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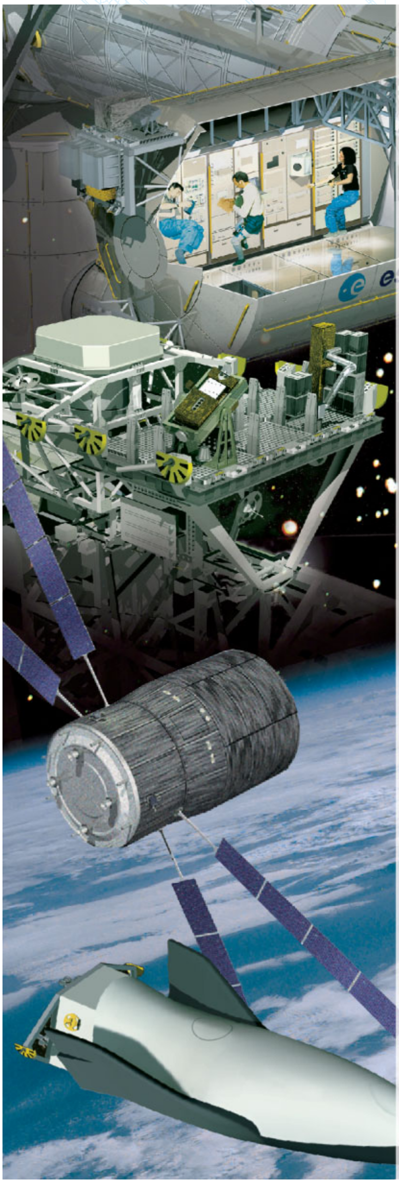
on station

The Newsletter of the Directorate of Manned Spaceflight and Microgravity

http://www.esa.int/spaceflight



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The ISS Must Have a Full Crew

Jörg Feustel-Büechl
ESA Director of Manned Spaceflight and Microgravity

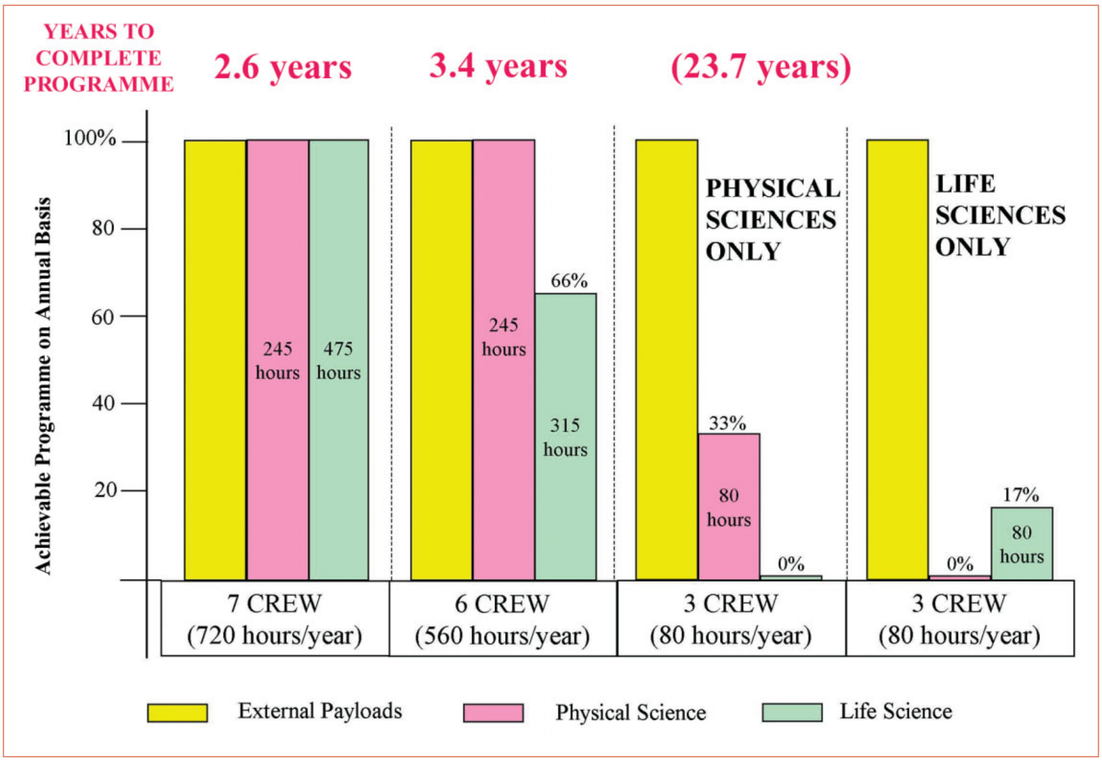
A significant event for the International Space Station programme took place on 3 June in Paris with a meeting of the Heads of Agencies, hosted by ESA. A key goal was to assess how we should consolidate our situation to date. Before going into details, I am pleased to say that everyone expressed their highest satisfaction with the technical progress of the ISS programme. So far, we have had 28 launches to the Station, of which 17 were assembly flights. This means that we have completed almost a third of the Station construction. Apart from some small hiccups that are to be expected during such a complex assembly, we can say that the Station is highly successful from an engineering point of view.

The meeting was not particularly easy but it did end with a good result – a Programme Action Plan. This now means that all five ISS Partner Agencies have documented a clear plan of actions to be accomplished before the next Heads of Agencies meeting around November/December 2002, when the potential End-State options will be discussed. The US left the meeting with three issues to address: completion of their Research Maximization and Prioritisation (REMAP) work; determination of the number of Shuttle flights to the Station each year (four or five); and, potentially the most important, conclusion of their ISS cost-to-completion reviews.

Since the Paris meeting, REMAP has been completed and it confirms what we had expected: a crew of three is too small for effective use of the Station. For the latter two issues, we are awaiting their results. The costing review should be received in September, and we will then have a clearer view on further progress. Meanwhile, the Partners are continuing their discussions on the technical and programmatic aspects of the End-State options. These include: a dedicated crew rescue vehicle, a second Soyuz return vehicle, and a crew safe haven concept. A number of sub-options containing a mix of these three major options are also being assessed.

ESA and Rosaviakosmos have worked hard together to

The ISS crewtime required to execute ESA's prioritised Utilisation Plan for the initial set of experiments. A crew of three provides only 80 man-hours per year for ESA experiments.



reach a formal agreement with NASA, but the US agency was not sure that any major decisions could be made in time for the November/December meeting because of internal clarifications being required. It was therefore agreed that the End-State options would be reviewed during the November/December meeting to agree on a process to select the End-State configuration, with a view to taking the final decision early next year. All in all, the Paris meeting was considered to be constructive and positive.

As a next step, we will have another important meeting, of the Multilateral Control Board, in September, when we will take stock of the situation for the Heads of Agencies meeting.

The Microgravity Science Glovebox was transferred into the ISS on 9 June. (NASA)

On 23 July, a consultation of all 15 signatories to the ISS Intergovernmental Agreement (IGA) took place at the US State Department in Washington DC. Representatives of all the 11 European States plus the US, Japan, Rosaviakosmos and the Canadian Space Agency were briefed on the current technical and programmatic issues. Europe, through Mr Heribert Diehl, Chairman of the IGA Coordination Committee, supported by ESA, expressed concern with the overall situation and reiterated its expectation that all Partners meet their IGA obligations – the full deployment of the Station as defined in the IGA with a crew of seven and a full utilisation potential. Our insistence on the full crew is triggered by the need for adequate astronaut flight opportunities and, more significantly, to ensure maximum Station utilisation. ESA has analysed how that can be achieved for the experiments already selected. Of the 250 experiments chosen by the science peer groups, some 100 are foreseen for the Station and about 150 on sounding rockets, parabolic flights or other means. In order to complete these selected Station experiments, some of which are relatively large, we need 2.6 years with a crew of seven, 3.4 years with a crew of six, and almost 24 years with a crew of three. It must be remembered that this is only the first selection process of many, so there are many more experiments to come. A crew of three is clearly unacceptable for our user community and ESA, and therefore we insist that we maintain the original baseline agreements.

All in all, we are still very concerned about the situation although the project is working so well technically. We have completed many of the Station elements and continue to insist that the Station is not only a wonderful piece of engineering but that it can also provide a maximum utilisation return on our investment.

We are still looking to install our Columbus core element on the Station in October 2004 and continue to plan on that basis. Columbus integration is progressing well at Astrium in Bremen (D) and the module will be ready for the addition of the research facilities next spring at the latest.

For the Automated Transfer Vehicle (ATV), testing has been successfully completed and the industrial activities are proceeding as planned. We are quite satisfied with ATV's progress after the Preliminary Design Review in late 2000.

Our various user facilities are nearing completion. The first element, the Microgravity Science Glovebox (MSG), is aboard the Station's Destiny science module and operational. The Minus Eighty-degree Laboratory Freezer for the ISS (MELFI) has been delivered to NASA and should fly early next year. Europe can be proud that it is meeting its commitments.

Following the successful Soyuz taxi flight of Roberto Vittori in April, we are now looking forward to the mission of Frank De Winne in October. Sponsored by the Belgian government, this 'Odissea' mission has a very demanding scientific programme (see the article on pp4-5 of this issue), the management of which is entrusted to ESA. Frank will be the first experimenter to use the MSG.

The new Astronaut Policy was approved at the June meeting of the ESA Council. It is an important step because it recognises the changes in this area since the different national astronauts corps were consolidated into the Single European Corps in 1999. We now have 16 astronauts and the policy provides guidance on crew selection, mission assignment, commercial activities and other aspects. The most important factor is that it provides dynamic management tools to support corps management in a more optimal manner with particular respect to astronaut careers. 'Non-flight' status enables an astronaut, after a flight, to work on a dedicated engineering or scientific project. An astronaut can then return to 'Flight' status as a further flight opportunity arises. This fills the gap between the flights in a concrete and positive way and increases the astronaut's valuable expertise.

The Programme Board and Council also discussed nationally sponsored flights, and we now have a clear understanding of the conditions for performing these flights.

Last but not least, we are planning a fourth ISS Industry Day at ESTEC on 27 September, when European industry will be cordially invited to discuss the current projects and their progress. ■

ISS launches planned for the next 12 months.

Flight #	Launch	Element/Task	Vehicle/Mission
30: 9P	10 Sep 02	Logistics (Progress-M1)	Soyuz
31: 9A	26 Sep 02	S1 Truss	Shuttle STS-112
32: 5S	22 Oct 02	Taxi Flight (**Frank De Winne**)	Soyuz-TMA 1
33: 11A	02 Nov 02	Expedition-6 Crew/P1 Truss	Shuttle STS-113
34: ULF-1	16 Jan 03	Expedition-7 Crew/**MPLM**	Shuttle STS-114
35: 10P	30 Jan 03	Logistics (Progress-M)	Soyuz
36: 11P	28 Mar 03	Logistics (Progress-M1)	Soyuz
37: 12A	10 Apr 03	P3/P4 Truss	Shuttle STS-115
38: 6S	28 Apr 02	Taxi Flight	Soyuz-TMA 2
39: 12A.1	05 Jun 03	Expedition-8 Crew/P5 Truss/ (**Christer Fuglesang**; 3 EVAs)	Shuttle STS-116
40: 12P	05 Jul 03	Logistics (Progress-M)	Soyuz
41: 13A	21 Aug 03	S3/S4 Truss	Shuttle STS-117
42: 13A.1	25 Sep 03	S5 Truss	Shuttle STS-118

ESA-related flights and deliveries for the next 12 months.

September: 33rd Parabolic Flight Campaign

October: Foton-M1 with ESA payloads FluidPac, Stone, Biopan, SCCO, Photo II, Aquacells, Biofilter, TeleSupport, 3 student/outreach experiments, material science experiments in the Russian Polizon (2x) and German Agat (2x) furnaces, biological experiments (2x) in the French IBIS facility

October/November: Soyuz taxi flight with ESA Astronaut Frank De Winne

January? 2003: STS-107 with ESA payloads APCF, ARMS, Biobox, Biopack, ERISTO, FAST, Com2Plex

January? 2003: MELFI; Pulmonary Function System, part of HRF-2 for Destiny, on Shuttle STS-114/ULF-1; MPLM Raffaello

February 2003: Node-2 delivery to Kennedy Space Center

March 2003: Maxus-5 sounding rocket

March 2003: Cupola delivery to Kennedy Space Center

March-April 2003: 34th Parabolic Flight Campaign

April 2003: Columbus completed and placed in storage

April 2003: ERA completed and placed in storage

June 2003: Shuttle STS-116/12A.1 with ESA Astronaut Christer Fuglesang

June 2003: European Modular Cultivation System (EMCS) delivery to Marshall Space Flight Center

October 2003: 35th Parabolic Flight Campaign

'Odissea' to the ISS

The Belgian/ESA Taxi Mission

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Introduction

The contract for Frank De Winne's Soyuz taxi mission to the International Space Station was signed on 18 April. Frank is the Flight Engineer for the Soyuz-TMA1 10-day mission in October, funded by the Belgian Federal Office for Scientific, Technical and Cultural Affairs (OSTC). The main goal is to exchange the Station's Soyuz vehicle, which serves as the main emergency return craft. This first improved Soyuz-TMA model will be swapped for Soyuz-TM34, delivered in April by a crew that included ESA's Roberto Vittori. The flight is part of a framework agreement for European astronauts to fly to the ISS on Russian vehicles during 2001-2006, signed between ESA and Rosaviakosmos in May 2001. Frank's programme of experiments is being managed on behalf of OSTC by ESA.

Survival training in Russia.

When Frank arrives at the ISS he will find quite a bit of research equipment waiting for him. He can then very quickly begin the packed and ambitious experimental programme of his 8-day stay. Most of the hardware will be delivered by an unmanned Progress freighter on 10 September and more will fly with him aboard Soyuz.

Frank will be the first visitor to work both in the Russian and American segments. He will be based in the Russian segment as a Flight Engineer, and there he will conduct the life science activities and two of the physical science experiments. Four other physical science experiments will use the ESA-developed Microgravity Science Glovebox (MSG), delivered in June to NASA's Destiny module. An agreement between OSTC and CNES allows some experiments to reuse equipment left onboard by Claudie Haigneré's Andromède mission. Odissea's international character is highlighted by the 24 experiments from five European countries, two from the USA and Russian involvement in three.

> *ESA Astronaut Frank De Winne will perform a wide range of experiments aboard the ISS ...*

The Biology Experiments

VITAMIN D Microgravity seems to modify the genes controlling osteoblasts, our bone-building cells, so that astronauts lose bone strength. The experiment investigates the effect of vitamin D on the osteoblasts. ***RHO SIGNALING*** studies the chemical signals used by cells. Laboratory-created human cells are being used to improve our understanding of cellular and molecular mechanisms, and how they are affected by microgravity.

RAMIROS studies the oxidation of cells by the Sun's ultraviolet radiation, and the affect on their behaviour. This effect has similar characteristics to cell stress in senility diseases, like Alzheimer's and Parkinson's. ***MESSAGE*** studies gene mutations caused by microgravity. Microbes are incubated at room temperature and every day a sample is removed and frozen (–20°C) for later analysis.

Cardioscience and Cogniscience

CARDIOCOG studies the effects of microgravity on our cardiovascular and respiratory systems, as well as the stress, cognition and physiological response during spaceflight. After even only short flights, the body has adapted

Frank working with the MSG training model at ESTEC.

to weightlessness, no longer having to pump blood 'uphill' against gravity. Once back on Earth, it leaves the brain short of blood until the body re-adapts. ***RYTHME*** focuses on the cardiovascular system and on its re-adaptation to gravity; ***RESPI*** similarly for respiratory system. Past studies show that an astronaut's changing heart rhythm provides information on autonomic nervous activity (the brain's automatic control of our bodies). ***STRESS*** and ***TEXT*** focus on the stress and the cognitive/ physiological aspects of a spaceflight. The stress level is measured via the 'Stroop effect': the time it takes to react to different stimuli, and how the memory is affected.

NEUROCOG studies the possibility that weightlessness affects how the brain works. This change is measured by recording two types of electrical signals from the brain.

Human Physiology

SYMPHATO tests the belief that our adrenal glands reduce their activity during the first 24 hours in space, but this is then matched by a pronounced drop in blood volume. ***VIRUS*** studies if the physical and physiological stresses of spaceflight can reactivate latent viruses and diseases. ***SLEEP*** studies how spaceflight disrupts astronaut's sleep and body cycles. Little is known of the problem on shorter flights. Frank's pattern of sleep/wake and exposure to light will be continuously monitored by a watch-like device – the Actilight Watch. ***XENON-1*** measures before and after flight how well the body controls blood flow when standing (the 'peripheral veno-arteriolar reflex'). ***AORTA*** studies 'orthostatic intolerance', when someone cannot stand for 10 min after a spaceflight because the cardiovascular system has adapted to weightlessness. Frank will be tested before his flight and then immediately after to gauge his system's intolerance. ***CHROMOSOMES*** draws blood samples before and after flight to see the chromosome damage caused by ionising radiation.

Material Science

The ***Granada Crystallisation Facility & PROMISS*** run complementary experiments on protein crystallisation in parallel in two different facilities. The protein solutions are injected into capillaries and crystallisation occurs as a precipitating solution diffuses along them. The GCF crystals will be analysed only once back on Earth, but PROMISS will be conducted in the MSG, where a digital holographic microscope can record the process.

NANOSLAB & ZEOGRID study the formation of zeolite minerals in microgravity. The NANOSLAB process is controlled in MSG. ***COSMIC*** uses MSG to study the creation of advanced materials, such as ceramics and metal-matrix composites, via combustion.

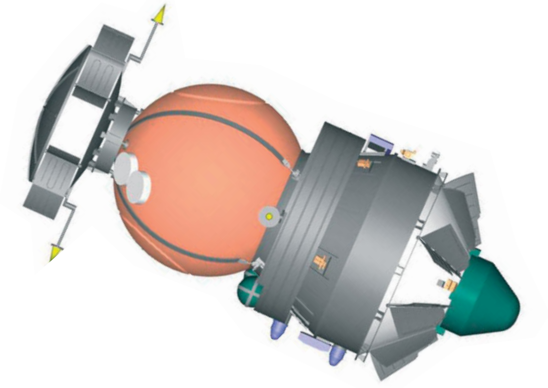
Fluid Science

DCCO measures the Diffusion Coefficients in Crude Oils. The oil industry needs the information to predict the potential of new reservoirs. Gravity on Earth masks this effect. A similar experiment will fly on the unmanned Foton-M1 mission at the same time (see the Foton article in this issue).

Other Experiments

LSO studies visible effects in the ionosphere connected with thunderstorms and earthquakes. ***VIDEO*** Video recording of simple educational demonstrations, like water globules, in weightlessness. ***ARISS*** Real-time radio contact with Belgian schools, offering the unique opportunity to question Frank in space (see pp.14-15). ■

Forty-four for Foton



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Introduction

The flight of ESA experiments on the Russian Foton-12 mission in September 1999 was a milestone success, but an even larger payload will soon be carried by Foton-M1. ESA is supporting 44 experiments from Austria, Belgium, Bulgaria, Canada, China, France, Germany, Italy, The Netherlands, Russia, Spain, Switzerland and UK that are now being integrated by the Russian prime contractor, TsSKB-Progress, in the spacecraft in Samara. Launch is targeted for 15 October from Plesetsk Cosmodrome for a 15-day mission.

The largest ESA payload yet is poised to fly on the next Foton mission ...

The Payload

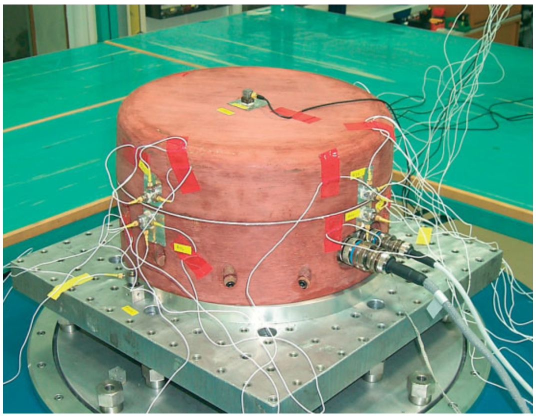
'How are we going to fit 44 experiments in a 2 m-diameter capsule?' '*Nyet prablema!*' replied the Russian engineers at TsSKB when an ESA team posed the problem during the first Foton-M1 technical meeting in July 2001. The mission contract had already been signed on 11 April 2001 at ESA Headquarters in Paris for a payload put together in conjunction with the French and German space agencies, but the total had continued to grow.

There followed a frantic design phase that gradually led to the current payload configuration. It is densely packed but niches were found for all the passengers. ESA's record contribution of 390 kg includes the Fluid Physics Facility (FluidPac, with four experiments), Biopan hosting a record nine experiments, the upgraded Telescience Support Unit (TeleSupport, which will assist both FluidPac and the German AGAT furnace), six Autonomous Experiments (three developed by university students as part of ESA's Outreach education programme), the latest Stone simulated meteorites, and the 'Soret Coefficient in Crude Oil' (SCCO) experiment, diverted from a Shuttle GetAway Special flight just last January.

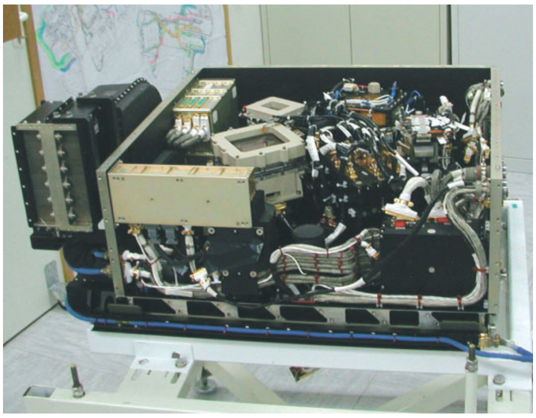
The 650 kg payload total is completed by France's IBIS biological incubator, DLR's AGAT, Russia's Polizon furnace (50% shared by ESA and DLR experiments) and four Russian experiments (Comparus, Mirage, Synus-16 and Chastata.

ESA payloads

FluidPac/ TeleSupport	208
Biopan	27
IBIS	76
AGAT	37
Outreach	7
SCCO	20
Photo II	4
Aquacells	6
Biofilter	4
Stone	1
Total mass (kg)	390



Right: the refurbished Biopan, with its brand new heatshield, is fitted to the shaker jig for the final vibration tests. Engineers had to modify its load-carrying structure to accommodate all the nine experiments.



Far right: the new FluidPac Experiment Box, carrying four fluid physics experiments, ready for flight.

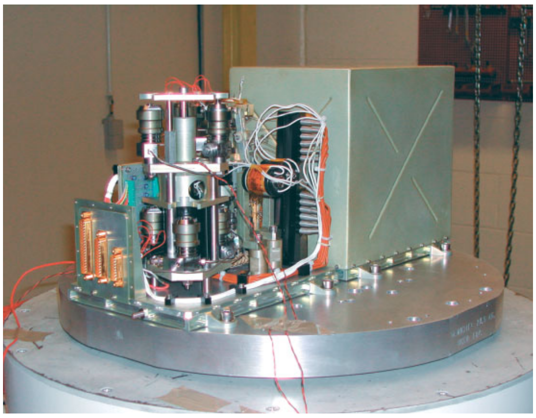
Uprated Spacecraft

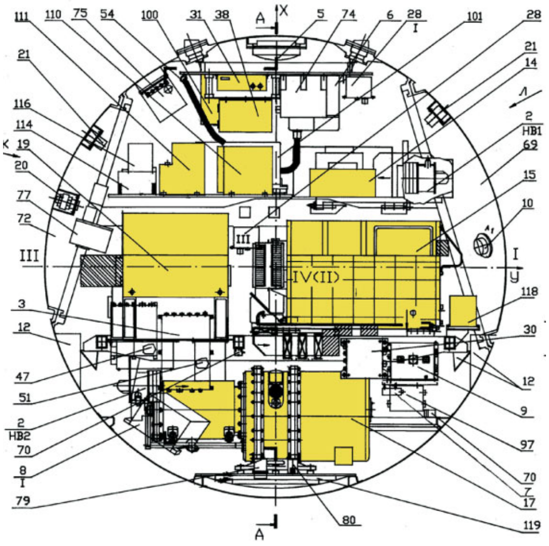
Foton-M1 is the tenth such mission that ESA has been involved in since 1987, but this is the first flight of an improved version of the venerable spacecraft. Increased battery capacity, boosted by lithium cells and coupled with enhanced thermal control, supplies the experiments with 500 W of average power throughout the orbital flight. The new telemetry and telecommand unit will increase the data flow. The Soyuz rocket will fly with a more powerful third stage motor, providing the mission with a higher perigee. The resulting near-circular orbit, in combination with a more even mass distribution within Foton, will further improve the already excellent microgravity quality to a few 10^{-6} *g*.

The experiments cover a remarkably wide range of scientific disciplines, including fluid physics, biology, crystal growth, meteoritics, radiation dosimetry and exobiology. Applied research is prominent: heat transfer experiments in FluidPac, chemical diffusion experiments in SCCO, and material science investigations in AGAT and Polizon will likely contribute, respectively, to new heat-exchanger designs, to more efficient oil extraction processes, and to better semiconductor alloys.

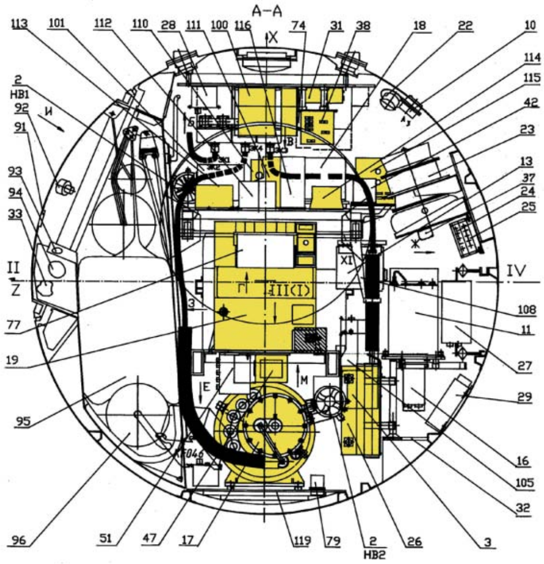
As on previous missions, biological research receives a great deal of attention, this time emphasising fundamental questions about the origin and spreading of life forms in space. IBIS and Biopan – both making their fourth Foton scientific flights – are hosting most of these ground-breaking experiments.

Although allocated less than 8 kg, the three Outreach experiments (protein crystal growth; bacterial growth; cartilage growth) are a first on Foton missions. They add an educational element to this ESA programme and produced an enthusiastic response from students eager to participate.





The Foton-M1 payload configuration. FluidPac's Experiment Box (15) and Electronic Box Assembly (14) occupy most of one hemisphere, while IBIS (19), TeleSupport (31, 38), and SCCO (100, 110, 111) occupy the other. Polizon (17) sits in the bottom of the capsule. An Autonomous Experiment (118) is also visible.



The payload viewed from the left side of the other drawing. AGAT (3, 47), two Autonomous Experiments (113, 114) and the SCCO electronics (115) are now evident. The dark ducts in the middle are the vacuum venting lines for the AGAT and Polizon processing chambers.

The strong cooperation between ESA and the national space agencies (Canada, France, Germany, Italy and The Netherlands), in conjuction with our long experience using Foton, allowed us to prepare this mission's payload in record time.

Now all the space hardware is lining up at TsSKB for the final system tests and the journey to Plesetsk. The tight schedule leaves no room for mistakes, but we are confident of making the launch date. Some of the experiments, with sensitive materials or living biological specimens, will be prepared later and sent directly to the Cosmodrome in northern Russia just five days before lift-off, when the ESA and Russian teams will together install them aboard Foton-M1. Only then will the '44 for Foton' be ready to go. Just wish us good luck! ■

Twin SCCO experiment boxes will fly on Foton-M1. Here, they are being qualified on a shaker for launch. The cover of one is removed to show the delicate hardware.

Minutes of Microgravity

ESA's Sounding Rocket Programme

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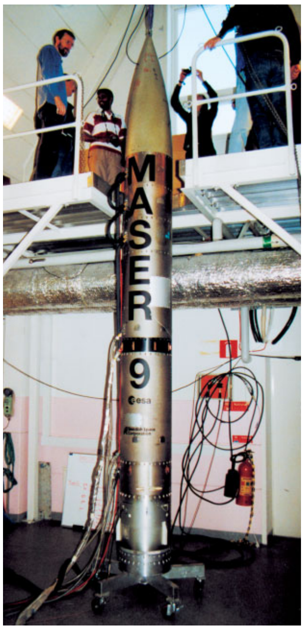


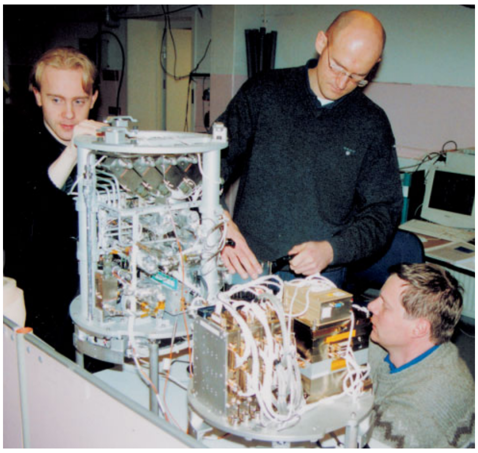
Top of page: the Maser-9 scientific payload.

> *ESA's sounding rocket programme continues to produce important results ...*

Maser 9

On 16 March 2002, ESA's Maser-9 suborbital microgravity research mission was launched from Esrange near Kiruna in northern Sweden. The flight and payload recovery went as planned, following a microgravity time of 6 min 15 s with a flawless telemetry and video downlink. The 237 kg research payload, all funded by ESA, carried seven experiments in three modules:

- Convective Boiling and Condensation of Ammonia in Microgravity; J. Delhaye (CEA Grenoble, F), Cyrene-2 module;
- Interfacial Turbulence in Evaporating Liquids; P. Colinet (MRC at ULB Brussels, B), ITEL module;
- Signal Transduction and Genetic Expression in Lymphocytes in Micrograviy; M. Cogoli (Space Biology Group, ETH Zurich, CH), CIS-6 module;
- Responses to Microgravity Exposure and In-flight Environment of in-vitro Cultures of Differentiated Functional Epithelial Follicular Cells from Thyroid; S. Ambesi (Univ. of Udine, I); CIS-6 module;
- Three Bioreactors for Medically Relevant Organ-like Structures: a) Chondrocytes; A. Cogoli (Space Biology Group, ETH Zurich, CH); b) Blood Vessel Tissue; A. Bader (Medical School Hanover, D); c) Thyroid Cells; S. Ambesi (Univ. of Udine, I), all in the CIS-6 module.



Preparing the Cyrene-2 module at Esrange.

Convective Boiling and Condensation

The Cyrene-2 module served an experiment to measure the heat transfer coefficient in a two-phase gas-liquid flow, of interest for developing more efficient thermal control for satellites. The module was developed by the Swedish Space Corporation (SSC), and its fluid circuitry provided by CNES. A series of five heat exchangers moved the heat between two fluid loops of anhydrous ammonia and water, using ice as the phase-change material. Rated as very successful.

Interfacial Turbulence in Evaporating Liquids

Evaporation is still not well understood so this experiment analysed the behaviour of an evaporating liquid (ethanol) in an open vessel with a laminar gas flow parallel to the liquid surface. The thermal field within the liquid resulting from evaporation and Marangoni flows was measured by an optical tomography system with six viewing directions parallel to the liquid surface (i.e. six Mach-Zehnder interferometers). This technique was developed by Lambda-X (B) and flown in space for the first time, working perfectly.

The ITEL module, developed by SSC and Lambda-X, was affected by a still-unexplained error in the automatic pressure control of the experiment chamber. The cell's high pressure prevented strong evaporation of the ethanol, but some results were still obtained.

Lymphocytes

Suspended human T-lymphocytes were activated by concanavalin A and their immediate gene expression was investigated. This aims at explaining why the blood of most astronauts shows depressed mitogenic activation of lymphocytes, found in 1985 by

The lymphocyte experiment is delivered. In the foreground are the two experiment drum assemblies of the CIS-6 module – one for installation on an inflight 1 g centrifuge and the other for exposure to microgravity. At rear is the ground reference version.

the same investigators. The technical challenge lay in exchanging the liquids in the reaction chamber while maintaining the lymphocyte suspension. Unfortunately, valve failures in 20 of the 48 experiment units reduced the scientific results.

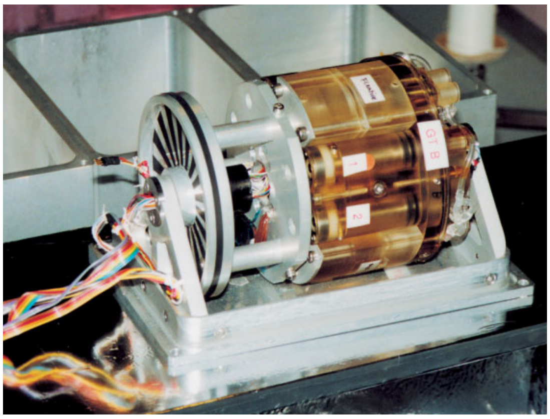
Thyroid Cells

The thyroid's epithelial follicular cells, which produce the thyroid hormone, control and stimulate virtually every organ and function of the human body. The experiment investigated the impact of microgravity on the cells' cytoskeleton, on signal transduction after application of the Thyroid Stimulating Hormone as a biochemical stimulus, and on the gene expression. Unfortunately, an electrical failure meant that no results were obtained.

Modular Space Bioreactors

In preparation for the International Space Station modular space bioreactor, three different types of bioreactor were developed by Dutch Space (NL) for flight on Maser-9 with three different species of tissue:

The thyroid cell bioreactor. The black drive belt at left rotated the unit before liftoff to prevent sedimentation.



Chondrocytes: this bioreactor used Sulzer's patented 'De Novo' insert to study the effect of microgravity on the cytoskeleton and the genetic expression of vimentin and tensin in cartilage cells. Rated as 100% successful.

Thyroid Cells: a different design to accommodate suspended thyroid cell clusters, allowing their activation with a hormone and their fixation in microgravity. To avoid sedimentation of the clusters before flight, the bioreactor assemblies were continuously rotated up to launch.

Blood Vessel Tissue: this bioreactor held 3-D cell tissues of human cells growing on pig blood vessels to study the impact of microgravity on the cytoskeleton.

The scientific success of the last two bioreactors was hampered by their failure to fix the products before the end of microgravity.

Digital Video System

Maser-9 also verified the digital video system developed by Techno System (I) for sounding rockets and the ISS. Derived from a system flown on Foton-12, it performed well and proved itself for future missions.

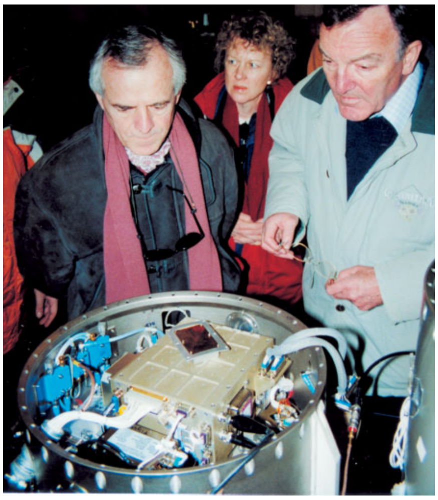
Future Sounding Rocket Missions

ESA's Programme Board for Microgravity has approved the experiments for two 12-min missions (Maxus-5 & -6) and one 6-min mission (Maser-10). Maxus-5 is planned for 31 March 2003: Drop Dissolution and Marangoni Migration (R. Monti, I); Crystallisation Kinetics of Silicalite-1 (J. Martens, B); Vibrational Phenomena in Inhomogeneous Media (P. Evesque, F); Gravisensitivity and Graviperception Mechanism of Characean Rhizoids and Protonema (M. Braun, D); Biological Gravity Dependance by way of Microtubule Reaction-Diffusion Processes (J. Tabony, F).

Maxus-6 is planned for April 2004: Physics of Foams (M. Adler, F); Control of Surface-tension Driven Convection in Floating Zone Growth (A. Cröll, D); Unconstrained Eutectic Solidification of Ternary Alloys (L. Froyen, B); Dynamics of Suspended Particles in Periodic Vortex Flows (H. Kuhlmann, D); Signal Transduction during Graviresponse (H. Schnabl, D).

Maser-10 is planned for November 2004: Interaction in Cosmic and Atmospheric Particle Systems (J. Blum, D); Thermal Radiation Forces in Non-stationary Conditions (F.S. Gaeta, I); Chemohydrodynamic Pattern Formation at Interfaces (S. Müller, D); Influence of Microgravity on the Activation of NF-kappaB (M. Peppelenbosch, NL); Role of Micrgravity in Mammalian Cells (J. Boonstra, NL).

Members of the Manned Space Programme Board inspect the Maser service module at Esrange.



How to Fly an Experiment

ESA announces research opportunities requesting scientific proposals at *http://www.spaceflight.esa.int/users/index.cfm*. All proposals received by the deadline are evaluated scientifically by external peers and technically by in-house experts. The most highly rated are submitted for approval by the Human Spaceflight, Research and Applications Programme Board. ■

Come-In!

Providing Commercial Equipment on the ISS

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Europe's first commercial equipment is already aboard the ISS ready for hire ...

Introduction

In order to exploit Europe's significant contributions to the development and operations of the International Space Station (ISS), ESA's Council has directed the Agency to promote the Station's use for commercial activities. As an important step towards reaching commercial users, ESA in March 2002 signed a Cooperation Agreement with 11 European space companies already involved in the ISS programme (Alenia, I; ALTEC, I; Astrium, D; Bradford, NL; Contraves Space, CH; Fokker Space, NL; Intospace, D; Kayser-Threde, D; Kesberg Buetfering & Partners, D; Laben, I; OHB, D). This alliance is laying the foundations during 2002-2006 before full commercial activities can begin. ESA and these companies are coordinating their efforts, resources and expertise to promote commercial activities by:

- maximising the use of ESA's ISS resources allocated to commercialisation. Areas of interest include applied research and development projects in life and physical sciences, technology, Station-based services (e.g. communications and Earth observation) and unconventional activities such as sponsorship;
- stimulating a market for providing industrial ISS services to ISS customers.

The Agreement is not exclusive and allows other partners who can offer value-added services to commercial users to join.

One partner to the Agreement is Intospace, who in June 2001 was already active in commercially promoting the ISS by signing with ESA a 'Frame Option Agreement for Purchase of ESA Resources and Services on the ISS'. Under this agreement, Intospace has developed the Commercial Instruments (Come-In) concept 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 Come-In Commercial Objectives

The Come-In 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 private users;
- marketing and promoting the instrument on Earth.

Roberto Vittori learning to use the Blood-pressure Measurement Instrument (BMI), now available for commercial lease on the ISS.

A pool of three instruments has been identified so far by Intospace as part of this concept. In addition to the blood-pressure monitor described in more detail below,

Roberto Vittori demonstrated BMI during his ISS mission.

the company is considering an Atomic Force Microscope for very high-resolution imaging of, for example, protein crystals and new materials. The third instrument is the 'biochip': an advanced Integrated System for Molecular Bioanalysis. It analyses and monitors fundamental biological processes by measuring the relative expression levels of thousands of individual genes in parallel.

The Come-In concept benefits both customers and partners. The customers obtain the latest technology at a reasonable price, releasing funds for research rather than for payload development. The instrument providers (and sponsors) increase their competitive advantages by improving the instrument design, leading to better products. This enhances the images of the company and product by creating a new platform for marketing and attracting the media's attention. Space industry is creating new markets by providing end-to-end services on a commercial basis.

Each project, once accepted by ESA's ISS Commercial Promotion Office, may be financed via the Cooperation Agreement with private/public funding, with the objective of keeping the accommodation and qualification costs at affordable levels. The initial investment required for the space demonstration consists of an in-kind contribution from the instrument provider, cash contribution from the sponsors, and the flight costs (covered by ESA). Storage, maintenance and operations are then covered by the income from leasing the instrument to customers and from sponsors wishing to be involved in using space and the Space Station for their commercial media communications.

The First Commercial Demonstration

Some 10 months after the ESA/Intospace agreement was signed, the Come-In concept was tested with the first commercial medical apparatus to be provided aboard the ISS. The Blood-pressure Measurement Instrument (BMI) was supplied by Boso GmbH, a medium-sized German company specialising in medical equipment. BMI already has a wide range of users, from general patients to pharmaceutical companies running clinical studies on hypotensive drugs. The commercial instrument was adapted and qualified to comply with ISS requirements.

BMI was demonstrated on 1 May 2002 aboard the Station by ESA Astronaut Roberto Vittori during his visiting mission. He prepared the equipment, put it on and recorded 8 h of continuous blood pressure and heart rate measurement under operational conditions. The demonstration included the recording of a 12-min DVD video that was brought back by Vittori and delivered to Boso.

The BMI industrial team was led by Intospace, who charged for its project management and for finding a customer. Qualification was performed by Kayser-Threde. As a partner in the project, ESA's ISS Commercial Promotion Office, in collaboration with the Italian space agency, provided all the technical support for the mission's ground preparation (documentation, flight authorisation, astronaut training, payload integration), for delivering the instrument to the Station aboard the Russian Progress freighter, and for performing the demonstration in space, including its video recording.

The payload was qualified, tested and accepted for flight in only 3 months – a record time that highlights how ESA can accommodate strict commercial requirements.

BMI is planned to remain in the Russian segment of the Space Station, ready for the second step of the Come-In concept: leasing by customers. Further information for prospective customers can be found at:

http://www.esa.int/spaceflight/isscommercialisation

or contact Elena Lippi at

isscommercial@esa.int ■

The EPM-1 Science Module Configuration

The initial configuration of EPM in Columbus (EPM-1) consists of six Science Modules provided by ESA and National Agencies. Although EPM-1 covers a broad range of potential experiments, thanks to the modular concept, the Science Modules are easily removable to allow on-orbit reconfiguration of the facility to accommodate new Science Modules.

MEEMM (Multi-Electrode Electroencephalogram Mapping Module)

Developed by ESA, MEEMM is dedicated to non-invasive studies of brain activity by measuring EEG and Evoked Potentials in stationary and ambulatory modes (e.g. sleep studies). In addition, MEEMM can be used for EMG measurements to investigate muscle deconditioning/atrophy.

BAM (Bone Analysis Module)

Developed by ESA, BAM measures demineralisation and changes in bone structure, using ultrasound signal propagation through the heel bone.

Cardiolab (Cardiovascular Laboratory)

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

SCK (Sample Collection Kit)

Developed by ESA, the SCK provides clinical equipment and tools, such as syringes, towels and sample containers, to collect blood, saliva and urine, for later analysis of e.g. hormonal regulation and demineralisation.

NASA Science Module

In exchange for an ESA Science Module on the NASA HRF-2 Human Research Facility, EPM will contain a Science Module provided by the NASA HRF team. The instrument remains to be selected.

ELITE-S2 (Elaboratore Immagini Televisive-Space 2nd generation)

Developed by ASI/CNES, ELITE-S2 enables the quantitative 3D analysis of human kinematics in weightlessness. Movements of astronauts within the Columbus module are recorded by a set of TV cameras to investigate the neurovestibular control of posture, balance and motion sensory coordination.

Further Information

http://www.spaceflight.esa.int/users/epm

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BR-167/II

EPM

Physiology Experiments on the International Space Station

MICROGRAVITY FACILITIES FOR COLUMBUS
BIOLOGY
FLUID SCIENCE
HUMAN PHYSIOLOGY
MATERIALS SCIENCE
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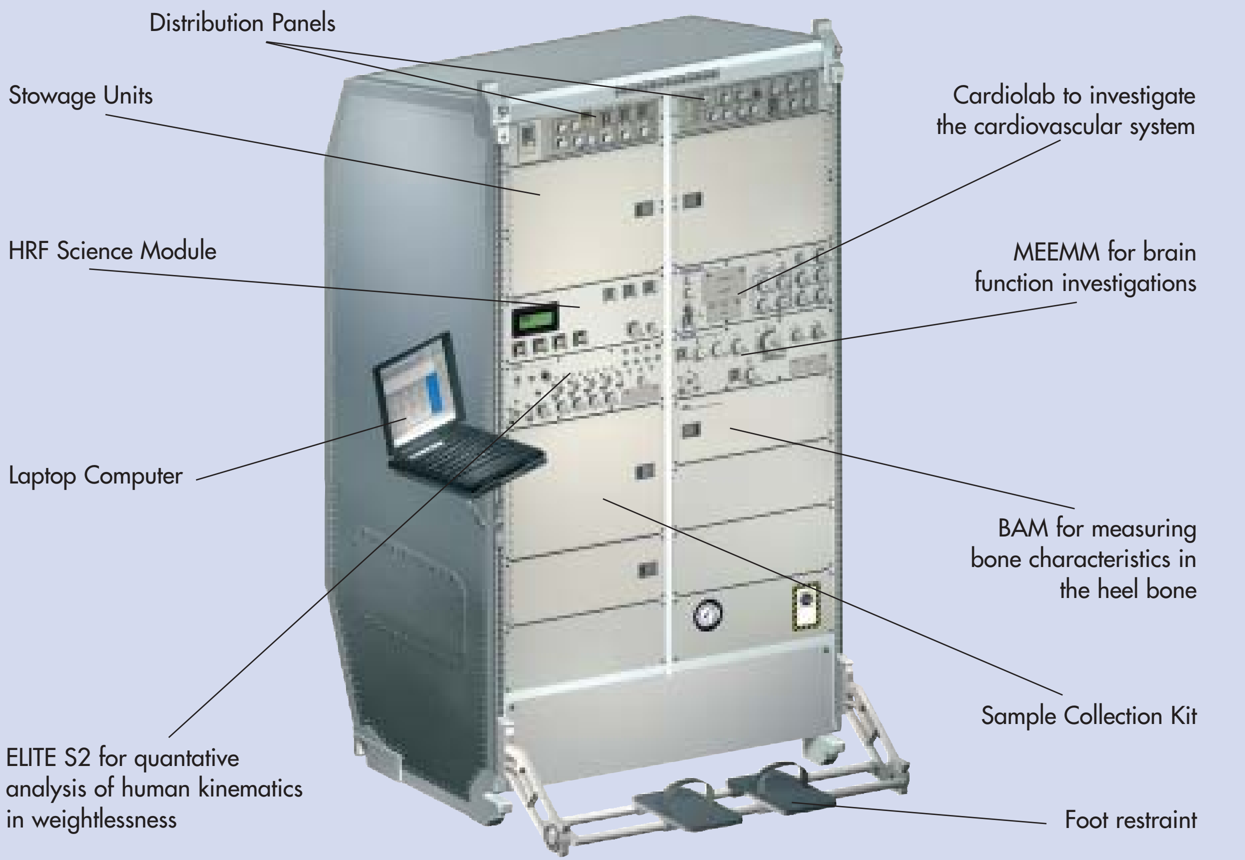
European Physiology Modules (EPM) Facility

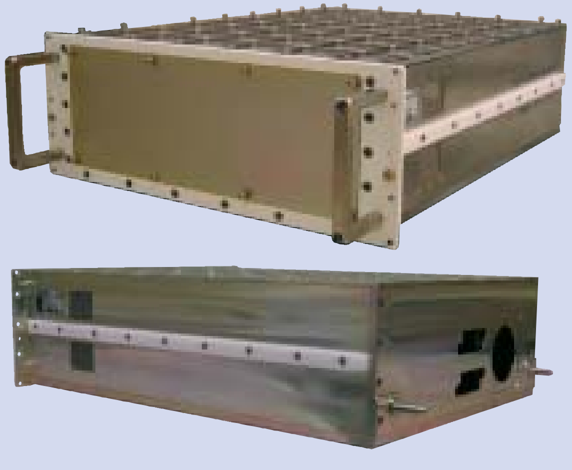
The European Physiology Modules (EPM) multi-user facility is part of ESA's 'Microgravity Facilities for Columbus' (MFC) Programme. It is designed to support research into human physiological adaptation to weightlessness aboard the **International Space Station** (ISS) in the European **Columbus** module. This research may also increase our understanding of terrestrial problems such as ageing, osteoporosis, balance disorders and muscle wastage. Typical research areas includes:

Neuroscience: neurovestibular control posture, balance and motion sensory coordination;
Cardiovascular and Respiratory System: control of blood volume and distribution; fluid volume shift;
Bone and Muscle Physiology: muscle deconditioning atrophy; bone mass loss;
Endocrinology and Metabolism: hormonal regulation; demineralisation.

EPM consists of a **Carrier**, interfacing with Columbus and providing a set of services (power, data, cooling) to **Science Modules** (scientific instruments). Two types of Science Modules are possible – rack-mounted and deployed. The rack-mounted instruments are accommodated in **Standard Active Containers** (SACs) available off-the-shelf from ESA, while deployed instruments interface with the Carrier via a **Utility Distribution Panel** (UDP). The same set of interfaces and services is provided for both types of instruments. Making the SAC available to instrument developers significantly reduces the cost, time and risk for development and integration of new EPM instruments. The Carrier includes a **laptop computer** for all interactions with the crew, including experiment execution and facility operations.

EPM includes tools for performing manual and automatic experiment procedures. The Science Module developer uses the **tool-kit** to generate the procedure inputs for execution on the laptop during an experiment session. The facility includes dedicated **stowage** to contain deployable instruments, sample collection and waste management equipment, as well as Carrier equipment such as laptop and crew aids.





Engineering Model of the Standard Active Container

Standard Active Container (SAC) for Science Modules

The Standard Active Container provides all the mechanical, thermal and electrical interfaces to the Carrier. The containers are available in two sizes: 4 & 8 PU (Panel Unit).

	4 PU	8 PU
Volume (mm)	400x150x580	400x328x580
Mass (kg)	25	30
Mounting interface for user equipment	70x70 mm grid	70x70 mm grid
Power	28 V / 10 A	28 V / 10 A
Cooling	Forced air	Forced air
Commanding	Redundant RS-485 link	Redundant RS-485 link
Science data	Ethernet & USB	Ethernet & USB
Video	NTSC	NTSC

FSL Engineering Model during the system test campaign

During non-operational phases, the ECs are stowed in dedicated locations within the Columbus module. They are inserted into and extracted from the facility by the flight crew. The built-in modularity of the EC assemblies allow the science protocol to be reconfigured on-orbit by the crew (e.g. exchange of the EC internal fluid cell, fluid and gas reservoirs).

Optical Diagnostics

The set of optical diagnostics comprises:

- visual observation along two perpendicular axes, with direct registration via internal CCD cameras and external Front Mounted Cameras (FMCs), allowing high-speed, high-resolution, infrared and colour recording;
- background, volume and travelling light sheet illumination by white or monochromatic light sources;
- particle image velocimetry, including simultaneous velocity and temperature mapping via liquid crystal tracers;
- thermographic mapping of free-liquid surfaces, using the infrared FMC;
- interferometric observation (Wollaston/shearing interferometer; Schlieren observation mode; Electronic Speckle Pattern Interferometer (ESPI)).

Operational Conditions

During experiments, the FSL internal primary data flow (maximum 240 Mb/s) goes into the **VMU** hard disks until their capacity (30 GB) is exhausted. The stored information then can be downlinked or transferred to the VMU tape recorder (capacity 30 GB). The tape cartridges are exchangeable so that the total recording capacity for each experiment can be extended as deemed necessary by the scientists.

Simultaneously with the internal data flow, a data stream can be downlinked at the rate the ISS can make available at that time (2 Mb/s on an average, 32 Mb/s maximum on request per timelining). This allows for a quick-look assessment of the experiment process. In addition, housekeeping data of the experiment and facility are made available to the payload controllers and scientists.

Further Information

FSL web page:
http://www.spaceflight.esa.int/users/fsl

Microgravity Vibration Isolation Subsystem
http://www.space.gc.ca/csa_sectors/space_science/microgravity_sci/domain/mim/mvis/default.asp

Contact address:
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Noordwijk, The Netherlands

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FSL

Fluid Science Experiments on the International Space Station

MICROGRAVITY FACILITIES FOR COLUMBUS
BIOLOGY
FLUID SCIENCE
HUMAN PHYSIOLOGY
MATERIALS SCIENCE
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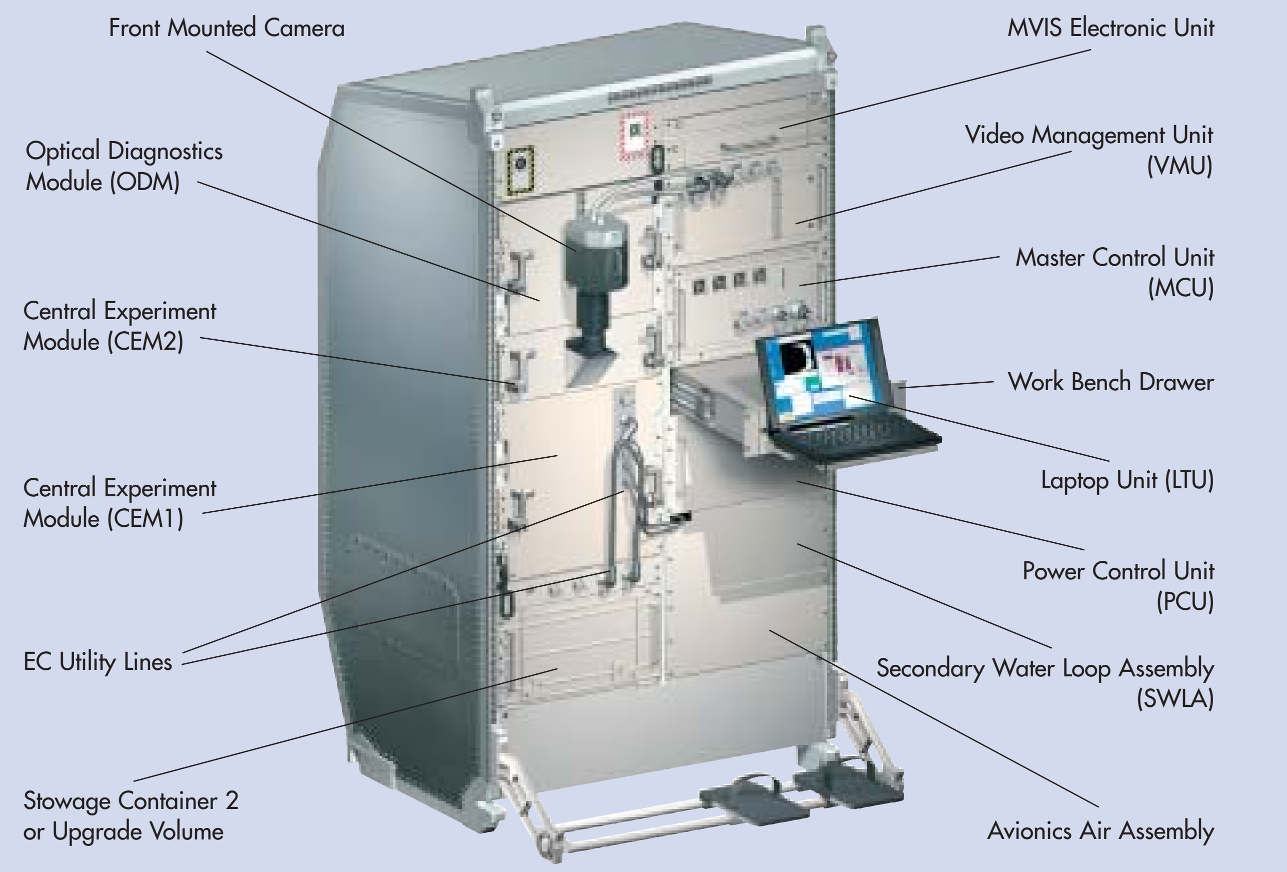
Fluid Science Laboratory

The Fluid Science Laboratory (FSL) is part of ESA's 'Microgravity Facilities for Columbus' (MFC) Programme. It will support basic and applied research in fluid physics under microgravity conditions. The design provides easy exchange of FSL modules in the case of upgrades and modifications. After setup by the crew, the facility can be operated in **fully automatic mode**, following a preprogrammed sequence of commands, or in semi-automatic **telescience** mode, enabling the user to interact with the facility in quasi-real time from the ground. This allows the scientists to follow the evolution of their experiments and to provide feedback on the data they receive at the ground station.

The **Facility Core Element** is a rigid frame that houses all the optical instruments and the experiment container within three different modules. It can be actively isolated from the Space Station vibration environment (g-jitter) using the **Microgravity Vibration Isolation System** (MVIS), a magnetic levitation system developed and provided by the Canadian Space Agency. The **Optical Diagnostics Module** (ODM) houses visual observation equipment, cameras, interferometers and illumination sources. The functional interfaces for additional Front Mounted Cameras are provided on the front panel. **Central Experiment Module 1** (CEM1) hosts the Experiment Container (EC), provides the functional interfaces (power, data, cooling, etc), additional optical equipment (such as mirrors, lasers and cameras) and the FSL microgravity-measurement assembly. **CEM2** contains further diagnostic equipment, including the laser sources for light-scattering measurements and equipment for creating two perpendicular light sheets.

The FSL uses standard **Experiment Containers** (ECs) for individual experiments. These ECs contain the fluid cell assembly and may provide special diagnostics (including dedicated imaging equipment such as microscopes and multiple miniature cameras) to complement the ODM standard equipment, and the stimuli for the individual experiment processes (heaters/coolers, stepper motors, mixers, pressure gauges, etc).



Experiment Container (EC)

- Standard Dimensions: 400 x 270 x 280 mm
- Typical mass: 25-30 kg
- Observation field of view: 80 x 80 mm
- Power lines: +28, ±15, +12, +5 Vdc
- Power consumption: 300 W maximum
- Heat rejection: 420 W maximum by water cooling
- Low-rate data: RS-422, MIL-1553 rate: 170 Kb/s max.
- High-rate data: 2 Mb/s average, 32 Mb/s maximum
- Pulse commanding: 125±5 ms
- Temperature monitoring: −40/+90°C (for higher temperatures, EC internal signal conditioning)
- Thermoelectric device driver and stepper motor driver external to EC
- Microgravity sampling frequency: 300 Hz (Microgravity Measurement Assembly)

The Space Factor

Fundamental and Applied Research Benefiting Europe

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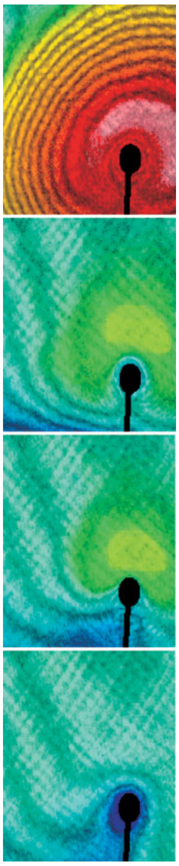
Email: Marc.Heppener@esa.int



Ignition of a spherical flame in weightlessness.

Introduction

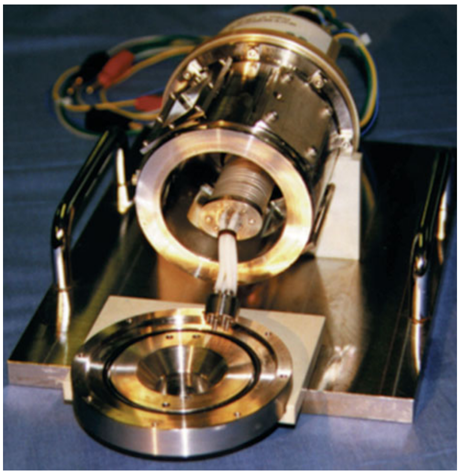
Although 'made in space' products will not appear on the market anytime soon, space as an arena for industrial and applied R&D is gaining interest. ESA is supporting a growing number of projects in which non-space industries, hospitals and other third parties are participating.

> *Research in space can be used to develop valuable applications on Earth …*

In any discipline, basic research is the starting point for progress. For that reason, basic research continues to be supported within ESA's ELIPS programme for life and physical sciences in space. Proposals of scientific excellence will generate new ideas in the pure sciences, that will, after gestation, find their way into novel practical applications. A good example is the laser. First predicted theoretically by Albert Einstein in 1917, the first operational laser was not built until 1960 and is now in everyday use. Several concrete ideas for applications are already emerging from ELIPS.

Since 1998, some 150 proposals for applied research have been received and 43 have been approved. All are run by trans-national teams. In total, 116 European companies are involved, among which there are very large multinationals and a significant number of start-up companies and Small- and Medium-sized Enterprises. The industrial participants bring their own funding. ESA, industries and academic institutions each participate at about the same level of funding, leading to true Public-Private-Partnerships.

An ESA space bioreactor for culturing tissue.



Project Details

The topics addressed in the 43 approved applied research projects cover a broad range. Here are a few examples.

Growing artificial tissues

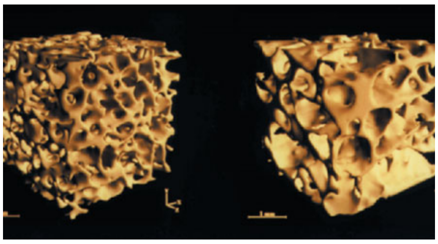
Growing artificial human tissue for transplant would answer important medical problems, especially if the starting cells came directly from the patient. Such tissue would be free from rejection problems and be essentially limitless. Unfortunately, all attempts on Earth to make human cells grow *in vitro* in three dimensions seem to fail. Gravity is clearly a disturbing factor. Therefore, this project will culture human cells in a bioreactor designed for weightlessness.

The first trials will use a relatively simple tissue: cartilage. Cartilage transplants could help large numbers of people suffering from joint problems. Later, growth of more complicated tissues will be attempted. The objective is not to grow tissues in space for transplant. Rather, it is hoped that the space experiments will lead to a method for growing usable tissues on Earth. Nevertheless, even if space experiments deliver only a few pieces of this complex puzzle, this project will prove its value.

Understanding and treating osteoporosis

One of the best-known effects of weightlessness on humans is the weakening of bones. Astronauts can lose up to 20% of their bone calcium in a year. This effect closely resembles osteoporosis. On Earth, it affects about 35% of women and 6% of men over 50 years of age.

Experiments in weightlessness are a good



Bone research in space will help the study of osteoporosis, a common age-related disease.

Dinner for a volunteer during the 90-day bedrest study.

way to study the underlying mechanisms. Several projects are being supported by ESA; participants include university and hospital researchers, medical companies and developers of medical equipment.

Apart from real space experiments, tests are also being performed using bedrest studies, in which weightlessness is simulated by keeping volunteers in a 6º head-down tilt for extended periods. Recently, a record 90-day bedrest study involving 25 volunteers was organised by ESA, CNES and NASDA at the facilities of MEDES in Toulouse.

Significant progress is being made in all areas. In particular, a novel exercise machine has been tested in bedrest studies and appears to be highly effective. Some new drugs show promise. Finally, a 3-D peripheral Quantitative Computed Tomography technique has been developed, with good prospects for clinical application.

Improving the efficiency of combustion

A 'classic' in space research is burning a candle in weightlessness. This simple experiment, in which the flame turns completely spherical and transparent blue, shows the strong influence of gravity on the burning process. On Earth, burning gives rise to convection of the surrounding air, thus providing the traditional flame shape. This convection also means the burning is incomplete, with soot creating the yellow flame.

Combustion is actually a very complicated process. Numerous chemical reactions depend on local conditions such as concentrations and temperature, which in turn are determined by the flow speeds of the constituents. In space, the flow is negligible, but artificial flows can be created using controlled airflow. These experiments can thus measure the various steps involved in the combustion process. The results are of great interest for developing numerical models that predict how combustion proceeds under variable circumstances and geometries. Interested parties include companies who build power plants or car engines. They plan to use these improved computer models to optimise the efficiency or reduce the environmental loads of their designs.

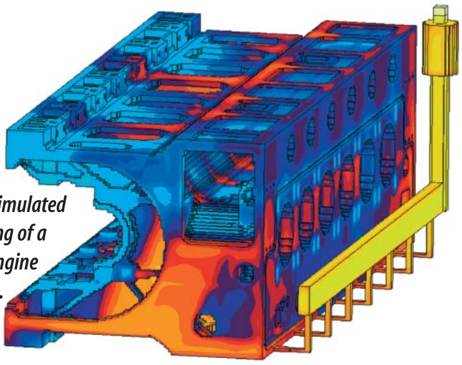
Increasing the yields of oil fields

Over geological timescales, the contents of an oil field are mixed by the diffusion caused by geothermal heating, gravity and layering. Understanding the diffusion is key to building computer models for companies to optimise their drilling strategy. On Earth, gravity prevents the measurement of diffusion in crude oil. The first measurements will be made during two missions this year: the Soyuz Taxi mission of Frank De Winne to the International Space Station, and the Foton-M1 unmanned mission, both in October (see the separate articles in this issue). If successful, more measurement campaigns will be planned. Some large oil companies are involved in this project, with several university groups.

Developing new casting techniques

In recent years, casting has developed into a very high-tech specialty. Today, very complicated moulds produce entire engine blocks and other complicated structures. In order to fine-tune and guarantee the desired mechanical and other properties, detailed knowledge is required of the underlying solidification physics and, in particular, the microstructure. Current computer models are not yet accurate enough to bridge the gap from the scientific microscopic scale to macroscopic models useful to the casting industry. A main factor is our poor knowledge of the essential thermophysical properties of liquid metals.

For example, even although molten iron is produced daily in enormous quantities, its very fundamental viscosity coefficient is known to an accuracy of only ±50%. Basically, only its order of magnitude is known because it is extremely difficult on Earth to obtain samples of pure molten iron. Its high temperature and chemical aggression mean that the walls of almost any container dissolve in the liquid metal and thus pollute it.



The simulated casting of a car engine block.

Under weightlessness, however, it is relatively simple to produce pure molten metal because, in principle, no container is necessary to hold the sample. With proper instrumentation, a sample can even be prepared in vacuum, and most of the important properties can be measured. The first trials are being planned for parabolic flight campaigns in the near future. For the longer term, experiments are being designed for the Space Station.

This materials theme is attracting high interest from academic groups and a large number of companies. Indeed, a recent survey identified the need for this type of data from companies in the glass-making, enamelling, energy production, welding, foundry, casting, spray casting, secondary refining, alloy production and primary metal production businesses.

The full version of this article appears in the August 2002 ESA Bulletin.

Astronauts in the Classroom

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A Dream Comes True

The tension was unbearable. The children in the classroom had learned so much about space in the last few months. Now it was time for one of the heroes in space to speak to them and answer their questions. On the computer screen, they saw the International Space Station (ISS) approaching. Within less than a minute, it rose over the horizon. Students and teachers held their breath. The media people fine-tuned their cameras.

'NA1SS, NA1SS here is F1MOJ, Foxtrot One Mike Oscar Juliet, calling the International Space Station. Do you copy?' The amateur radio operators had set up a station to link with the ISS. On the roof was a big antenna, like a TV antenna, but motorised. From the operations desk, the computer automatically turned the antenna to track the Station during its pass. Hissing filled the air. Then, suddenly *'F1MOJ, F1MOJ here is NA1SS. Fine copy. The name is Carl. Nice to hear you. Over'*. Carl Walz was answering their questions – an astronaut in their classroom.

Schools can now talk to the astronauts aboard the ISS ...

VK5ZAI antenna.jpg
Tracking the ISS at VK5ZAI, Paringa, South Australia.

How it Began

Since the early days of radiocommunications, at the dawn of the 20th century, radio enthusiasts have been at the forefront of innovations in the field. Officially recognised since 1927 as a radio service, the radio amateur activities are defined by articles S1.56 and S1.57 of the Radio Regulations of the International Telecommunications Union, a United Nations agency.

Only 4 years after Sputnik 1 ushered in the Space Age, the US Air Force orbited the OSCAR 1 piggyback satellite on 12 December 1961, the first 'Orbiting Satellite Carrying Amateur Radio'. Since then, the worldwide amateur radio community has built tens of satellites for a wide range of space communications experiments.

Russia's Mir space station and the US Shuttles carried amateur stations. The ISS now has a station on board. Many astronauts and cosmonauts are licensed amateur radio operators. The space agencies consider astronaut-school links as a valuable educational outreach activity. An international working group was created by the amateur radio community to build, develop and maintain the amateur radio station aboard the ISS: Amateur Radio on ISS (ARISS). The space agencies have entrusted ARISS with helping schools to contact astronauts aboard the Station. European schools are taken care of by ARISS-Europe.

How it Works

Many of the ISS astronauts volunteer to earn an amateur radio licence and are trained to operate the ARISS station. Many ESA astronauts are also licensed and use the ARISS station during their visiting missions.

ARISS includes representatives from the USA, Canada, Europe, Russia and Japan. For school contacts, two committees have been set up. Schools wishing to invite an astronaut into their classrooms join a waiting list. The ARISS School Selection Committee meets every month by teleconference, when special attention is paid to space-oriented educational projects.

Expedition-3 Commander Frank Culbertson using ARISS radio aboard the ISS. (NASA)

Waiting for the radio contact with astronaut Carl Walz at the Louis Pergaud school in Raphèle-lès-Arles, France.

Scheduling the radio contacts is the task of the ARISS Operations Committee during its weekly teleconferences. This committee interfaces with the ISS space agencies and the amateur radio operators who volunteer to set up well-equipped ground stations in the selected schools.

Close cooperation between the coordinating teacher and the ground station is a must, so the Operations Committee nominates a 'mentor' for each school as the 2-month scheduling process begins. ARISS School Mentors are experienced satellite amateur radio operators. They must check the performance of the ground station and prepare the school for the space encounter, paying attention to aspects such as public relations. The students have to prepare 20 questions to be faxed to the astronaut in charge. From horizon to horizon, a pass lasts only 10 min at most, but careful planning means that most questions can be handled.

Scheduling a school contact is a complicated process that accommodates the time appropriate for the school, the school location, the orbital movement of the ISS related to the rotation of the Earth, and the astronaut's workload. The goal is to place the 15 min timeslot needed for an ARISS contact on the astronaut's timeline while satisfying all the constraints.

Scheduling has to occur in progressive stages. For long-stay astronauts, NASA agrees on scheduling ARISS School Contacts once a week, but the daily timeline of crew duties cannot be prepared long in advance. Moreover, the ISS raises its orbit about every 3 weeks in order to stay close to its nominal 400 km altitude, so accurate long-term predictions for a useful pass over a school cannot be made.

For taxi-flight astronauts, ESA's Directorate of Manned Spaceflight and Microgravity places ARISS Contacts on the astronaut's timeline when the Public Relations department agrees on requests from ESA members. Coordination with NASA and the Russian Space Agency is also needed. Frank De Winne will talk to Belgian schools during his ISS visit in October.

Contacts are also possible by 'telebridge'. A dozen dedicated ARISS ground stations, run by experienced operators, are located all over the world: US East Coast, Texas, California, Hawaii, South Australia and South Africa. Scheduling is easier when the radio contact can be done during a pass over one of these ground stations, whereas the link from the Station to the school is by teleconference.

Students of the Peter Anich High School for Surveyors, Bolzano during a telebridge space talk with astronaut Dan Bursch. Assisting is coordinating teacher Dr. Peter Kofler, IN3JHZ. The radio contact was by Tony Hutchison, VK5ZAI in Paringa, South Australia.

Students at Harrogate Ladies' College, England, all with an amateur radio licence, chatted with astronaut Carl Walz. Richard Horton, G3XWH, the physics teacher, operated the College Ham Radio Club station GB2HC.

Success

Amateur radio is an experimental service. Success cannot be guaranteed, but careful preparation will produce excellent results.

'NA1SS, F1MOJ. Many thanks Carl for this space talk. We wish you and all the crew a safe journey in space. You are doing a great job. F1MOJ signing off and clear.'

'F1MOJ, NA1SS. I was delighted to talk to you and the students. Greetings from space and see you later. NA1SS signing ... '

Carl Walz's last words were lost in the hiss – the Station had disappeared over the horizon. For 10 min, an astronaut had visited their classroom. Applause and excitement filled the place. ■

ISS Payload Operations

Decentralised User Operations and Support Centres (USOCs)

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Introduction

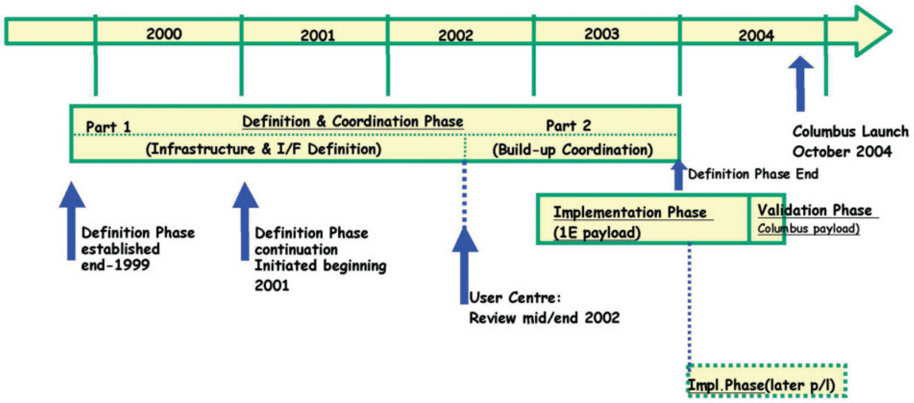
The definition and implementation of an infrastructure for payload operations is under way to enable the early utilisation by Europe of the International Space Station (ISS) from 2003, and later the exploitation of the Columbus module. These efforts are leading to a decentralised operations concept that will allow the investigators to perform their experiments using telescience techniques and remote experiment operations whenever feasible. A decentralised operations concept is planned:

- experiment operations executed by the Principal Investigators,
- operation of multi-user facilities by User Support and Operation Centres (USOCs),
- European payload operations management and coordination.

> *ESA's facilities and payloads will be operated aboard the ISS from User Support and Operation Centres (USOCs) spread around Europe ...*

The operation of ISS payload facilities and the scientific, technical and operational support for the users will be provided through nationally funded and geographically distributed USOCs. The payload operations will be coordinated through the Columbus Control Centre (COL-CC), which will also coordinate the European communications infrastructure to allow the exchange of telemetry and telecommand data, voice communication and video distribution, by setting up communication links to USOCs and investigator sites.

Figure 1. The overall USOC development schedule.



Basic functions of a USOC

USOCs will play an important role in linking the user community with ISS utilisation. The various discipline-oriented USOCs around Europe will ensure that there are focal points for ESA payload operations close to the user groups.

Before a payload's launch, the USOCs will be concerned with activities such as ground model operations, procedure development, sample calibration and crew training. During a payload's operation, the USOCs will receive facility and experiment data and operate the payload. In addition, the USOCs will be responsible for the interaction with the User Home Bases (UHBs), disseminating Station and experiment data, and receiving and processing requests for experiment scheduling and direct commanding.

Depending on the scope of the task assigned to a USOC, it can assume three basic levels of responsibility:

- an Experiment Support Centre (ESC) is responsible for single experiments. These are either self-standing experiments using specific equipment or performed in a payload rack. The ESC focuses on science and experiment operational matters;
- a Facility Support Centre (FSC) is responsible for a sub-rack payload (facility insert, experiment container, drawer payload, bioreactor);

Figure 2. Locations of the USOCs.

- a Facility Responsible Centre (FRC) has overall responsibility for a payload facility (full-rack payload). It focuses on payload systems and all phases of payload operations, including before and after flight.

FRC specific functions
Payload operations from the FRC will be supported by the associated Support Centres (FSCs/ESCs). For experiment operations, the FRC will provide the user, who might be accommodated at another centre, with a communication and data processing infrastructure that allows real-time data monitoring and control. The FRC is responsible for interfacing and coordination with the Remote User Locations, such as the UHB. The FRC will also support the specification of hardware and software outfitting and the connection of the UHB to the ISS ground segment. Specifically, the FRCs will have sufficient knowledge of the functionality of the facilities allocated to them that they can operate the payload in flight.

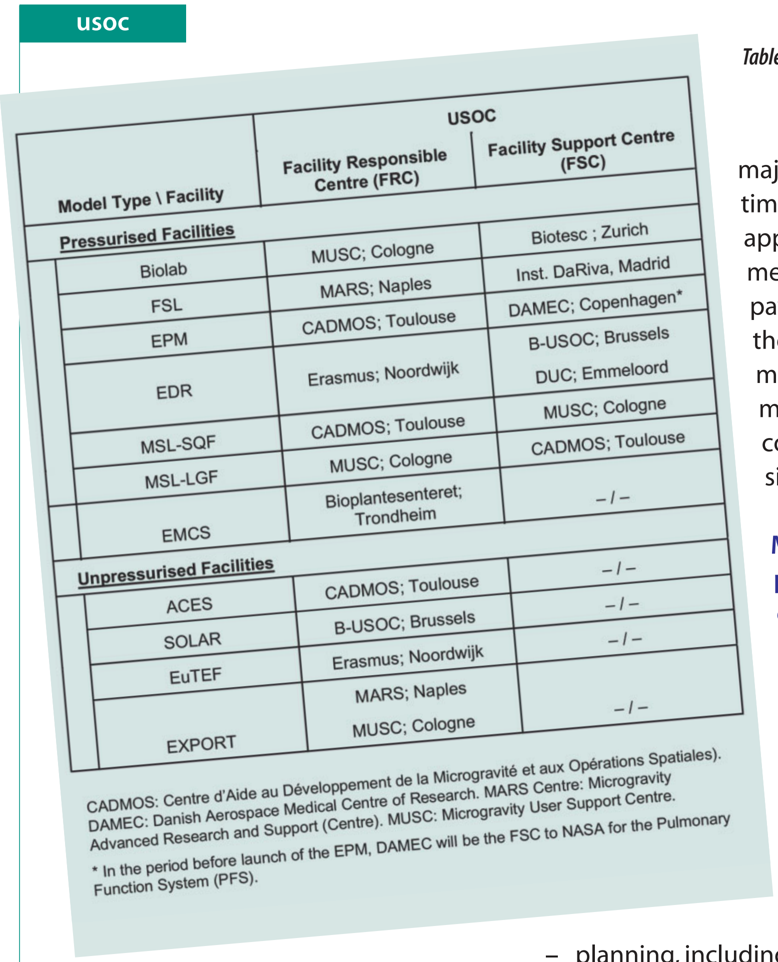
Telescience and remote operations

Telescience provides remote, interactive and real-time operation of an experiment in space by the ground-based researchers. ESA's ISS payloads are designed for telescience. Dedicated telescience consoles will allow investigators at remote sites, supervised by the FRCs and the COL-CC, to interact directly with their experiments.

Telescience allows science to be performed in a flexible laboratory-like fashion. Its feasibility and usefulness have been demonstrated on missions such as Texus and the International Microgravity Laboratory Spacelab. Experiments were monitored and controlled by the investigators in real-time from USOCs. This concept has been further developed and applied over the years during various international Spacelab missions involving various European USOCs and User Home Laboratories. For ISS utilisation, telescience is now considered as the baseline for remote experiment operations.

The users conducting their experiments may be located either at their home locations (UHB) or at USOCs (FRC, FSC, ESC). If required, the COL-CC also provides limited user accommodation. Remote operations are possible within a window, according to a resource envelope defined on the basis of a set of previously validated commands. The user

Table 1. The USOCs and their responsibilities



Model Type \ Facility	USOC Facility Responsible Centre (FRC)	 Facility Support Centre (FSC)
Pressurised Facilities		
Biolab	MUSC; Cologne	Biotesc ; Zurich
FSL	MARS; Naples	Inst. DaRiva, Madrid
EPM	CADMOS; Toulouse	DAMEC; Copenhagen*
EDR	Erasmus; Noordwijk	B-USOC; Brussels DUC; Emmeloord
MSL-SQF	CADMOS; Toulouse	MUSC; Cologne
MSL-LGF	MUSC; Cologne	CADMOS; Toulouse
EMCS	Bioplantesenteret; Trondheim	– / –
Unpressurised Facilities		
ACES	CADMOS; Toulouse	– / –
SOLAR	B-USOC; Brussels	– / –
EuTEF	Erasmus; Noordwijk	– / –
EXPORT	MARS; Naples MUSC; Cologne	– / –

CADMOS: Centre d'Aide au Développement de la Microgravité et aux Opérations Spatiales). DAMEC: Danish Aerospace Medical Centre of Research. MARS Centre: Microgravity Advanced Research and Support (Centre). MUSC: Microgravity User Support Centre.

* In the period before launch of the EPM, DAMEC will be the FSC to NASA for the Pulmonary Function System (PFS).

will be able to monitor all payload data, using the infrastructure implemented at the FRC.

Payload commanding from a USOC is always coordinated between the FRC and COL-CC. Direct payload commands from the USOC will be checked by the FRC/COL-CC against the scheduled operations command path and window, which is also in charge of enabling or disabling the command path.

In response to contingencies or anomalies according to pre-defined procedures (safety-critical payload commands), the COL-CC, Payload Operations & Integration Center (POIC, at NASA Marshall) or crew can issue payload commands. For payload commands from the USOC, receipt and execution acknowledgements will be sent to ground and forwarded to the originating centre. The FRCs will monitor, verify and acknowledge that the commands have been executed and produced the desired results, thus closing the loop.

Resource consumption by each major ESA payload will be monitored by the COL-CC via the rack-level interface, enabling them to detect any major excursions in time and to take appropriate measures. European payloads outside of the Columbus module will be monitored and controlled in a similar way.

Management of payload operations

ESA's management of ISS payload operations includes:

- operations management and integration;
- planning, including strategic, tactical and execution-level planning with support of the relevant USOCs and ISS Partner control centres;
- increment preparation management and coordination for the ESA payload complement on the ISS;
- supervision of real-time mission management at the control centres and USOCs;
- provision of real-time payload operations management and science coordination.

During the increment preparation phase, ESA's Utilisation Management Team will be responsible for concluding all payload interface and operations agreements, for ensuring the generation of all payload documentation, and for carrying out final payload acceptance for flight. The Team will supervise the system-level test activities at the payload integration centre, and will subsequently be responsible for shipping payloads to the launch site. ESA Utilisation Management will also be responsible for receiving and dispatching hardware that returns from orbit, including samples, specimens and collectors, as well as instruments and facilities if required.

Real-time operations activities for payloads will be performed directly from the User Centres responsible for a payload. These activities are performed under the overall payload operations coordination and management of ESA. The ESA payload operations management, collocated with COL-CC, will supervise and coordinate payload operations on the ESA payload complement level.

Implementation of USOCs

ESA is now establishing the Mission Management Scheme within which the USOCs can conduct their activities. This includes the technical capabilities that enable assigned USOCs to conduct payload operations.

A phased approach has been defined for implementing the European USOC infrastructure: Definition, Implementation and Validation. The D/MSM Utilisation Division, with the active participation of the User Centres, is managing and coordinating the project. Fig. 1 shows the schedule for the decentralised USOC network. Fig. 2 shows their locations; Table 1 lists their responsibilities.

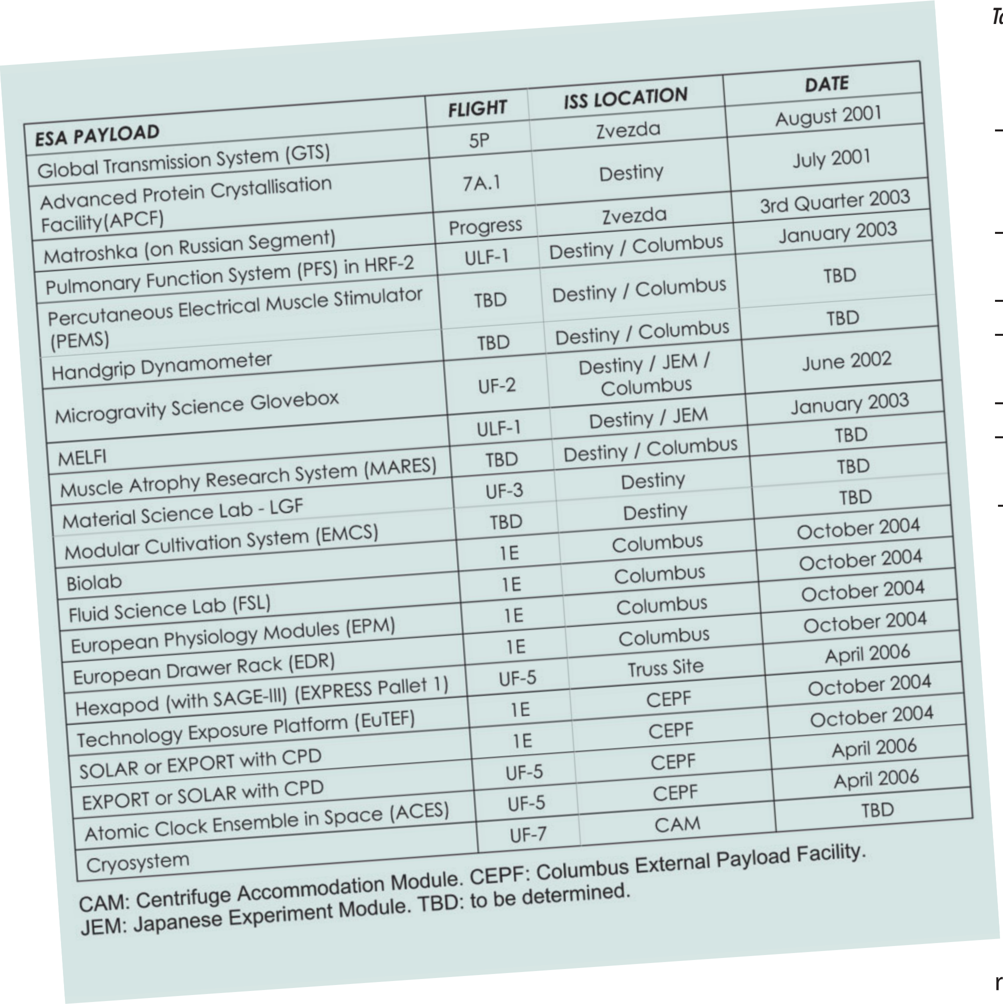
The Definition Phase

This phase is concerned with the conceptual and requirements definition activities in preparation for the subsequent hardware and software activities. The phase will establish the technical and programmatic baseline for the USOCs and prepare the build-up according to their different roles. The USOC baseline documentation is being generated during this phase, establishing requirements, interfaces control and architectural design.

The phase began in December 1999 and will last about 3 years, partially overlapping with the Implementation Phase.

The Implementation Phase

The majority of the technical activities are concentrated in the



ESA PAYLOAD	FLIGHT	ISS LOCATION	DATE
Global Transmission System (GTS)	5P	Zvezda	August 2001
Advanced Protein Crystallisation Facility(APCF)	7A.1	Destiny	July 2001
Matroshka (on Russian Segment)	Progress	Zvezda	3rd Quarter 2003
Pulmonary Function System (PFS) in HRF-2	ULF-1	Destiny / Columbus	January 2003
Percutaneous Electrical Muscle Stimulator (PEMS)	TBD	Destiny / Columbus	TBD
Handgrip Dynamometer	TBD	Destiny / Columbus	TBD
Microgravity Science Glovebox	UF-2	Destiny / JEM / Columbus	June 2002
MELFI	ULF-1	Destiny / JEM	January 2003
Muscle Atrophy Research System (MARES)	TBD	Destiny / Columbus	TBD
Material Science Lab - LGF	UF-3	Destiny	TBD
Modular Cultivation System (EMCS)	TBD	Destiny	TBD
Biolab	1E	Columbus	October 2004
Fluid Science Lab (FSL)	1E	Columbus	October 2004
European Physiology Modules (EPM)	1E	Columbus	October 2004
European Drawer Rack (EDR)	1E	Columbus	October 2004
Hexapod (with SAGE-III) (EXPRESS Pallet 1)	UF-5	Truss Site	April 2006
Technology Exposure Platform (EuTEF)	1E	CEPF	October 2004
SOLAR or EXPORT with CPD	1E	CEPF	October 2004
EXPORT or SOLAR with CPD	UF-5	CEPF	April 2006
Atomic Clock Ensemble in Space (ACES)	UF-5	CEPF	April 2006
Cryosystem	UF-7	CAM	TBD

CAM: Centrifuge Accommodation Module. CEPF: Columbus External Payload Facility.
JEM: Japanese Experiment Module. TBD: to be determined.

Table 2. European utilisation plan for the ISS.

Implementation Phase. This phase covers the actual build-up and hardware/software implementation at the USOCs according to the agreed Design and Development Plans. The communications and data infrastructure will be established in parallel with the preparation of the local infrastructure in the centres. This phase will also cover the preparation of the validation and qualification of the centres and the preparation of operational documentation.

The Implementation Phase will begin after the User Centre Review, in mid-2002. The activities include:

- development of the USOC infrastructure, including the USOC internal communications network and the link to the Interconnected Ground Subnet or public networks;
- adaptation of existing building infrastructure to accommodate the assigned facility ground models and their Ground Support Equipment;
- preparation of the test environments and procedures for the Validation Phase (software tools, Software Validation and Verification Plan, and Acceptance Test Plans for procured hardware and software);
- crew training support;
- deployment of operation planning tools;
- training of USOC staff on ISS design and operations;
- procedure development and validation for on-orbit payload operations;
- supporting the operations preparation for the mission increment.

The Validation Phase

This phase is the final stage of implementation and covers the validation of the payload operations infrastructure and set-up at the USOCs (communications infrastructure, operational interfaces, performance of all hardware and software installations). In addition, the operations preparation for the Columbus commissioning phase is performed during this phase. Activities include:

- test and validation of the communications systems and software products;
- finalisation and verification of USOC-specific procedures;
- supporting end-to-end simulations;
- validate operations support tools and procedures;
- certification of USOC staff;
- supporting test and verification of the assigned payload facilities;
- supporting/performing payload commissioning.

Outlook

Table 2 shows the European Utilisation Plan for the major European Payloads on the ISS. It is apparent from this list that there will be a major ESA payload complement after flight UF-2. As soon as more than one complex payload (multi-user facility) needs to be supported, adequate payload coordination functions and a reliable operational infrastructure and ground segment setup need to be provided by ESA, though only as an initial capability:

- payload operations management;
- science coordination;
- payload planning;
- payload data management;
- communications coordination.

These functions will be accommodated in an infrastructure consisting of a focal point for management and coordination, and ISS interfaces and an initial network of USOCs.

However, the most significant milestone is the launch of the Columbus module, when the majority of ESA's pressurised payloads will be delivered to the ISS. This event is driving the individual implementation schedules for the USOCs. The majority of the planned infrastructure will be in place for this flight.

ESA's external payloads will be delivered on flights following Columbus, although the possibility of launching two at the same time as Europe's module is being studied. ■

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