with each other, with the DSC being the active transfer spacecraft. The initial XEUS consists of the DSC1 and the 4.6 m-diameter MSC1. Both will be launched directly into their observational orbit of 600 km altitude, which is compatible with the ISS orbit for visits, and operate there for a maximum of 4.5 years. The sensitivity goal of XEUS requires the mirror aperture to be increased to 10 m. The necessary aperture segments will be added to MSC1 following docking to the ISS. In total, eight mirror sections will be added using the ISS robotics infrastructure.

3.4 Earth Observation

A study is under way for a commercial remote-sensing system based on Rapid Eye: a commercial enterprise for agricultural applications and for observing man-made structures on Earth for insurance verification. The system consists of several free-flying cameras, with one camera on the CEPF. Obviously, an ISS payload location with an open view to nadir is required. The system would achieve a ground resolution of 4-4.5 m, and the inclination of the ISS orbit would provide very good coverage of regions around 51° and allow for varying observing times and observing angles. The planned ready-for-launch date of the Rapid Eye system is 2007.

3.5 Technology

The main accommodation scenario for ESA technology experiments is the European Technology Exposure Facility (EuTEF), dedicated to providing the means to gather scientific technological data in the ISS environment. The EuTEF technical capabilities are fully explained in Annex B.

In its current configuration, EuTEF accommodates four Standard Instrument Modules containing the following five instruments/experiments:

- TRIBOLAB: tribology testbed;
- PLEGPAY: plasma electron gun payload;
- MEDET: Material Exposure and Degradation Experiment on TEF;
- DEBIE-2: debris detector;
- FIPEX: Flux Probe Experiment.

In addition, the EXPOSE facility for exobiology is also located on EuTEF. Some details on the technology research on EuTEF are described below.

TRIBOLAB

Some of the potential tribology experiments that will fly on EuTEF are:

Liquid lubrication:

- Evaluation of fluid losses from surfaces, cages and porous reservoirs by evaporation through
  - known defined labyrinth seal geometries;
  - evaluation of unstable porous cage behaviour for wheels;
  - evaluation of effectiveness of creep and anti-creep measures in zero gravity;
  - evaluation of the effects of additive boil off.

Solid lubricant tests:

- Evaluation of wear of polymer and metallic cages;
- Evaluation of unstable solid lubricant cage behaviour for mechanisms;
- Evaluation of start torque effects on solid-lubricated ball bearings when subject to periods of stationary motion (local environment/contaminants);
- Evaluation of the effects of launch vibration and atmospheric changes on metallic surfaces.

PLEGPAY

The scientific objective of PLEGPAY is the study of the spacecraft/space environment interactions in low Earth orbit (LEO), with reference to electrostatic charging/discharging phenomena. The spacecraft community is very interested in understanding the mechanisms for electrostatic charge accumulation, which often produces uncontrollable discharge events, adversely affecting spacecraft electronic systems.

Among the existing active methods to mitigate charging effects, the hollow cathode plasma contactor (an electric propulsion spin-off technology) has proved itself to be the most effective. It could become a standard facility for commercial and scientific satellites and the ISS infrastructure.

MEDET

This is the Material Exposure and Degradation Experiment testbed. There are three main scientific objectives:

— evaluation of the effects of the total space environment on the optical and thermo-optical properties of materials for LEO spacecraft;
— validitation of laboratory space simulation by comparison with flight results;

The CEPF provides four attachment points on the Columbus end-cone. (ESA/D. Ducros)

— monitoring the size distribution and origin of solid particles impacting spacecraft surfaces.

DEBIE-2

DEBIE is a standard space debris and micrometeoroid-monitoring instrument that requires low resources from the spacecraft. A significant benefit of a standard instrument will be that the scientific results from several DEBIE instruments aboard different spacecraft can be easily compared and compiled to a single database.

The DEBIE-2 flight model is essentially similar to DEBIE-1, with some improvements in the flight hardware and software. DEBIE-1 is flying on Proba-1, an ESA technology demonstration small satellite launched in October 2001.

FIPEX

The drag on space vehicles in LEO is influenced mainly by the flow density, so it is important to know the exact conditions. However, because solar radiation and Earth's magnetic and gravitational fields influence the atmospheric composition, the exact constitution at a given point depends upon many different parameters, which include long-term, short-term and spatial variations. Many different semi-empirical models have been developed that can produce the data for any spatial position at a given time. However, their results in some cases differ by more than an order of magnitude. Thus, the accuracy of the prediction of total density and gas partial pressures for satellites and the ISS at these altitudes is insufficient. The atomic oxygen flux is important because it has different interactions with spacecraft surfaces, such as erosion of the surface material. The FIPEX micro-sensor on EuTEF will measure the atomic oxygen flux as well as the oxygen molecules in the ISS environs.

3.6 ISS Commercialisation

ESA has decided to offer access to the European part of the ISS on a commercial basis. The objective is to allow European companies to gain or increase their competitive advantage by using LEO as a platform for commercially-based Research & Development and innovative activities based on sponsorship, product placement, education and edutainment.

In order to support the development of this commercial utilisation, ESA has forged a strategic alliance with industrial partners to implement general promotion activities for raising the awareness of utilisation opportunities in Europe and activities for supporting specific commercial utilisation projects. This alliance has been concluded with 12 European space companies via a Cooperation Agreement for Promotion and Preparation of Commercial ISS Utilisation.

On the basis of an approved Promotion Policy, the ESA ISS Promotion Office has developed, together with the industrial partners of the cooperation agreement, a Marketing Plan for promotion activities to be commonly implemented by ESA and the Partners. This plan defines in particular the communication guidelines, the approach and criteria for selection and implementation of the General Promotion activities (including ISS image promotion), the criteria for the selection of supported commercial projects and the criteria and rules applicable to the allocation of Promotion Support measures to those projects. A specific section describes the promotion activities to be undertaken in Europe in order to promote the commercial utilisation of ISS to market sectors such as biotechnology, health, environment, food and new materials.

Policy Objectives
The general ESA policy objectives for promotion of commercial ISS utilisation are to:

— stimulate commercial utilisation of ISS for applied R&D projects in life and physical sciences, technology, ISS-based services (e.g. communications and Earth observation) and other types of commercial utilisation;
— maximise commercial use of the ESA ISS resources allocated for such purposes;
— stimulate the development of a market for the provision of industrial ISS services to commercial ISS customers;
— support the development of a clear and strong market position of European industry for serving commercial ISS customers.

Specific objectives for provision of ESA promotion support are to:

— demonstrate commercial viability of ISS utilisation in new market segments;
— foster long-term relationships with commercial ISS customers;
— enable access to ISS utilisation resources for all types and categories of industries including space and non-space companies, and in particular Small- and Medium-sized Enterprises.

As a principle, ESA promotion support will target projects using ISS for R&D activities. In addition, promotion support to other commercial activities will be given, if the policy criteria above are met.

Implementation
Promotion support to projects will be restricted to the space-related part of the utilisation project, in particular procurements of:

— project definition phases;
— precursor flight opportunities (e.g. drop towers, parabolic flights, sounding rockets);
— payload and payload technology development;
— payload facility development;
— payload support equipment development;

The Biolab Engineering Model.

— ISS services: transportation; payload ground processing; payload integration; payload operations; payload communications; astronaut training.

Concerning specific opportunities for commercial research in the life and physical sciences, the ESA MFC facilities (see Annex A) will be offered for use by commercial customers:

— Materials Science Laboratory (MSL), e.g. industrial materials research, new materials development, and thermophysical properties measurement);
— Bioloab, e.g. cell biology research, biotechnology;
— Fluid Science Laboratory (FSL), e.g. fluids research related to new materials and processes development;
— European Physiology Modules (EPM), e.g. biomedical research;
— European Drawer Rack (EDR), for commercially developed payloads for research in materials/fluid sciences;
— potentially, MSL Electromagnetic Levitation, e.g. research on containerless processing).

In addition to MFC facilities, part-time commercial use of other facilities may be foreseen:

— European Modular Cultivation System (EMCS), for plant biology research.

New facilities to be developed and presently under study:

— facility for metal foams;
— facility for magnetic fluids, for research on ferrofluids;
— facility for complex plasma/cosmic and atmospheric particle interaction.

All these facilities are described in Annex A.

Commercial Pathfinder Projects
Following the publication by ESA of an Open Call for Commercial Proposals (*http://www.esa.int/spaceflight/isscommercialisation*), a stream of projects has been proposed to ESA. Innovative proposals lead the way – projects in sponsorship and commercially-based manned missions are under evaluation.

For commercial use of external locations, Rapid Eye is planned as a commercial payload mounted on the Columbus External Payload Facility. Details are given in Section 3.4 above.

Also in the commercial area, the Commercial Instruments concept allows ESA to make available new equipment and services to customers on a commercial basis. The customer base potentially consists of institutional users (ESA peer-reviewed scientists, astronaut health monitoring, other agencies, the scientific community) and commercial users involved in applied research.

The concept aims at three objectives for each instrument:

— demonstrating technology aboard the Station. Space is a unique environment for testing products: the lack of gravitational effects, vacuum, radiation and mass and safety constraints force continuous improvements in technology, with direct benefits for users in space and consumers on Earth;
— leasing the instrument to institutional or industrial ISS users;
— marketing and promoting the instrument on Earth.

A pool of three instruments has been identified so far: a blood-pressure monitor, an atomic force microscope for very high-resolution imaging of, for example, protein crystals and new materials, and the 'biochip' advanced Integrated System for Molecular Bioanalysis. The biochip analyses and monitors fundamental biological processes by measuring the relative expression levels of thousands of individual genes in parallel.

Finally, a set of proposals concerning the improvement of the quality of life of crew has been received. These projects encompass applications in food, clothing and body care. The interest of the companies proposing these projects is two-fold. On one side there is the potential application of space-proven technologies to products and processes for the consumer segments, while on the other there is the possibility to promote the products via the association with space.

ESA astronaut Roberto Vittori working with the Blood-pressure Measurement Instrument (BMI) aboard the ISS, May 2002.

The ISS is open for business and accessing it commercially has been made easy by the Cooperation Agreement services and a simple evaluation process. Further information is available at the ESA ISS Commercial Promotion Office at:
iss.commercial@esa.int

3.7 Education

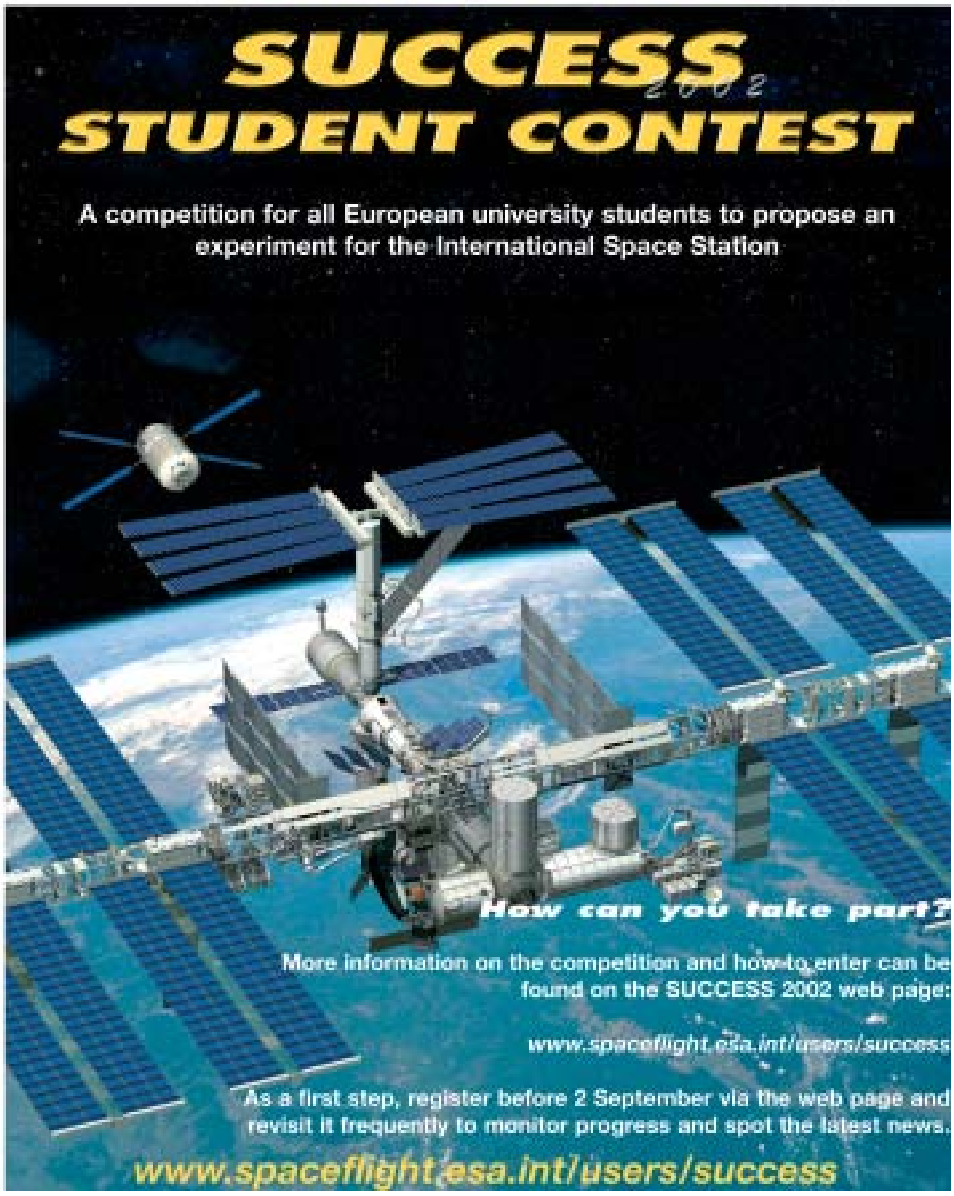
In its report on the evaluation of the proposed contents of the ELIPS programme, the European Science Foundation stressed the importance of education and outreach. Education related to ISS is considered to be an important activity within ELIPS, which is the major ESA user programme of the ISS. In order to prepare an educational use of ISS the following activities are planned:

Generate multimedia and interactive teaching material for 8-18 year-old pupils and students including:
— ISS Education Kit for 8-12 year-olds (games, teaching material, exercises, supporting material, teacher guide, references, web references for interdisciplinary lessons using space as a tool);
— ISS Education Kit for 12-15 year-olds (teaching material, exercises, supporting material, teacher guide, references, web references for interdisciplinary lessons using space as a tool);
— ISS: Lessons in Life and Physical Sciences for 15-18 year-olds;
— Educational Experiments on Soyuz taxiflights and, later, Columbus (series of videos): prototype with the Odissea mission in October 2002.

Activities for 18+ year-old students including:
— SUCCESS 2002 (student competition);
— support to Student Parabolic Flight Campaign ;
— collaboration with Teacher Training Colleges.

Activities for teachers covering:
— collocation of Teachers in ESA (part of the EIROFORUM European Science Teachers Initiatives, ESTI); e.g. the teachers contribute to the creation of the ISS Education Kits.

Promotional activities such as:
— ham radio contacts with schools during Soyuz taxiflights (implemented in 2002 during the Marco Polo and Odissea missions);
— web chats with European astronauts (implemented in 2002 with Roberto Vittori and Frank de Winne);



— educational activities in European science museums and travelling exhibitions; implemented in June 2002 at the Valencia Science Museum (Space Walk).

It is expected that these educational preparatory activities will lead to a limited number of experiments conducted by students using ISS facilities such as the MSL, Biolab, EPM and FSL and, potentially, the new facilities for Ferrofluids, Metallic Foam and IMPF/ICAPS. One percent of ESA's overall ISS resources has been allocated to ISS student experiments.

4

The AO and Peer-Review Process and International Coordination in the Life and Physical Sciences

4.1 Objectives of an Announcement of Opportunity (AO)

An Announcement of Opportunity (AO) is issued by a Partner Agency and solicits research programme proposals by investigator teams with a long-term perspective, including the related sequence of flight experiments.

The first aim of an AO is to maximise the scientific return on investments in hardware development by acquiring users of facilities under development in Europe, while also enabling European scientists to utilise unique facilities developed by other agencies. The second aim is to sustain the dynamics inherent to a research programme by offering to scientists the opportunity to consolidate or refine research objectives through preparatory experiments on short-duration carriers, and to evaluate the space and applications relevance of new research topics with European colleagues. The Announcement thus encompasses several levels to address scientists with different degrees of maturity in their research in space activities.

An International Announcement of Opportunity (IAO) is issued at international level and is coordinated by the International Microgravity Strategic Planning Group (IMSPG) or the International Space Life Sciences Working Group (ISLSWG). The purpose is to obtain the highest quality research through international solicitation and scientific peer review of research proposals, to increase the effective use of the ISS through international cooperation and utilisation of the ISS facilities, and to avoid duplication of projects by fostering international collaboration. The research solicitations aim to optimise the use of facilities available for microgravity research on the ISS.

4.2 Proposals Evaluation Procedure

The evaluation of all flight experiment proposals in response to an AO or IAO is performed against the following criteria outlined in the AO:

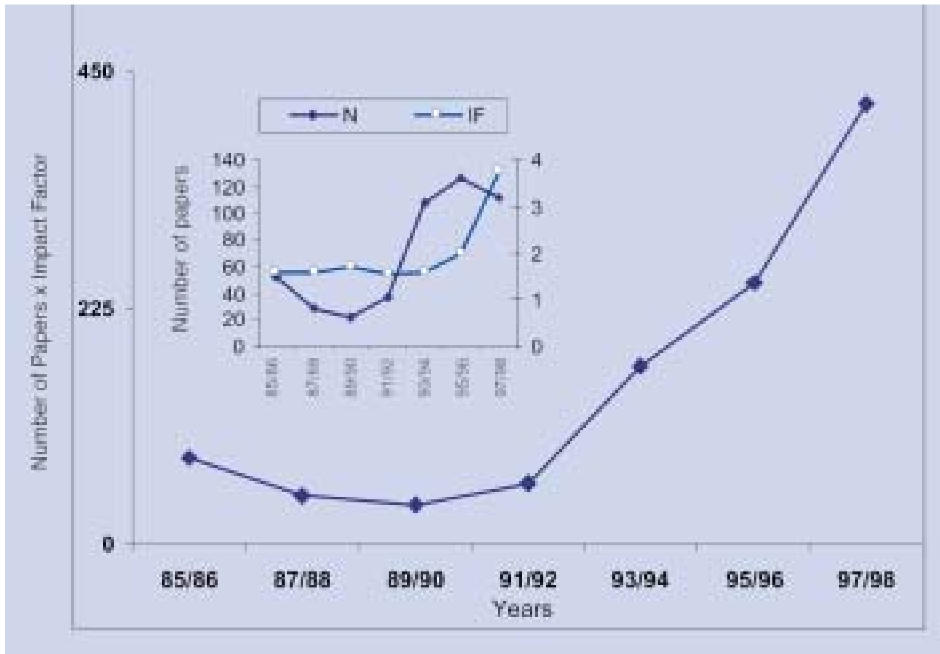
Space Relevance

Does the proposed project require space conditions? Does the experiment need long-duration space conditions (e.g. microgravity) to obtain unique scientific information not accessible by other means?

Scientific Merit

Significance: does this study address an important problem? If the aims of the application are achieved, how will scientific knowledge or technology be advanced? What will be the effect of these studies on the concepts, methods or products that drive this field?

Approach: are the theoretical framework, experimental design, data analysis and interpretation methods adequately developed, well integrated and appropriate to the aims of the project? Is the proposed approach likely to yield the desired results? Does the applicant acknowledge potential problem areas?



Increase in quantity and quality of publications in space-related European life sciences over the past few years. From a survey made in 1999.

Innovation: does the project employ novel concepts, approaches or methods? Are the aims original and innovative? Does the project challenge existing paradigms or develop new methodologies or technologies?

Personnel: are the scientific personnel appropriately trained and well suited to carry out this work? Is the evidence of the personnel's productivity satisfactory? Are the functions and responsibilities of the team members adequately described and appropriate? Does the project employ useful collaborative arrangements?

Environment: does the institutional environment in which the work will be performed contribute to the probability of success?

The detailed definition of the score scales for each criterion and sub-criterion is provided to all reviewers so as to assure a full coherence of the evaluation within and across the different panels. A summary definition of the range of the final scores is provided in Table 4.1.

An international panel of independent reviewers is set up for each discipline included in the IAO. The composition of each panel and the assignment of each proposal to five of the panel members for detailed evaluation are established with the advice of a panel chairman and approved by a Discipline Task Group where the participating agencies are represented. The reviewers are selected on the basis of their competence and independence

Table 4.1. Summary definition of the score ranges for microgravity relevance and scientific merit.

Criterion	Score	Descriptive Features
Microgravity relevance	81-100	The proposal gives quantitative requirements based on the ground based research and/or appropriate analysis and modelling.
	61-80	The proposal gives quantitative requirements based on ground-based research and/or analysis and modelling, but there are minor concerns.
	31-60	Alternative experimental approaches may provide equivalent but less complete, information. The proposal gives requirements based on ground-based research and/or analysis and modelling, but there are concerns.
	1-30	Microgravity is potentially useful, but alternative approaches have not been thoroughly examined.
	0	No benefit from use of microgravity is likely.
Scientific merit	86-100	Outstanding. The probable results are expected to advance science and/or technology significantly and have a broad impact beyond the immediate field of study. Presents a convincing case for the likely success of the experiment. The proposal is distinguished by highly novel or imaginative scientific content. The investigators are leaders in the field of the proposed research, and are well-positioned to lead further advances. The institutional environment is superior, and is completely adequate to support the investigation and its scientific goals. The proposed institutional arrangements bring noteworthy strengths to the investigation.
	66-85	Highly Recommended. The probable results of the research are expected to advance science and/or technology significantly. Likelihood of experimental success is high, but minor concerns or unfinished work remain. The proposed effort distinctly displays creative and valid concepts and methods. The investigators are clearly capable of accomplishing all the work described. The institutional environment is adequate to support the investigation and its scientific goals. The proposed institutional arrangements bring definite strengths to the investigation.
	47-65	Recommended. Potential results should advance knowledge in the field of study. The objectives, concepts or methods of the proposed research have identifiable original elements. The proposed effort is largely derivative of previous work. Likelihood of experimental success is reasonable, but clear gaps exist in the definition and description of the experiment. Investigators are adequate for most of proposed tasks, but inclusion of additional expertise would be desirable. The institutional environment is generally adequate to support the investigation and its goals, but some uncertainty or risk is evident. The proposed institutional arrangements do not pose major risks.
	5-46	Poor. Proposed work has vague or uncertain significance. The proposed approach presents a clear risk of not meeting important objectives. The originality of the proposed work is vague. The work, while not previously performed, is generally repetitive of prior research. Performance of the proposed research is questionable with the proposed personnel. Clear inadequacies in the institutional environment are displayed.
	0	No probable significance in proposed work. Proposed effort has clear and fatal flaws, with no likelihood of success. Proposed work is purely repetitive of existing research. Proposed personnel are clearly unqualified to undertake the described research tasks. The proposed research activities cannot be accomplished in the institutional environment.

Launch of a Maxus sounding rocket from Esrange in Sweden. Sounding rockets provide up to 14 min of microgravity for shorter and preparatory experiments.

with respect to the proposals to be evaluated, and with a view to achieving a balanced geographical representation in the panels. Following on the submission of the written reports of all peers, the panels meet to confront their views, reach consensus on their final score and synthesise their comments in a final report on each individual proposal. Proposals involving exclusively European scientists and hardware do not call for coordination with the other ISS Partners and have to be dealt with at European level only and from the perspective of already-recommended projects.

Proposals involving either non-European scientists or non-European hardware require coordination with the international partners and their implementation are subject to further discussions in the framework of the IMPSG or ISLSWG. The agencies jointly establish a coordinated recommendation of selection of proposals for definition phases based on a preliminary allocation of shared resources in order to optimise the science return and resource utilisation. This selection is submitted to the relevant Programme Boards for approval.

ESA has always realised that the operational resources on the ISS are limited and that, in particular, crew time and upload resources are very precious. ESA has therefore been extremely restrictive in the development of its Partner Utilisation Plan for the ISS. The application of an 8.3% entitlement to the total available crew time has since the beginning called for strict prioritisation of its research. This prioritisation is based on the result of the Peer Review Process and resulted in a Partner Utilisation Plan which contains only experiments that were rated as 'Outstanding', 'Highly Recommended' and 'Recommended' according to the marking shown in Table 4.1.

4.3 International Coordination of Research

After several years of discussion, the various space agencies involved in the Space Station Utilisation activities agreed to establish official Working Groups to coordinate on a global scale research in life and physical sciences on the ISS. Two such Working Groups are now in place: ISLSWG and IMSPG. They operate according to the following general principles:

— a coordinated international solicitation, review and selection process will be used to develop the life and physical sciences research programmes to be conducted by the Agencies on the ISS. The goal of this process is to ensure that the highest quality scientific research is performed aboard the ISS.
— the autonomy of each Agency in determining priorities for its science research programme is maintained.
— the utilisation hardware provided by each Agency to the ISS through its science research programme can be made available to the international research community. That is, researchers sponsored by the Agencies are able to propose use of hardware provided by any of the Agencies.
— providers of infrastructure and user accommodations to the ISS (NASA, CSA, ESA and NASDA) are allocated utilisation resources for their research programmes under the Intergovernmental Agreement and the Memoranda of Understanding Concerning Cooperation on the Civil International Space Station.
— each Agency sponsoring a flight experiment is financially responsible for the associated unique costs. General costs, such as payload engineering support, are provided by the Agency that provides the hardware for the flight experiment.
— each Agency sponsoring a prime investigator/team coordinator or a co-investigator/team member is financially responsible for the performance of his/her work.
— the financial burden of common activities required to implement the international scientific research solicitation, evaluation and realisation programme, such as the administration of the peer-review process and coordination of a baseline data collection capability in Russia for the life sciences research projects, is shared. Every effort is made to avoid or limit exchange of funds in the sharing of these responsibilities.
— over a period of ISS utilisation, each Agency may expect to receive a level of resources with which to perform research that is commensurate with the resources it contributes.

In this context, resources may include in-orbit facilities usage or ISS resources allocated to an Agency through the ISS strategic and tactical planning processes such as power, data transmission capability, up/down mass or crew time.

In addition to encouraging scientists to team up for the submission of joint proposals, optimal use of limited on-orbit resources is achieved by combining experiments that require common hardware and/or specimens into coordinated experiment teams. Such coordination experiment teams work together to achieve all individual objectives while maximising the use of constrained resources. These teams are manifested and implemented as a group.

It is through (1) the International AO process, (2) the rigorous and independent proposal evaluation and (3) the overall international coordination that the research on the ISS is maximised and prioritised in every respect. Not only is the highest level of research by high-standing investigator teams selected, but the development of high-quality hardware is also guaranteed without the danger of duplicating unnecessarily expensive hardware items. The solicitation process is asking for the elaboration of coherent and longer-term research projects. One-shot experiments, as flown on earlier short-duration space missions, are accepted only as exceptional cases and only if the scientific case is convincing. All proposed research projects for on-orbit implementation must be preceded by a well-founded ground preparation programme prior to selection for space implementation.

With the international coordination of ISS research taking place, there is now on a global scale both a maximisation and a prioritisation in the utilisation of the ISS by all Partners.

In line with the established Research Plan and based on highly rated individual experiments and research project proposals, ESA prepares its Partner Utilisation Plan for the ISS. The plan takes into account the current research facility configuration on the ISS and the operational resources available in the period under consideration. The Utilisation Plan for the first years after the launch and on-orbit commissioning of Columbus was developed on this basis. The required resources and the plan's critical dependence on crew availability are highlighted in the next chapter.

4.4 Prioritised Research Requirements in Life and Physical Sciences and Applications

ESA's Research Plan for Life and Physical Sciences and Applications for the ISS was developed on the basis of Research Projects that were prioritised according to the outcome of the Peer Reviews process. In response to AOs issued in 1995-2001, some 1000 responses were received. Out of these, some 250 proposals received the rating 'Outstanding', 'Highly Recommended' and 'Recommended'. 150 of these proposals are aiming at preparatory research, either ground-based or using short-duration precursor flight opportunities. Ninety-five were proposals for direct execution on the ISS. They were related to the disciplines given in Table 4.2. These 95 projects constitute ESA's Research Plan for life and physical sciences for the first years of routine ISS operation. Through the underlying peer-review process and the ensuing selection this plan is by definition prioritised.

4.5 Analysis of Utilisation Plan Implementation

The most precious resource from the beginning for this type of research aboard the ISS is crew time. The presence of an astronaut to conduct an experiment and/or to serve as subject for medical research has always been the main asset and, in fact, the basic rational for research in manned spaceflight. In view of the criticality and scarcity of this resource, the allocation of crew time to selected research projects has been carefully evaluated. Table 4.3 shows for the disciplines Life and Physical Sciences the crew time required to carry out the prioritised investigations listed in

ESA astronaut Frank De Winne working with the ESA-supplied Microgravity Science Glovebox aboard the ISS. (NASA)

Table 4.2. Number of ESA Selected and Prioritised Experiments for the ISS.

	Complex Plasmas and Dust Particle Physics	Cold Atoms and Quantum Fluids	Fluids and Multi-phase Systems	Combustion	Thermophysical Properties	New Materials and Processes	Plant Physiology	Cell and Developmental Biology	Biotechnology	Integrated Physiology	Bone and Muscle Physiology	Neurosciences	Origin, Evolution and Distribution of Life	Preparation of Human Planetary Exploration	Number of Experiments
Outstanding	5	1	2	–	1	–	–	1	–	–	3	–	–	1	14
Highly Recommended	4	–	5	1	1	10	8	4	4	5	7	3	4	4	60
Recommended	1	–	3	3	4	9	–	3	2	2	–	5	5	2	39
Number of Experiments	10	1	10	4	6	19	8	8	6	7	10	8	9	7	**113**

Physical Sciences		*Life Sciences*	
Outstanding	9	*Outstanding*	5
Highly Recommended	21	*Highly Recommended*	39
Recommended	20	*Recommended*	19
Total	50	*Total*	63

Table 4.3. Estimated Crew Time Requirements (in hours) to Perform ESA's Prioritised ISS experiments.

Facility used	FSL	MSL	EML	MRF–ACAPS	PCDF in EDR	ACES	Insert in Partner's Facility	Standalone Experiments	EPM or HRF	EMCS	Biolab	BMTC in EDR	MISS	Number of Crew Hours
Physical Sciences	114	178	75	135	68	10	70	–	–	–	–	–	–	650
Life Sciences	–	–	–	–	–	–	–	204	810	39	38	89	60	1243
Total Number of Crew Hours														**1893**

Table 4.2 on available facilities. The analysis shows that 650 crew hours are required to execute the established and prioritised utilisation in Physical Sciences, and a total of 1243 crew hours in Life Sciences.

5

Overall ESA Prioritised Utilisation Requirements

In addition to the substantial resource requirements of the ESA life and physical sciences, other activities also place requirements on scarce resources: space science, Earth observation, technology, commercialisation and education. Taken globally, the two main limited resources are crew time and up/download masses. In order to evaluate these, the following (already well-established) planning assumptions were taken into account:

— the ESA payload facilities EMCS and MSL (part of NASA MSRR-1 or, in case MSRR-1 is not forthcoming, as a standalone payload designated EMSL) will be launched on ULF-2 and accommodated in Destiny. The utilisation resources for ESA research projects will be drawn from NASA resources for 2 years;
— the launch of Biolab, FSL, EPM, EDR and ETC will take place with Columbus on flight 1E in 2004;
— the launch of SOLAR, EuTEF-1 will take place with Columbus on flight 1E in 2004;
— the launch of EML in 2007 as a cooperative payload with NASA;
— the launch of IMPF/ICAPS in 2008 to exchange with an earlier onboard ESA facility;
— ESA assumes a capability for –80°C up/down transport in the middeck lockers;
— the upmass estimated are ‘net’ mass (do not include 1.6 ‘rack-transport’ factor);
— the launch of EuTEF-2 (replacing EuTEF-1) will be in 2007;
— the upload of SOLAR (2004), EuTEF-1 (2004), ACES (2006), SPORT (2006) and EuTEF-2 (2007) will all be on NASA resources according to the Early Utilisation Agreement;
— the launch of EUSO (replacing ACES and RapidEye) will be at the end of 2008;
— ESA will, in accordance with the Early Utilisation MoU, occupy one NASA external payload site on Columbus from 2005 onwards and one from 2006 onwards. The total ESA entitlement is 9 site-years.

Based on these assumptions and on the operational requirements of the ESA research facilities and the operational requirements of the utilisation plans of the scientific community involved, the total ESA prioritised utilisation requirements have been derived as indicated in Table 5.1-5.4 for the years 2005 to 2008.

The following should be noted:

— these prioritised utilisation requirements were given as official ESA inputs to the multilateral User Operations Panel (UOP; the official body for the integration of the ISS Partners’ utilisation plans) in late 2002 and served as the basis for the Mutilateral Programme Planning Team exercise to define an ISS configuration for optimised utilisation capabilities;
— the level of medical research envisaged in 2005 is consistent with the amount of crew time possible with a 3-person crew. Other disciplines are, relatively speaking, less sensitive to lower crew time availability;

Table 5.1. Prioritised Utilisation Requirements for 2005.

Discipline	ESA ISPRS Transported	Middeck Locker (kg)	Pressurised Outfitting (kg)	Pressurised Resupply (kg)	Unpressurised Outfitting (kg)	ESA Attached Facility Transported	Crew Time (Hours/Year)
Life Sciences				345 + [130][1]	–		50* + [20][1]
Physical Sciences	[MSL]			460 + [170][2]	–		40 + [59][2]
Technology				–	–		–
Space Science		6 total @ 35kg		–	–		–
Commercial				100	–		10
Education				10	200	Student Experiment	5
Total	–	210	–	915 + [300][1,2]	200		105 + [79][1,2]

* assumes minimum operations for medical experiments
[...][1] EMCS bartered with NASA, not counted in ESA resources allocation.
[...][2] (E)MSL bartered with NASA, not counted in ESA resources allocation.

Table 5.2. Prioritised Utilisation Requirements for 2006.

Discipline	ESA ISPRS Transported	Middeck Locker (kg)	Pressurised Outfitting (kg)	Pressurised Resupply (kg)	Unpressurised Outfitting (kg)	ESA Attached Facility Transported	Crew Time (Hours/Year)
Life Sciences				360 + [130][1]	–	–	380 + [20][1]
Physical Sciences				435 + [170][2]	[350][3]	[ACES]	130 + [59][2]
Technology	None in 2006				–	Exchange [SOLAR] by [SPORT]	
Space Science		7 total @ 35kg			[350][3]		
Commercial				150	350	RapidEye	105
Education				10	–	–	5
Total	–	245	–	955 + [300][1,2]	350 + [700][3]		620 + [79][1,2]

[...][1,2] bartered with NASA, not counted in ESA resources allocation.
[...][3] ACES and SPORT launch bartered with NASA, not counted in ESA resources allocation.

— the amount of crew time indicated in Table 5.2 for 2006 is consistent with what is considered possible with a crew of 6. In the event that the overall crew complement for 2006 also turns out to be a 3 person crew, then the crew time figures would be similar to those in Table 5.1 for 2005;

— the final availability of crew time for ESA in this early period depends on on-going (February 2003) discussions with NASA and the results of a crew efficiency optimisation exercise;

— the barter arrangements with NASA for EMCS, EML, ACES and SPORT are assumed to cover bartered crew time and up/download.

Table 5.3. Prioritised Utilisation Requirements for 2007.

Discipline	ESA ISPRS Transported	Middeck Locker (kg)	Pressurised Outfitting (kg)	Pressurised Resupply (kg)	Unpressurised Outfitting (kg)	ESA Attached Facility Transported	Crew Time (Hours/Year)
Life Sciences		↑		400			370
Physical Sciences	[EML]		[600]	742			170
Technology				–	[350]	[Exchange EuTEF1 by EuTEF2]	
Space Science		7 total @ 35kg		–			
Commercial				200			125
Education		↓		15			5
Total		245	[600]	1357	[350]		670

[...] bartered with NASA, not counted in ESA resources allocation

Table 5.4. Prioritised Utilisation Requirements for 2008.

Discipline	ESA ISPRS Transported	Middeck Locker (kg)	Pressurised Outfitting (kg)	Pressurised Resupply (kg)	Unpressurised Outfitting (kg)	ESA Attached Facility Transported	Crew Time (Hours/Year)
Life Sciences		↑		425			380
Physical Sciences	Exchange TBD by IMPF/ICAPS		500	327			160
Technology						Exchange ACES and RapidEye by EUSO	
Space Science		7 total @ 35kg			1500		
Commercial				250			145
Education		↓		15			5
Total		245	500	1017	1500		690

6

Conclusions

ESA has selected and prioritised its utilisation projects for the baseline of a 7-person crew on the ISS and has committed the corresponding budgets for facility developments and preparatory activities. European investigator teams are conducting preparatory ground-based and short-duration space experiments awaiting the opportunity to start their long-duration research on ISS. Hardware for the 113 selected research projects in life and physical sciences to be executed on ISS is under development.

Hardware development and studies are also under way for projects in solar physics, astronomy and technology. Activities are well-defined for the promotion of commercial utilisation of the ISS and for educational activities related to Space Station and to space in general.

This document presents a detailed and comprehensive Utilisation Plan developed by ESA for the optimised use of its investments in the ISS and targeted at the clear perspective of a launch of its Columbus laboratory in October 2004. The resources available at the ISS allow the conduct of a full utilisation programme to meet the needs of the user communities. The scarce availability of crew time in the early period limits the extent of research in human physiology. Nevertheless, an acceptable level of research activities in this discipline can still be carried out in this period. The present estimates of resource availability are considered to be relatively conservative and the ISS Partners are actively engaged in seeking increases in crew efficiencies leading to the optimised use of resources.

In conclusion, and taking into account the Utilisation Plan presented here, the now firmly-established launch of ESA's Columbus Laboratory in October 2004 is fully justified.


ESA/D. Ducros